Achieving Construction Project Success through Integration in the Project Delivery System from an Owner's Perspective

By

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My loving parents: *Ghanimah* and *Jassim*, I am grateful for your continuing prayers, love, support, and knowledge you have provided me over the years. My lovely wife: *Faitmah*, your endless love, support, and patience were inspirational to me.

I dedicate this dissertation to you.

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ABSTRACT

Integrated Project Delivery (IPD) is a newly evolved project delivery system which has been capturing the attention in the Architecture / Engineering / Construction (AEC) community. IPD promotes more integration among project stakeholders and more optimal use of project resources. IPD, like any other new method or technology, needs to be approved in order to be widely accepted and used in the AEC community. As leaders and decision makers in the AEC community, owners are the most important AEC industry participants to give IPD their approval. The proper way to prove this new system – and integration in construction projects in general – is to objectively compare its benefits to those of other more established delivery systems in the industry.

Literature was reviewed about the subject matter and a gap was identified in the construction literature for this study to fill. The literature also helped identify variables in construction project delivery to observe and analyze. In addition, owners-specific success criteria were gathered from the literature to measure project performance. Then, a data collection tool was developed based on project delivery variables, and data was collected from 34 projects executed by construction owner organizations. The collected data was analyzed to test this study's main hypothesis that IPD and more integrated projects give better results to owners. The analysis was performed in a univariate level first, then in a multivariate level.

Univariate analysis results showed that IPD and more integrated projects were statistically proven to have better performance than other more conventional and less integrated project delivery systems in four owner-specific performance areas: quality, communication, safety, and owner satisfaction. This result confirms the result of previous studies that measured IPD project performance from a contractor's perspective and concluded that IPD delivered higher quality facilities at no significant cost increase.

A comprehensive tool that measures overall project success based on owner-specific criteria called Owner Project Quarterback Rating (OPQR) was developed in this study, and employed in the multivariate analysis. Multivariate analysis helped develop a predictive and explanatory model for project performance with OPQR being the dependent variable and project delivery characteristics being the independent variables. The multivariate analysis highlighted project delivery characteristics that significantly affected project performance. Integration initiatives such as collaboration and open communication, financial transparency, and applying lean construction tools were found to significantly affect project performance.

These contributions should serve as a stepping stone in proving IPD as a construction project delivery system, and integrated projects in general, to the AEC community and most notably owners.

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Chapter 1. INTRODUCTION

Construction owners are constantly looking for new ways to get the most of their investment in capital construction projects. This necessity of executing capital projects as efficiently as possible increases with a difficult economy such as the current, specifically from 2007 and onward. Adaptability is the proper state of mind any architecture, engineering, or construction (AEC) industry participant should have with such a tough environment. Owners, as the leaders and the driving force of the AEC industry, should also be the role model of adaptability. Nelson et al. (2008) argues that construction leaders should prepare to face "realities of their own set of brutal facts" in the AEC industry, that includes the availability of capital, and come up with new innovative strategies to deal with those realities. As a matter of fact, a shift in construction owners' strategies and methods has already been noticed. FMI, a management and consulting agency in the AEC industry, has conducted annual surveys of construction owners with the help of the Construction Management Association of America (CMAA) from 2005 to 2011. The results revealed some of the economic implications on owners' strategies such as staff down-sizing and future hiring outlook, and on their methods of project execution by exploring different project delivery strategies including planning, design, procurement, and management (FMI Management Consulting 2005, 2006, 2007, 2008, 2009, 2010, 2011).

In the midst of this uncontrollable, tough economic environment comes the Integrated Project Delivery (IPD), a newly evolved construction project delivery system. IPD is considered a shift in the delivery paradigm of construction projects (CII 2011). *This thesis explores construction project success from an owner's perspective through integration in the project delivery system with IPD as the focal point.*

IPD, since introduced to the construction scene, has been capturing the attention of different professional organizations such as the American Institute of Architects (AIA), the Construction Industry

Institute (CII), the Construction Users Roundtable (CURT), and others according to several reports and studies (AIA and AIA-California Council 2007; CII 2011; CURT 2004, 2007). Moreover, construction news magazines such as *Engineering News Record* (ENR) and *Tradeline* have put IPD as a delivery system under the spotlight (Allen 2007, 2009; Christian et al. 2011; Post 2010). In addition, the attention of academic researchers has turned toward IPD in the form of published articles in the Journal of Construction Engineering and Management and the Lean Construction Journal (El Asmar et al. 2013; Cho and Ballard 2011; Kent and Becerik-Gerber 2010). *Section 2.5 in Chapter 2* of this thesis will explain in details what has been published in the literature about IPD.

Although high-profile projects have adopted IPD as a delivery system, such as the Cathedral Hill Hospital project in San Francisco with a budget of two billion dollars (AIA and University of Minnesota 2012; Rauber 2013), IPD is still under the AEC industry participants' scrutiny and criticism (Post 2010). There are the IPD enthusiasts in the AEC industry and the skeptics as well. This dichotomy splits the construction owners as any other industry participant group. The main purpose of this thesis is to bring about the proof of IPD and integrated projects' superiority in delivering successful projects to owners compared to other project delivery systems (or lack thereof) by statistically studying the performance of projects that have been executed using IPD as a delivery system versus other projects that used more traditional methods of project delivery.

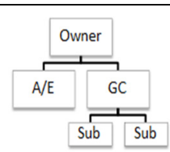
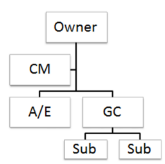
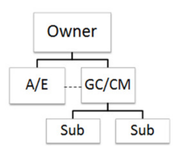
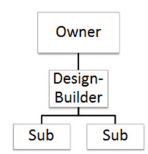
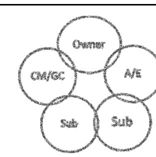
1.1 Project Delivery Systems – Introduction, History and Definitions:

In the planning effort of this thesis, project delivery system was decided to be the *vehicle to measure project success.* The success of a project depends on the management of a multitude of factors that affect the end product which is the facility being built. Managing these factors is a daunting task due to a number of reasons. One reason is the large number of role players associated with a construction project. The larger the team, the harder it is to manage, let alone different times of involvement for different players. Another reason is the length of a project's life span. Construction projects extend from the inception of the project idea during the strategic planning of an entity all the way to the occupancy phase. A third is volatile uncontrollable external conditions (weather, economy, politics, etc.) surrounding a project region or the industry as a whole. Project delivery systems determine the how, who, and when for project execution and participants (Hanna 2010; Oyetunji and Anderson 2006; Sanvido and Konchar 1998). In order to address the entirety of these issues and help steer the project towards success, an owner needs to choose an appropriate project delivery system.

Current project delivery systems have evolved from the ancient concept of the master builder which was a system that dominated until early in the 20th century (Branca 1987). As resources became limited, building designs became rather simpler, technology advanced, building sophistication increased, and competition among builders increased. All of this led to the conventionally known Design-Bid-Build (DBB) delivery system where services are divided into several specialties and then competitively bid by contractors and designers separately (Sanvido and Konchar 1998). With the rapidly rising construction costs due to inflation and other factors, time has become a valuable commodity and the inefficiencies associated with DBB delivery system have grown to be very expensive. Thus, new delivery systems have stemmed from the issues with DBB and as answers to the cost and time dilemmas in construction. One is the construction management delivery systems in its both types as Agency (CMA) and at Risk (CMR), where owners have the advantage of employing the expertise of a constructor during planning with a phased design and advanced ordering of long lead items. Finally, the more integrated design-build (DB) delivery system was developed in which the design and construction parties in a project act as one entity where there would be more integration among them and overlap between the design and construction phases, which sometimes called fast-track construction (Sanvido and Konchar 1998).

Given the above mentioned brief history and variation about project delivery systems, a clear definition for a project delivery system needs to be consistently used throughout this thesis. With a deep look at each and every project delivery system available, one can find that delivery systems define the relationships, roles and responsibilities of project participants; establish the project execution framework by sequencing the different project phases to provide the built facility; and also describe the techniques and methods the project management team uses (Oyetunji and Anderson 2006; Sanvido and Konchar 1998). Hanna (2010) based his definition for a project delivery system on the above mentioned elements, and therefore his definition will be used for this thesis as: *a system that defines the relationships of different project participants and their timing of involvement in that project. Table 1* shows schematically how these relationships are set among project participants, and their timing of involvement presented in the percent of design complete. The table also shows a spectrum of these delivery systems' integration and innovation potential.

Table 1: Variations in the Project Delivery Systems

Project Delivery System	**DBB**	**CMA**	**CMR**	**DB**	**IPD**
Relationships in the System					
Design Complete At the Contractor's Engagement	100%	⟷			0%
Integration	Less	⟷			More
Innovation	Traditional	⟷			Innovative

The spectrum in the table above starts with the very traditional, and well known by the industry participants, DBB system. The DBB carries the least potential for integration within the project due to the late engagement of the contractor, which in most cases after the design is completely done. On the other hand, the spectrum ends up with the newly evolved IPD system that carries the highest potential for integration due to the early involvement of different project participants, ideally before the start of the design.

1.2 Motivation of this Study

Motivation for this study stems from the economic value of construction industry, paired with the inefficiencies in construction methods. The following subsections will explain more.

1.2.1 Construction and the Economy

Even though the U.S economy is still recovering from the economic dip that started in 2008, construction spending is still sizable with respect to the U.S. Gross Domestic Product (GDP). The value of construction put in place at the end of December 2013 was about $930 billion (U.S. Census Bureau 2013). The U.S. GDP of the fourth quarter of 2013 was estimated to be $18 trillion (U.S. Department of Commerce 2013), which implies that construction accounts for about 5.2 % of the U.S. GDP.

1.2.2 A Flaws-Plagued Industry

With this significant amount of money and capital being poured into construction, the construction industry, in its current state, is full of flaws. According to a U.S. Department of Commerce, Bureau of Labor Statistics study, productivity of the construction industry has decreased since 1964 while all other non-farm industries have increased by almost 100% (Teicholz 2004). *Figure 1* shows a graphical display of this decline. Two things need to be mentioned here about this statistic. First, the context of this graph is the construction phase of a project. Although, the statistic shown by the graph is not inclusive to all the productivity being put in a project delivery (i.e. design, procurement, commission, etc.), it gives a reasonable representation to the construction industry productivity. Second, this decline is sustained even though the AEC industry is acquiring an abundance of technological advancements.

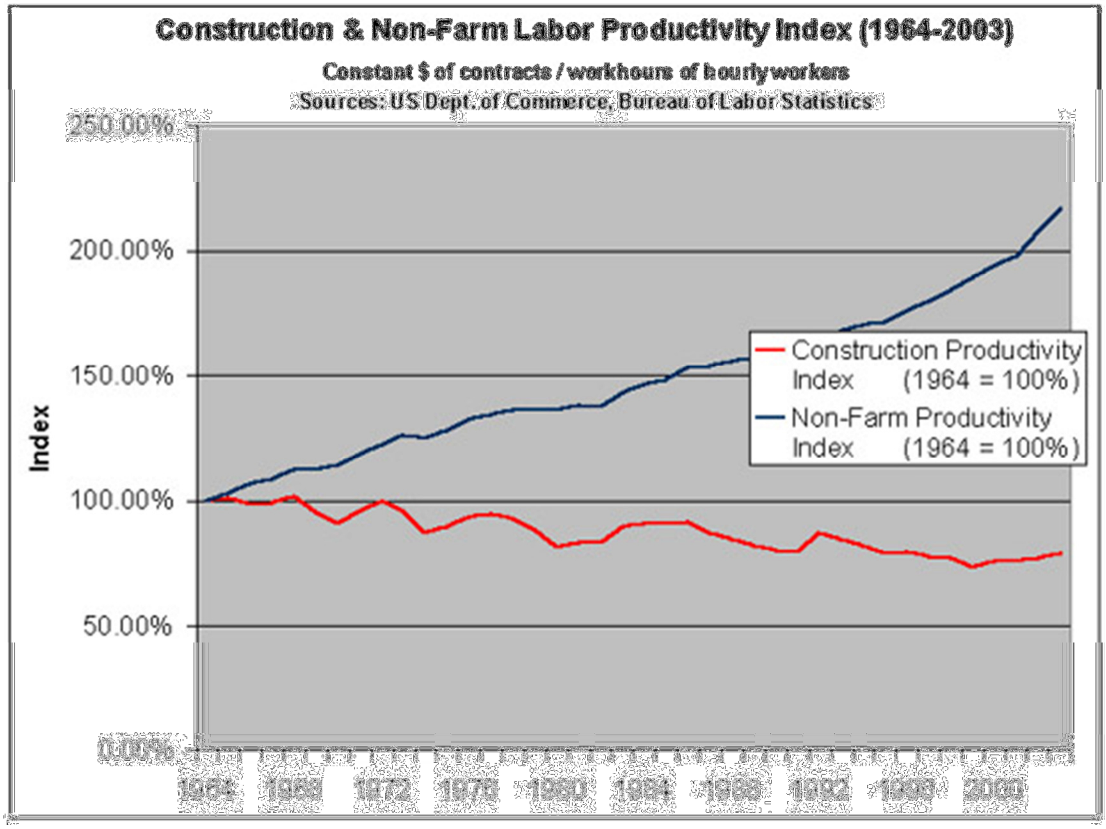


Figure 1: Construction Industry Productivity (Teicholz 2004)

Several studies focused on how to address the wasted resources in the construction industry. A study by the Construction Industry Institute / Lean Construction Institute in 2004 concluded that as much as 57% of time, effort and material investment in construction projects are almost wasted and regarded as non-value adding to the final product, as compared to only 26% in the manufacturing industry (NASFA et al. 2010). Another study by Horman and Kenley (2005) reported that wasteful activities in construction account for an average of 49.6% of work hours in a project. Moreover, Hanna (2010) showed the value adding versus non-value adding activities by breaking down a typical work time in a project and concluded that 59 % of a typical work time are non-value adding activities. A graphical representation of this breakdown can be found in *Figure 2*.

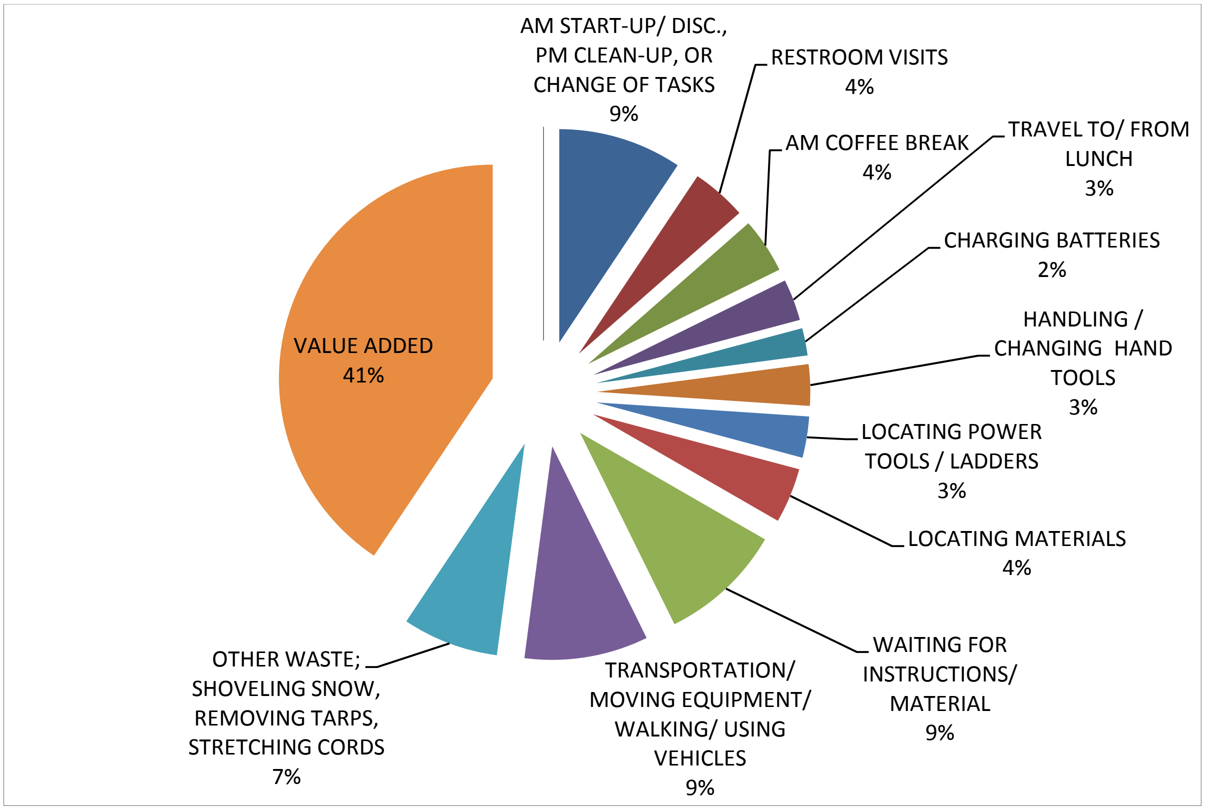


Figure 2: Value vs. Non-value Added Activities (Hanna 2010)

To further explain these non-value adding activities or waste. Liker (2004) listed eight types of "non-value-adding waste" in manufacturing or production process, which is applicable to a large extent in construction projects. These waste types include – but not limited to – waiting, excess inventory, unnecessary movement, and defects. Every type of these waste examples can be easily identified in a construction project.

Hanna (2010) further explained the factors affecting the poor productivity in construction and categorized it in three levels: Industry, Company, and Worker. Factors at the industry-level are common among the AEC industry participants including owners. The project delivery system was one of the industry-level factors affecting productivity listed by Hanna. The traditional DBB delivery system qualifies as a good demonstration of waste created by a project delivery system. DBB is a sequential / linear system with little-to-no collaboration effort among project participants. The design has to be completely done in order for the procurement, and then construction, to begin. The lack of collaboration leads to inefficient processes and communication resulting in wasteful practices and methods such as waiting and rework. Rework alone was found to account for 52% of a project's cost growth (Love 2002). The schedule growth is easily affected by these inefficient and wasteful activities. The Construction Management Association of America (CMAA) found in a study that 40-50 % of all construction projects have schedule delays (CMAA 2010).

The notion that such an amount of resources spent in construction projects ends up wasted, coupled with the considerable amount accounted for construction within the US economy as mentioned in the previous section, is very discouraging, yet motivating to look for new methods through which construction projects are executed.

1.2.3 Integrated Project Delivery – A New Comer:

Owners have been acknowledging waste, low productivity and, at the same time, advancement in technology in the construction field and, therefore, have been demanding more efficient ways to manage their construction projects. Construction Users Round Table (CURT) highlighted these needs from the owner's perspective in one of their publications. Typical problems that CURT cited included errors, omissions, inefficiencies, coordination problems, cost overruns and productivity losses delivered by lack of cooperation and poor information integration. Furthermore, the historical reasons for this lack of cooperation are many, including conflicting interests of many participants, incompatible cultures among project participants, and limited timely access to project information. Therefore, CURT advocates that the goal of all the industry participants should be better, faster, and more capable project delivery created by *fully integrated and collaborative teams* (CURT 2004).

Recently, IPD has evolved as a new project delivery system. IPD has been gaining momentum in the construction industry since 2005. The American Institute of Architects (AIA) - California Council has taken a lead role in promoting this new delivery system. The definition put forth by the American Institute of Architects for IPD is,

> *"Integrated Project Delivery (IPD) is a project arrangement that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants (a team setting) to reduce waste and optimize efficiency through all phases of design, fabrication and construction.*
>
> *Integrated Project Delivery principles can be applied to a variety of contractual arrangements and Integrated Project Delivery teams will usually include members well beyond the basic triad of owner, architect, and contractor. At a minimum, though, an Integrated Project includes tight collaboration between the owner, the architect, and the general contractor ultimately responsible for construction of the project, from early design through project handover."* (AIA-California Council 2007)

What makes this system different than the conventional construction project delivery systems mentioned above is the relational (multi-party) contract that regulates the relationship between the owner, the architect, and the general contractor who form the team that is ultimately responsible for construction of the project, from early design through project handover. The difference this relational contract creates – as oppose to the conventional transactional contracts used for construction projects – is the shared risk and reward, and the collective stakeholder success that is dependent on project success (AIA and AIA-California Council 2007).

Integration in construction projects is not only found in an IPD setting specified by AIA publications with a multi-party contract. Integration, and sometimes referred to as collaboration, can be found with a variety of levels in construction projects even with the use of traditional project delivery systems. In construction, owners have the upper hand in dictating the degree of collaboration or integration that takes place in projects, especially in the early stages. A report which was a joint effort by the National Association of State Facilities Administrators (NASFA); Construction Owners Association of America (COAA); The Association of Higher Education Facilities Officers; Associated General Contractors of America (AGC); and the American Institute of Architects (AIA), offered a tiered approach to achieving collaboration in construction projects based on three levels, as shown in *Figure 3*. The first level has a typical collaboration and no contractual collaboration requirements; the second has an enhanced collaboration and some contractual collaboration requirements, also known as IPD-like, IPD-ish, or IPD-lite; the third has the highest level of collaboration where collaboration is required by a multi-party contract, also known as pure-IPD or IPD (NASFA et al. 2010).

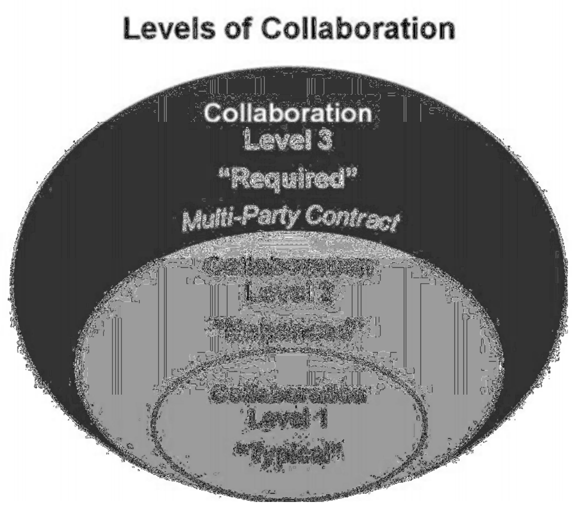


Figure 3: Levels of Collaboration (NASFA et al. 2010)

This study will test the level of integration within each project delivery system, and whether the more integrated projects lead to more efficiency and, eventually, more success to owners. This study’s effort is intended to be another step in the process of approving this newly evolved IPD system in delivering capital construction projects especially for owners and decision makers.

1.3 Problem Statement

The room for improvement in the capital construction industry remains large. Owners are the natural leaders in the capital construction industry due to the nature of their decisions, which is relative to what they have at stake.

As mentioned in the introduction, one potential area that could increase project efficiency is project delivery system. An increasing number of participants in the AEC industry see IPD – or integration in the project delivery system in general – as a new and promising tool to increase the value of resources spent in the industry's capital projects and ultimately the value to owners (CURT 2004, 2007; FMI Management Consulting 2010). However, IPD represents a radical shift that not every owner is willing to take (AIA and University of Minnesota 2012). The current generated conviction of IPD is based only on anecdotal experiences, which is not enough for skeptics in the industry including many owners. One way for this new system to be approved by owners is to be put to test against other project delivery systems. There have been a good number of notable empirical investigations of the main construction project delivery systems used in the US that showed the merits, shortcomings, and differences of each system (Debella and Ries 2006; Gransberg et al. 2003; Pocock, Liu, and Kim 1997; Rojas and Kell 2008; Sanvido and Konchar 1998; Thomas et al. 2002).

However, due to the novelty of IPD system, only two studies that were recently published included IPD in their analysis (El Asmar et al. 2013; Cho and Ballard 2011). Cho and Ballard (2011) data was very limited, and assessed project success based only on cost and schedule. El Asmar et al. (2013) study is more comprehensive in the data collected and therefore arrived at more comprehensive conclusions, however from a contractor's perspective. Owners, as main participants in the AEC industry, should be the focus in such studies. Kent and Becerik-Gerber (2010) published a study where a collection of AEC participants were surveyed including owners to basically measure their knowledge of IPD. Interestingly enough, owners were seen by all the participants to be the least experienced with IPD. Thus, owners are the main target of this study. Such inclusion would give owners and decision makers the appropriate knowledge to make sound decisions about the project delivery system that suits their endeavors, including IPD, and ultimately increase the value of their investments in capital projects.

In addition to what has been stated above, there is one more dimension to the problem. Studying IPD presents a very challenging task. Very few available completed projects used IPD or IPD principals. This requires commitment from a very limited pool of owners to provide data in order to analyze the true performance of IPD. As daunting this task might be, it should lead to worthy results, especially to owners.

In summary, a good way to convince construction owners of IPD, and integration in construction projects, is through addressing their current needs and then exploring the different project delivery systems and different integration levels in a project to see what caters the most to current owners' needs.

1.4 Study Questions and Hypotheses

The focus of this study revolves around the following two questions:

1. What are the current owners' needs when constructing new capital projects?

   Since the owners' perspective is the focus of this study, knowing what owners consider as success in capital projects is an essential part in this study. This inquiry also allows for the proper assessment of project delivery systems.

2. Would more integration in a project delivery system lead to greater success for owners, in meeting their needs in their capital projects?

   Can integration be considered the main ingredient or the shortest route to capital project success? From DBB, through CMR and DB, and ending with IPD, the level of integration increases. Does this increase in integration come in tandem with owner success?

Correspondingly, the study attempts to provide enough evidence to support the following main hypothesis:

More integration in a project leads to better outcomes for owners.

This hypothesis encompasses IPD to outperform other project delivery systems.

1.5 Study Goals and Objectives

The objectives of this study stem from the two questions above, and they are as follows:

1.5.1 Determining Owners' Needs in New Capital Projects:

Owners' needs change constantly for different reasons such as resources availability or economy. Therefore, these current needs need to be addressed and associated as possible with measurable metrics. Cost, time, and quality, have been historically the most acknowledged / measured metrics in construction projects. Therefore, a first objective for this study is an investigation of current owners' needs and priorities, and whether there has been a shift in priorities. A prioritized list of these needs will be formulated.

1.5.2 Investigating the Relationship between Integration in a Project Delivery System and Project Success (Owners' Needs):

After knowing the owners' needs and priorities which represent project success to owners, another step to be followed is to investigate the relationship between integration in the project delivery system and project success, and whether more integration lead to greater success. Three sub-objectives are essential to achieve this objective. The first is creating a data collection tool (survey) to collect the data to be analyzed. This includes designing and validating this survey. The second sub-objective is categorizing the level on integration in construction projects with a predefined methodology. This would allow for equal comparison among projects. The third sub-objective is creating an overall, comprehensive project success measure. This overall success measure should enable the use of multivariate analysis by representing the dependent variable.

The investigation will be done empirically using quantitative and qualitative measures. Individual performance measures will be compared across different levels of project integration in what is called univariate statistical analysis. In addition, using multivariate statistical analysis the study will investigate overall project performance on one hand; and project management setting and level of integration / collaboration among project participants' efforts, experiences and resources on the other hand. Multivariate analysis should produce predictive and explanatory models for construction project performance.

1.5.3 Determining the Project Delivery System and/or Project Characteristics that Lead to More Project Success to Owners:

The intention behind this objective is to find the ideal project delivery system or project characteristics that lead to owners' success in capital projects. The predictive and explanatory models generated from the multivariate analysis will emphasize on these characteristics statistically. The resulted models would present project characteristics and settings significantly affect project performance, either positively or negatively.

1.6 Study Scope

The scope of the study is to investigate project delivery characteristics and measure the level of integration incorporated in a project delivery, and the effect of this on the project outcomes from the perspective of owners. The investigation of the said items will be entirely within the construction phase of a project. Efforts exerted during the planning of a project or operation of the facility will not be included in the analysis of this study.

Because IPD system is newly evolved and in order to include it in the mix, owners that are known to be using innovative project delivery systems such as IPD were targeted among other owners that are willing to participate in this study. In addition, because IPD was introduced to the AEC industry as a distinguished delivery system in 2005, only projects that have been executed in the past eight years (since 2005) were included in the study. Moreover, due to the prior knowledge of the type of projects IPD system was used for, which were institutional complex projects, only owners of said project types were targeted in this study within the US.

1.7 Study Methodology

The following paragraphs represent the proposed roadmap to meet the proposed objectives. The proposed objectives are represented in three main tasks: (1) identifying owners' needs, (2) investigating whether incorporating more integration in a project would provide better chance to meet those needs, and (3) determining the project delivery system and/or characteristics that lead to project success to owners. The procedure proposed is a collection of steps consolidated in three phases as represented in *Figure 4* below. Each phase in the figure below is further explained in a separate subsection as follows.

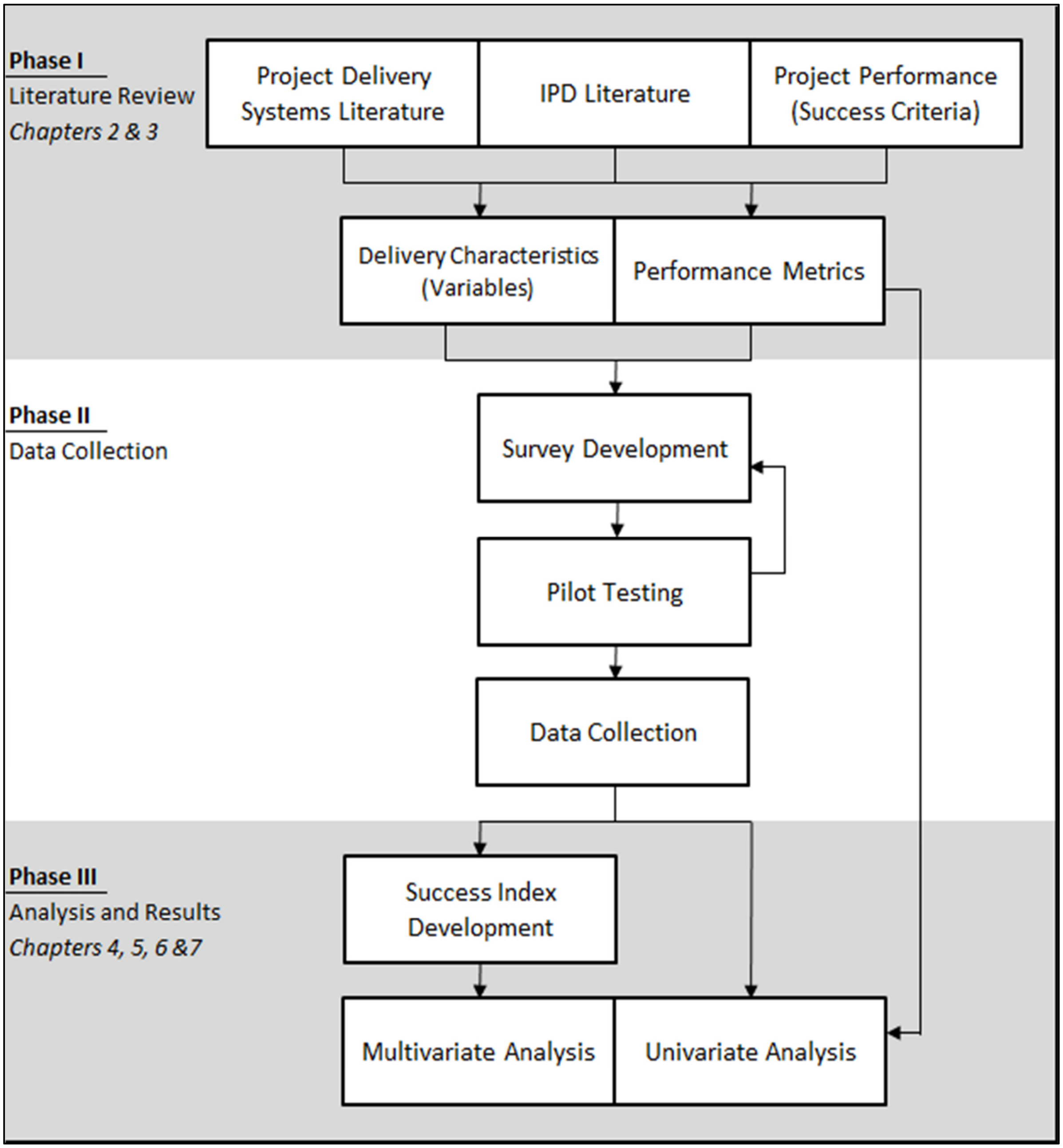


Figure 4: Study Methodology

1.7.1 Phase I – Literature Review

The literature review should set the ground for what has been researched on the subject matter to date, and how to correctly start this study's endeavor. The literature search was with a predefined search method. At the end, objectives from the literature review were met.

1.7.1.1 Method Followed

The literature review was mostly performed under three main topics. The first topic searched under was *the project delivery systems.* Project delivery systems types, performances and performance comparisons were looked at, for the main aim in this study is exploring project success through integration in the project delivery system. In addition, since IPD has newly evolved to be a stand-alone project delivery system, the second topic was *IPD*, a focus on what has been published about this new project delivery system, which includes study cases highlights and experiences. Finally, this study will examine project success through integration in the project delivery system from owners' perspective. Therefore, the third topic covered in the literature review was *the project success criteria* for construction owners. This includes metrics owners consider important in measuring construction project performance and outcomes.

Electronic databases were the primary source of reviewing literature of the subject matter. Those databases were searched for journal articles, conference proceedings, books, and reports issued by professional organizations. An example of the journals that were extensively searched was the *Journal of Construction Engineering and Management* of the American Society of Civil Engineers (ASCE). ASCE journals contributed the most in the first topic of this study's literature review, project delivery systems' details. Contribution for the second topic of this study's literature review, IPD, came from publications issued by professional organizations such as the American Institute of Architects (AIA) and the Lean Construction Institute (LCI). AIA has taken the lead in preaching for IPD to the AEC community since 2006. Their contribution to the IPD literature comes in the form of guiding report to implementing IPD

(AIA and AIA-California Council 2007), and IPD case studies reports that serves as a proof of concept (AIA and University of Minnesota 2012; AIA-California Council 2010). LCI has considered IPD to be an integrated part of the Lean Project Delivery System (LPDS) and had dedicated a special issue of *the Lean Construction Journal* in 2011 for Lean and IPD. Contribution for the third topic of this study's literature review, owners' success criteria for construction projects, came from ASCE journals and publications of professional organizations that represent owners in the AEC community such as the Construction Users Roundtable (CURT).

Relative keywords were used consistently in the database searches to confine the results from different databases. "Project Delivery System", "IPD", "Project Performance", "Project Success", and "Owner Success Criteria" were the main keywords used in this study's literature review search.

A consistent method was followed to thoroughly review the literature for this study's subject. A gap to be filled in the literature was revealed as a result of this review. Details of what was found in the literature review published and relative to the subject matter will come later in this thesis in *Chapter 2*.

1.7.1.2 Literature Review Outcomes: Key Variables

At the end of the literature review, methods of similar studies done in the past were revealed which significantly helped formulating the analysis path to be followed for this study. Determining project performance in past studies was performed using a collection of variables. There are the independent and control variables, which represent project characteristics and conditions surrounding it. There are also the dependent variables, which represent the project performance outcomes; and in this study, the owners' project success criteria. And between the two groups – independent and dependent variables – lies the recipe of project success. The independent and control variables serve as the input of the analysis, and the dependent variables as output.

Independent and Control Variables

Reviewing past studies in the literature revealed a collection of different variables that differentiate one project from another. "Independent variables" is a label used by some past studies for variables consist of project characteristics and management traits applied during the project delivery process. Examples of project independent variables found in the literature were project delivery system, compensation method used, and project participants' selection (buyout) basis. Other variables were labeled by past studies as "control variables". These control variables were associated with a project also as characters and conditions surrounding it; however, these are uncontrollable by the project management. Examples of project control variables were legal constrains and localities and size or type of the project.

Sanvido and Konchar (1998) and Korkmaz et al. (2010) have defined and listed these two kinds of variables that will also be further discussed in more detail in *Chapter 3* of this thesis. Independent and control variables used by previous studies will be used in this study. Other variables will also be considered in this study that have not been discussed by previous studies such as liability waivers, risk and reward considerations, and Building Information Modeling (BIM) which are mostly linked with IPD.

Dependent Variables – Performance Metrics

Also revealed from reviewing previous studies are the variables by which project performance and outcomes are measured, also known as project performance metrics. Previous studies have labeled these performance metrics as "dependent variables". The performance metrics can be classified as both quantitative and qualitative variables that are measured at the completion of a project. For this study, the focus in reviewing the literature for these performance metrics was on owners-specific criteria since the study is being carried from the owners' perspective. An initial list was put together from reviewing the literature for these performance metrics, which then was enhanced after collecting data from the surveyed sample as will be discussed later in *Subsection 1.6.2.2*.

Sanvido and Konchar's (1998) study of comparing different project delivery systems have composed a significant part of the background that this study is built upon especially identifying key variables to be observed for this study's subject. Identifying key variables helped formulate successive steps to be followed in meeting this study's objectives. This was evident in developing the survey to be used to collect the data for this study and the kind of questions to be asked, and then the analysis of the data collected. A complete list of independent, control and dependent variables to be used in study can be found in *Chapter 3* of this thesis.

1.7.2 Phase II – Data Collection

Reviewing the literature was followed by data collection in the study's methodology. As it appears in *Figure 4*, the data collection phase breaks down into three main tasks: the development of the survey to be used in collecting this study's data, testing and validating the aforementioned survey, and the actual collection of data.

1.7.2.1 Survey Development

After reviewing the available literature on this study's subject, all the elements needed to develop the data collection tool (survey) is now in hand. After highlighting the key variables to be studied, what to ask for and how to ask for it has become well known. Moreover, surveys of similar previous studies have directly influenced the development of this study's survey (Korkmaz et al. 2010; Sanvido and Konchar 1998). Both quantitative and qualitative measures were used in the development of the survey.

The study survey consists of two levels: the Executive-Level and the Project-Level in the form of two completely separate surveys.

The Executive-Level Survey

The purpose of the Executive-Level survey is to capture what construction owner organizations currently see as success criteria and value in executing their capital projects. Responders to this survey should hold an executive – decision making – position in an organization, and each organization was to fill this survey once. In developing this survey, emphasis was put on its length and conciseness of its questions due to the nature of responders' schedules and availability. Data collected using this survey served in formulating the dependent variables of this study.

The initial form of this survey was based on findings from the literature review, especially owners' criteria of success in construction projects. Then, the survey was further enhanced after validating it as will be discussed in *Subsection 1.6.2.2.*

The Executive-Level survey was comprised of four sections. The first section asks general questions about the organization, its structure (public / private, for profit / not for profit, etc.), and its business type. The second section inquires about the success in capital project execution from the construction owners organizations. It asks participants to rate ten project success criteria according to their impact on the project success. The section also asks participants to prioritize the stages of project development according to which requires their attention the most. The third section asks participants to evaluate the current project delivery systems. This section asks participants to give percentages of use of each project delivery system in their project execution. It also asks participant to rate their level of satisfaction with each project delivery system. Finally, the forth section asks participants about any obstacles that would be in the way of change to better and more innovative project delivery methods.

Details and descriptive statistics about the actual data collected using the Executive-Level survey can be found later in this thesis in *Chapter 4.* Also a copy of the actual Executive-Level survey can be found in *Appendix D*.

The Project-Level Survey

The purpose of the Project-Level survey is to collect data from projects executed by participants of the Executive-Level survey, construction owner organizations. The data collected using this survey will be enlisted under all three types of variables of this study, independent, control and dependent variables. Responders to the Project-Level survey should be close to the project-level in the organization, someone that would know all the details of a specific project. An owner organization responder can fill surveys for more than one project. Each survey represents one specific project.

Similar to the Executive-Level survey, the initial form of this Project-Level survey was based on findings from the literature review, especially key variables to be measured for project delivery and performance found in aforementioned project delivery comparison studies. In addition, new variables that measure innovative tools in a project that are mostly related to IPD such as BIM and liability waivers were also added to the survey. Then, the survey was further enhanced after validating it as will be discussed in the following *Subsection 1.6.2.2.*

The Project-Level survey is longer than the Executive-Level survey and acquires more details. It comprises of ten sections, each section is for a specific element in a construction project. Each element is comprised of a single variable or number of variables, which in part fall under either the independent, control, or dependent variables category. There are the cost, schedule, overall outcome, quality, claims, and safety sections that supply the dependent variables for this study. There are also the project general information, project delivery system, project management team, project management techniques, and project innovation that will supply both the independent and control variables for this study.

Data collected using the Project-Level survey contributes directly to both the Univariate and Multivariate Analysis of this study as can be found later in this thesis in *Chapters 5 & 7.* Also a copy of the actual Project-Level survey can be found in *Appendix E.*

Both, executive and project, surveys have been developed to meet this study's objectives. Extensive effort was put in both surveys to capture the whole picture this study seeks, yet concise enough to be more inviting for more participants' commitments. At the end of the survey development stage, both surveys were converted from paper version to an online version using online survey software, Qualtrics ®, through the University of Wisconsin-Madison's web services. The decision to convert both surveys to online surveys was based on the size of the task that lies ahead: collecting data from different organizations in different states with different schedules. Managing an online survey would make the task feasible.

1.7.2.2 Survey Validation

The developed survey underwent a validation process prior to distribution for data collection. Validating the survey means giving it a reality check and testing its appropriateness to the purpose for which it was developed. The survey validation went through two stages. First, it was reviewed by an academic panel from the University of Wisconsin-Madison Construction Engineering and Management Program. Then, it was presented to a professional panel representing construction owner organizations for further review and validation.

Academic panel

Both surveys were presented first to an academic panel from the University of Wisconsin-Madison Construction Engineering and Management Program. The panel checked the comprehensiveness, organization and question types of both surveys and their applicability to the targeted sample which is, in this study, construction owner organizations. It took more than one deliberation by the academic panel to agree on the final form of the survey.

The academic panel had one main concern since both surveys would be managed virtually (online): clarity of terms used in the surveys. Both online surveys were then supplemented by a comprehensive list of definitions for terms that would have potential of misconception. The definitions were added to the online surveys in a convenient way to responders. When in doubt about a term, a responder would only need to click on the term and a window with the term definition will appear. Finally, the surveys were presented to a survey professional from the University of Wisconsin-Madison Survey Center for final checks on the survey design.

Professional panel

Both surveys were then taken a step further in the validation process. They were presented to a professional panel. The professional panel was formed in collaboration with the Construction Users Roundtable (CURT), a professional organization that represents owners in the AEC community. CURT was approached with the study idea and they showed immediate interest in the subject since it directly affects their members, construction owner organizations. CURT named five owner representatives from their member organizations, and the meetings with the said panel were through teleconferences.

A total of three teleconferences were conducted for the validation and enhancement of both surveys. Three main concerns guided this validation process by the professional panel: (1) are the information asked for in the surveys applicable for our responders? In other words, is it something that you relate to and have experienced in your projects? Also, (2) are the information asked for attainable? In other words, could it be easily acquired by responders? And finally, (3) is the survey length appropriate for the targeted responders? At the end, the panel's comments and suggestions were taken into consideration, and the final forms of both surveys were agreed upon by the panel.

After the validation process of the survey by the academic panel first and then the professional panel, the survey was ready to be launched to collect responses.

1.7.2.3 Data Collection

The data collection for this study started right after the validation process. The collection had begun through CURT as well. Since CURT had been invested in this study's effort as mentioned earlier, as well as they were representing the exact population targeted by this study, invitations to this study's surveys were sent to all CURT members via email. An invitation letter to the survey, with cyber links to both surveys, was composed by the study team and then was sent to CURT's correspondence person whom in part sent it out to their members. A copy of the invitation letter can be found in *Appendix C*.

Beyond CURT members, the study team has sought after members of the construction owner organizations to invite them to participate in the survey. In a typical situation, randomization is the ideal sampling method for a population in order to statistically support a hypothesis and generalize a result. However, since IPD is a newly evolved project delivery system, and plays a main role in this study, randomizing a sample of the construction owner organization population would unlikely to include proper number of IPD projects to statistically analyze their performance. Therefore, this study uses purposive sampling (Babbie 2010), where construction owner organizations that were known to have recently used IPD were combined in a list. Organizations on the said list were persistently contacted by the study team to insure a proper number of IPD projects would be in this study's sample of data. The list was then expanded beyond organizations with IPD experience to include regular construction owner organizations to ensure a proper number of projects were acquired in order to do a valid statistical analysis. Two conditions were looked at in potential participants to be added to the contact list. First, an organization need to be large enough to have a designated staff or at least a person overlooks their construction projects. This shows that the organization manages its construction in-house, as oppose to hiring another firm to do the work. It also helps directing the invitation to the proper person or entity in an organization. The second condition that was looked at was the availability of contact information. Unlike the case with CURT, the study team had to look for contact information of potential participants, which in many cases was not available for public. Whenever these two conditions were met in an owner organization, it was added to the contact list, and then was contacted using the same invitation letter used with CURT members via email.

The invitation letter would initially be directed to an executive person in the organization to fill the Executive-Level survey. The letter then instructs the executive to delegate a person or more in the project-level in the organization to fill the other survey for one project or more. In some cases of the data collected, the same person in the executive-level also fills the Project-Level survey. Descriptive details of the data collected for this study can be found in *Chapter 4*.

1.7.3 Phase III – Analysis and Results

Analysis of the data collected revolves around proving this study's main hypothesis as stated in *Section 1.4.* What this study is trying to determine is whether more integration in the project delivery system would bring more success to owners in their construction projects. Following this endeavor, the analysis was done on two levels, Univariate and Multivariate.

1.7.3.1 Univariate Analysis

Univariate analysis is used to measure the effect of Project Delivery System (PDS) as a single independent variable, hence the name of the analysis, on project performance. PDS will not be categorized according to the conventional types (i.e. DBB, DB, CMR, etc.). A new categorization based on the level of integration in a project will be used with three types: IPD, IPD-like, and non-IPD. Details of the categorization method will be presented later in *Chapter 5*.

Project performance is represented in this study in various areas: cost, schedule, quality, safety, owner satisfaction, etc. The project performance, as the dependent variable for the univariate analysis, is measured for each individual performance metric separately at first. Later in this study, the performance of the project is measured as a combined metric of all the performance areas as will be explained next (*Subsection 1.6.3.2*).

Two types of statistical tools are used for the univariate analysis of this study. T-test will be used for the normally distributed data, and Mann-Whitney-Wilcoxon test for the non-normally distributed data. *Chapter 5* of this thesis will explain in great details the univariate analysis.

1.7.3.2 Owners Project Quarterback Rating (OPQR)

The development of a single success measure for construction projects is a primary part of this study's analysis. This single measure complements the univariate analysis comparisons by giving a comprehensive and inclusive success measure that would allow for project-to-project – and at the same time PDS-to-PDS – comparison. Moreover, the single success measure plays a primary role in the multivariate analysis as will be explained in the next subsection. It represents the dependent variable in the multivariate statistical tools when comparing IPD projects to non-IPD.

Metrics used in this success index are derived from owners success criteria extracted from both literature review and data collected from the Executive-Level survey. For the purposes of this study, this single overall success measure is called Owners Project Quarterback Rating (OPQR). More details about OPQR and how it was derived can be found in *Chapter 6* of this thesis.

1.7.3.3 Multivariate Analysis

Multivariate analysis takes the univariate analysis results a step further. With the univariate analysis, PDSs are linked with project performance in general without looking at the separate characteristics of the project delivery. Multivariate analysis gives more robust results by including separate project delivery characteristics – as independent variables – to allow for more comprehensive explanation of performance variation. As a result of the multivariate analysis, project delivery characteristics that have significant impact on project performance are identified and highlighted.

Multivariate analysis involves the development of a performance prediction model which is the product of the collection of significant project delivery characteristics, especially project delivery system and integrating tools and initiatives as this study is titled to achieve. Statistical tools used for this task are multiple regression and factor analysis. The produced model should help in guiding the AEC industry participants, and specially owners, to more success in their capital construction projects. More details about multivariate analysis performed in this study can be found in *Chapter 7* of this thesis.

1.8 Study Contribution

Four outcomes are expected at the end of this study. The first outcome is a prioritized list of owners' needs for their capital projects. Such a list should be valuable to AEC industry participants and researchers as well. It will help other AEC industry participants to deal better with owners, and researchers targeting construction owner population can use and update such a list. The first outcome should meet the first objective of this study. The second outcome is a data collection tool to collect the sought data for this study. Such a tool could also help future researcher in developing and building upon this study. A third outcome is a quantitative relationship between the level of integration in a project and the level of success associated with it, which also includes a mathematical predictive and explanatory model. Such a model would be a valuable tool to owners – and other AEC industry participants working with owners such as contractors and designers – in managing their capital construction projects. Both second and third outcomes should meet the second objective of this study. Finally, the fourth outcome is the determination of the project delivery characteristics and settings that caters to current owners' needs. This outcome should meet the third objective of this study.

1.9 Thesis Organization

This thesis starts with an introduction to the subject. The introduction includes background and history of the subject, motivation of the study, problem statement of the subject at hand, study questions, goals, methodology, scope and expected contributions.

After the introduction of the subject in *Chapter 1*, findings from the literature review of the subject are presented in *Chapter 2*. The literature review includes findings about success in construction, the effect of project delivery system on project performance, integration in construction projects and IPD.

After the appropriate background about the subject is presented in the first two chapters an introduction to the study variables comes next in *Chapter 3*. This includes dependent, independent and control variables. The first three chapters represent preparations for describing the data, which will come in *Chapter 4*, and performing the univariate (*Chapter 5*) and multivariate (*Chapter 7*) analysis. Within the analysis comes the introduction of a project success index (OPQR) in *Chapter 6*. At the end, the study conclusions are presented in *Chapter 8* followed by the supplemental appendixes.

Chapter 2. LITERATURE REVIEW

After introducing the subject of this study and the frame of work designed for it in *Chapter 1*, the literature review will be presented in this chapter as it is the first step taken in this study's endeavor. The following paragraphs lay out what was found in the literature regarding the subject of this study, and specify the potential gaps to be filled with this study's findings.

The title of this thesis is achieving construction project success through integration in the project delivery system from the owner's perspective. Therefore, a good starting point in the literature review is looking at the work done in the construction project success area and how success is measured.

2.1 What is Success in Construction in General?

Project Success as a subject has been very well served in the organizational and business literature for projects in general, and in the civil engineering and construction management literature for construction projects in particular.

From the organizational and business literature, the one main attribute that can be associated with project success is that it doesn't have a solid definition. There is almost a total agreement that project success definition stems from the subjectivity of the party giving the definition. The subjectivity is regarded to a multitude of project stakeholders, and how each stakeholder has different objectives entering a project (Atkinson 1999; Baccarini 1999; Shenhar et al. 2002; de Wit 1988). The Project Management Institute in their *Guide to the Project Management Body of Knowledge* (PMBOK® Guide) define project stakeholders as "persons or organizations (e.g., customers, sponsors, the performing organization, or the public), who are actively involved in the project or whose interests may be positively or negatively affected by the performance or completion of the project." PMBOK ® Guide also links the stakeholder to the success of the project by stating that "the project manager must manage the influence of the various stakeholders in relation to the project requirements to ensure a successful outcome"

(Project Management Institute 2008). De Wit (1988) did not stop at addressing the stakeholders' objectives when assessing the project success. He went further to argue that the stakeholders change throughout the project life cycle and along the management hierarchy which should also be accounted for in the success definition. Baccarini (1999) associated project success to two main components: product success and project management success. The first deals with the goal and purpose of the project and the latter deals with the inputs and outputs of the project execution process to reach the project goal. Both, he argues, should address the different stakeholders' objectives. Therefore, the conclusion that could be drawn from the organizational and business literature review about project success is that success means different things to different entities. These different entities also share one common factor: stakeholder satisfaction. Stakeholder satisfaction is a significant part of the success of any project in general and it depends on addressing the different objectives and needs of the different stakeholders that are invested and involved in that project.

The important role that stakeholders' satisfaction play in the success of project in general applies as well to construction projects. Many studies found in the civil engineering and construction management literature recognize the importance of addressing the different perspectives of stakeholders in the success of construction projects (Chan et al. 2001; Collins and Baccarini 2004; Hughes et al. 2004; Munns and Bjeirmi 1996; Sanvido et al. 1992; Shokri-ghasabeh and Kavousi-chabok 2009).

Sanvido et al. (1992) argues that success criteria for a person as it relates to a construction project often changes from project to project, and differences in the definition of success from one person to another are often very evident. Through literature review, brainstorming sessions, and consulting construction professionals, Sanvido and company put together a list of success measures for three different groups of AEC participants: owners, designers, and contractors. When analyzing these lists of success measures, Sanvido and company found "Common Criteria" among the three groups and "Unique Criteria" for each group. Making profit, avoiding legal claims, and finishing on schedule were common success criteria among the three groups. On the other hand, the designer is usually looking for a project that will increase the level of professional development satisfaction among his / her employees, the contractor highly prioritized the safety which is not normally an issue with the other two groups, and the owner is usually interested in knowing that the building project functions properly for the intended use and is free from latent defects or persistent maintenance problems.

Another example of the different perspective on project success in construction is a study done by Park (2009). Through a questionnaire, Park Investigated a number of critical factors grouped in eight categories by project phase, and as perceived by some of the project stakeholders including clients, contractors, and subcontractors, in order to identify critical success factors for each phase of the whole life of the project. Using a relative importance index, the top ten critical factors for each category from the perspective of project participants were analyzed and ranked. Then the project participants' agreement on these factors was further analyzed. Park found a stronger positive relationship between client and contractor rather than contractor and subcontractor, or client and subcontractor.

Chua et al. (1999) surveyed professionals in the construction industry with at least 15 years of experience from different organizational backgrounds including consultants, contractors, owners, and project managers in an effort to address critical success factors pertaining to construction projects. Although the results were not conclusive due to the small sample surveyed in this study according to the authors, the study did experience dissimilarities from the participants of different organizational backgrounds in their ranking to the critical success factors.

A similar study to Chua et al. (1999) done by Collins and Baccarini (2004) surveyed a sample of professionals from different organizational backgrounds which included owners, consultants, contractors, government employees, and educators to rank a list of success criteria for construction projects identified from the construction management literature. The study found both similarities and dissimilarities in the participants' priorities of the success criteria. The participants all agreed on satisfying owners' needs. Contractors were found to put more emphasis on "project completed on time" and "project completed on budget" than the other participants from different organizational backgrounds. The authors attributed this difference in the success criteria to the nature of contractors' involvement in a project which is to produce the actual final product, and that they had little involvement in the use of the product.

Another facet that shows the different perspectives of success within the construction industry by different participants is the direct focus some authors took in their studies at one specific AEC industry participants. Gambatese and Dunston (2003) surveyed designers to explore what designers consider important in construction projects. Menches and Hanna (2006) surveyed project managers on what project managers consider a successful project. Cox et al. (2003) surveyed top executives in construction firms on what an executive considers a key performance indicator in construction projects.

The previously mentioned studies showed how addressing the different stakeholder perspective in a construction project is an important part in acquiring project success. *An owner* qualifies as the most important stakeholder in a construction project and at the same time is the main focus of this study. Addressing owners' needs in executing their capital construction projects is a main part of this thesis. The following section explores in detail how these needs were catered in the construction literature.

2.2 What is Success in Construction to Owners in Particular?

Success criteria in construction projects are ultimately driven by and important to owners for they are the recipient of the final product. It has been established in the previous section that during different phases of a construction project, different participants might have different goals or milestones to achieve. However, these goals and milestones all converge to achieve the ultimate goals of projects that are solely set by owners. In order to optimize the use of their resources in their capital projects, owners' priorities need to be well understood. Different studies were found in the civil engineering and the construction management literature that talked about what owners consider a success criteria or a performance metric for a successful project.

Sanvido et al. (1992) used literature review and a brainstorming session with research team to establish lists of success criteria for project participants including owners. The list for owners' project success criteria in the study included: the project finished on schedule and on budget, the building functions for intended use by satisfying users and customers, the final product to be as envisioned, quality of workmanship and final product, the project to be aesthetically pleasing, return on investment, building must be marketable, and minimize aggravation in producing a building. This list was supplied by the authors with no priorities or ranking.

Songer and Molenaar (1996) conducted a study to address owners' attitudes toward the Design-Build (DB) project delivery system. Both public and private owners were targeted for the study. From a thorough literature review, the authors extracted a list of seven design-build selection factors. These factors and their definitions can be found in *Table 2*.

Table 2: Design-Build Selection Factors and Definitions (Songer and Molenaar 1996)

Selection Factor	Definition
Establish cost	Secure a project cost before the start of detailed design
Reduce cost	Decrease the overall project cost as compared to other procurement methods (design-bid-build, construction management, etc.)
Establish schedule	Secure a project schedule before the start of detailed design
Shorten duration	Decrease the overall project completion time as compared to other procurement methods (design-bid-build, construction management, etc.)
Reduce claims	Decrease litigation due to separate design and construction entities
Large project size complexity	The project's shear magnitude is too complex to be managed through multiple contracts
Constructability/ innovation	Introduce construction knowledge into design early in the process

The total responses collected for this study were 108 responses, 63% of them came from public owners and 37% from private owners. The participants were asked to rank the seven factors – listed in the table above – as reasons to choose DB delivery system. Using the mean scores of the participants ranking produced an overall ranking as follows: Shorten duration, establish cost, reduce cost, constructability / innovation, establish schedule, reduce claims, and finally large project size / complexity. This study represents owners' point of view towards selecting a specific project delivery system, which is DB, during specific period of time, the nineties.

Chua et al. (1999) surveyed 20 respondents with at least 15 years of experience with each respondent, and all being top executives. The sample size for this study was small (20 respondents), however the scope was broader than what Songer and Molenaar (1996) dealt with. This study's scope was not specific for single project delivery system; it was for construction in general. The respondents had different background affiliations. Some worked with contractors, others with consultants, or owners. According to respondents working with owners, critical success factors for construction projects – and in particular – during the construction phase are listed and ranked as follows: (1) Constructability, (2) Adequacy of plans and specifications, (3) Clear objectives, (4) Supplier level of service, and (5) Site inspection. These success factors are supposed to carry out the project to the ultimate project objectives under budget, schedule, and quality performances.

Griffith et al. (1999) focused on project success criteria from owners' perspective for, specifically, the execution of capital industrial projects. Data for this study was collected via interviews with a total of 131 responses from personnel employed by facility owners. According to this study, the four main variables that success depends upon are: budget achievement, schedule achievement, design capacity measured in the facility actual output rate compared to the planned, and plant utilization measured in the actual days in a year the plant is utilized compared to the planned. The ranking of these criteria is according to their mention. Again, this is another example of a study that captured owners' interest in a specific sector in the AEC industry, industrial construction.

More recently, Collins and Baccarini (2004) surveyed a sample of diverse group of AEC industry participants. They collected 150 responses, from which 33 were from owners or owner representatives. The authors found eight project success criteria in the literature and asked the respondents to rank them. According to owners and owner representatives in this study, the ranking of the success criteria is as follows:

1. The product satisfies owner's needs
2. Meeting specification
3. Project completed on time
4. Project completed on budget
5. The users of the project are satisfied
6. Efficiency of the project management effort
7. Third parties affected by the project are satisfied
8. The project team members are satisfied

Bowers et al. (2003) did a study to establish a framework for owners to manage their capital facility construction through choosing the proper project delivery and contract strategy. One of the objectives of this study was to create a list of typical project objectives that usually serves owners' interests. Each team member of the research team of this study; which was comprised of 13 company representatives, 10 of which represented owner organizations; were asked to list those typical project objectives that were consistent with projects developed and executed by their companies. The contribution of the research team members were combined in a generic list with the additions of some of the literature findings. The list then was used in a questionnaire to be ranked by owner organizations. Each response of the questionnaire represented a project executed by an organization, and the organization was asked to choose and rank its objectives for that project from the list included. A total of 82 responses were collected from 26 owner organizations. The ranked list was as follows:

1. Meet or exceed cost performance measures
2. Meet or exceed schedule performance measures
3. Emphasize safety in construction
4. Attain high quality of the constructed facility
5. Achieve customer satisfaction
6. Meet business requirements
7. Minimize interference with existing operation
8. Attain high quality of the production process
9. Maximize plant reliability
10. Emphasize operational safety in the design philosophy
11. Minimize contractor scope changes
12. Minimize risk
13. Ensure confidentiality
14. Optimize risk / return (high risk, high return)

One thing worth mentioning about this study is that the "safety" criterion started to get recognized by owners as a success criterion as it is ranked 3rd among this study criteria. This is the beginning of a trend, as safety would be recognized by owners as an essential part of project success along with the conventional criteria of cost, schedule, and quality. This is also evident in the subsequent studies.

The Construction Users Roundtable (CURT), which is a professional organization representing construction owners, published a report in which CURT has combined what their owner members consider critical areas of construction management and which should be assigned as proper measures.

These critical areas – not in particular order – are: cost, schedule, change management, safety, quality, productivity, reliability, and customer satisfaction (CURT 2005).

Del Puerto et al. (2008) did a study intended to first understand owners' motivations for selecting DB as a delivery system, and then how to determine the owner's definition of success for a given DB project. This is done by analyzing projects requests for proposal (RFP). Using a survey, owners were asked to select the reasons for their previous selection of DB project delivery system from a list of criteria. The ranked list of the reasons was: reduced schedule, early cost establishment, single entity responsible for design and construction, innovation, qualification / past performance of the designer and the builder, builder involvement in the design process, best value, cost savings, and enhanced quality.

Finally, the most recent study steered towards exploring construction owners' success criteria is joint effort by CURT and a management consulting agency called FMI (FMI Management Consulting 2012). The study surveyed 45 construction owner organizations. Sixty percent of the respondents were from the private sector and 40% were from the public sector representing a broad range of construction industry sectors: industrial, energy, transportation, commercial, and others. Among the issues covered in this study's survey is a specific question addressing owner's needs as they pertain to owners' capital projects. The "frequently cited owner needs" and their corresponding ranking of this study can be found in *Table 3*.

Although the report of the survey does not mention where these needs were cited from, the needs do resemble to a large extent what has been found in the previous literature listed above. Cost, schedule, quality and safety remain on the top of the owners' list of needs.

Table 3: Frequently Cited Owners' Needs and their Ranking (FMI Management Consulting 2012)

Frequently Cited Owner Needs	Average Rank
Safety	1
Best value and low price	2
Schedule	3
High quality	4
Long-term operational efficiency	5
Improved productivity	6
Low price	7
Sustainability	8
Greater depth of expertise	9
Reduced conflict resulting in lawsuits and delays	10
Single source (contract)	11

This section is a presentation of what has been published in the literature about owners' success criteria in construction projects and what they consider needs or performance measures. *Table 4* summarizes what was found of these criteria in the literature, with studies ordered chronologically by the date they were published. These criteria have evolved over time as witnessed in the published literature with the recent emergence of *Safety* and *Productivity* on the owners' priority list. However, meeting *Cost*, *Schedule* and *Quality* requirements remain at the forefront of those owners' requirements and criteria. This represents a good starting point in exploring construction owners' criteria for this study.

Table 4: Summary of Owner's Criteria for Construction Projects from the Literature Review

Success Criteria	Sanvido et al. (1992)	Songer & Molenaar, (1996)	Chua et al. (1999)	Griffith et al. (1999)	Bowers et al. (2003)	Collins & Baccarini (2004)	CURT (2005)	Del Puerto et al. (2008)	FMI / CURT (2012)	Total
Meets Cost[1] Requirements	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Meets Schedule Requirements	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Meets Quality[2] Requirements	✓		✓		✓	✓	✓	✓	✓	7
Customers/Users Satisfaction	✓				✓	✓	✓			4
Reduced Claims	✓	✓			✓				✓	4
Expertise[3]					✓	✓		✓	✓	4
Safety					✓		✓		✓	3
Functionality[4]	✓			✓					✓	3
Innovation		✓						✓		2
Constructability		✓	✓							2
Reliability[5]					✓		✓			2
Meet business plans	✓					✓				2
Productivity							✓		✓	2
Single Source Contracting								✓	✓	2
3rd Parties Satisfaction						✓				1
Project team satisfaction						✓				1
Good Suppliers' Service			✓							1
Minimized risk					✓					1
Reputation/ Social Gains	✓									1
Sustainability									✓	1
Aesthetically pleasing	✓									1

[1]*Cost: meets cost requirement, and value*
[2]*Quality: of workmanship, contract specification, and final product.*
[3]*Expertise: of project participants in design, construction, and construction management.*
[4]*Functionality: functions well for the intended use*
[5]*Reliability: of the construction processes*

In the former part of this literature review, a decent review of project success, and more specifically construction project success, published work has been presented. How owners' opinion forms an important part in project success and what success means to owners were also presented. As a result a list of owners' success criteria has been extracted from the literature as in *Table 4*.

Success criteria for any construction project describe the expected *output* of that project. The needed *input* of a construction project that would lead as close as possible to the expected output is best described by the project management processes. In his study, Baccarini (1999) divided project success into two components; product success which is what owners are looking for in the built facility, and project management success. Baccarini states that project management success is subordinate to product success. And that succeeding in project management doesn't guarantee product success. At the same time, product success doesn't mean that project management was successful. However, project management success does influence product success. As was established in *Chapter 1*, project delivery system qualifies as the best frame to encompass all project management processes.

2.3 The Effect of Project Delivery System on Project Success Outcomes

The Construction Management Association of America (CMAA) dubs the decision an owner takes to choose a project delivery system as the most important decision in a construction project (CMAA 2012). The importance of project delivery system choice in a construction project has its solid foundation in the construction literature. Extensive work found in the literature explains the effect of a project delivery system on project outcomes. This part of the literature review will be a presentation of the published work about the effect of project delivery systems on project outcomes.

Historically, measuring the performance of a project delivery system has been and still remains a subject of great interest to the construction industry participants as evidenced in the amount of work published under this subject. Studies of this topic are traced back to the early 90s of the last century. It actually gained momentum and interest in the mid-90s, and the reason for that interest probably the introduction of the Federal Acquisition Reform Act (FARA) in 1996 which explicitly authorized Federal agencies to use the, newly emerged project delivery system design-build (DB) (Hale et al. 2009). Subsequently, and with the positive experience using DB in several projects, many states passed new legislation and codes to allow alternative project delivery systems, i.e. DB and Construction Management at Risk (CMR).

Studies found in the literature were both empirical and non-empirical. In addition, due to the emergence of – what was called then – alternative project delivery systems, the majority of the studies' methodologies came in the shape of comparing project delivery attributes mostly between Design-Bid-Build (DBB) and DB, and occasionally, CMR. Moreover, some studies were found to explore the capabilities of a single project delivery system, as opposed to comparing it with another project delivery system, which was the case in other studies.

Through a non-empirical study, Songer and Molenaar (1996) attempted to address owners' attitudes toward one specific project delivery system, the DB system. Using a questionnaire, the authors asked for the reasons owners select DB delivery system. That study concluded that owners were choosing the DB delivery system due to its "fast-track" nature as one of its outcomes. Anderson and Oyetunji (2001) through another non-empirical study established a framework for managing project execution through project delivery and contract strategy. The authors proposed a structured procedure to help owners make this important project management decision. The procedure focuses on the owner's overall project objectives and the execution environment and employs a quantitative assessment of 12 project delivery and contract strategy alternatives in a decision support tool. These are two examples of non-empirical studies found in the literature that have related the project delivery systems to the project outcomes.

The focus in this part of the literature review, however, will be more on the empirical studies, since they represent similar route as this study. Empirical studies in the literature are many and with lots of variations. Therefore, to clearly present these studies, the discussion will be about the scope of the study in terms of how many project delivery systems were included, type and context of the data used, and any significant results found.

The studies found in the literature differed in their scope in terms of how many project delivery systems were included. Some studies were focused on one project delivery system. Molenaar (1997) measured the performance of DB in an attempt to show that the DB delivery system is an appropriate fit for some of the public sector projects, and that success in these DB public projects can be predicted using statistical models. Then, as a continuation to the previous study, Molenaar and Songer (1998) looked for associations and correlations between project variables and project outcomes in terms of budget variance, schedule variance, conformance to expectations, administrative burden, and overall satisfaction. The study collected data from 122 public sector projects. Five regression models were developed, one for each outcome. Chan et al. (2001) conducted another study that focused on the DB project delivery system. The study was set to identify a list of important factors contributing to the success of DB projects, examine the relative importance of these factors, and examine the relationship between project performance and project participants' satisfaction on the performance. The data for the study was collected from 53 experienced construction professionals from 19 different projects. The participants were asked to rate 31 factors contributing to project success. Using Factor Analysis technique, six factors were extracted from the 31 that accounted for 78 % of the variance in the responses. This followed by stepwise multiple regression analysis with the overall performance of the project as the dependent variable and the six extracted project delivery characteristics factors as the independent variables. The study was concluded with three significant factors in the project delivery that contributed to the success of the project: project team commitment, client's competencies and contractor's competencies. These two studies are examples of empirical studies focused on merely one project delivery system.

Other studies in the literature included more than one project delivery system in the form of outcome comparison of each. Zeitoun and Oberlender (1993) is one of the earliest studies detected that attempted to study the impact of some project characteristics that occur at the very early stages of a project, on project outcomes, in the form of cost and schedule growths, and included three project delivery systems in that mix: DBB, DB and CMR. A total of 106 projects formed the sample for this study which was further divided into two categories: fixed price and cost reimbursable projects. The study, however, did not arrive at any conclusion that relates the project delivery system, which was called execution format in the study, to the cost and schedule growth of a project. Pocock et al. (1997) is another early study comparing the performance of different project delivery systems. A total of 209 projects were used for this study's sample. The findings of this study showed that alternative project delivery systems – Partnering and DB – gave better performance than the traditional system – DBB. The performance comparison was based on cost and schedule growths, modifications per million dollars, and modifications due to design deficiencies.

The study done by Sanvido and Konchar (1998) as a report for the Construction Industry Institute (CII) had a larger scope in the project delivery comparison literature. The study was an empirical comparison of cost, schedule and quality attributes of three project delivery systems: CMR, DB, and DBB. The study included collecting and analyzing data from the building industry, significance testing of univariate comparisons and statistical development of multivariate linear regression models. For the statistical analysis, 100 explanatory (independent) and interacting variables were used to explain project cost, schedule, and quality performance. Several variables in project delivery process critical to project performance were identified, with a special emphasis put on the type of project delivery system. The data used was from 351 U.S. building projects, with six facility classes including light industrial, multi-story dwelling, simple office, complex office, heavy industrial, and high technology projects. The study produced a valuable decision making tool supported by quantitative data to help owners chose a delivery system. What gives this study its significance is the large and diverse sample size used, the intensive statistical analysis that was done, and the very important results it concluded. *Table 5* gives a summary of the results this study concluded.

Table 5: Average Percentage of Performance Difference among Project Delivery Systems (Konchar and Sanvido 1998)

Delivery System Comparison	**Performance Metrics**				
	Unit Cost	**Construction Speed**	**Delivery Speed**	**Cost Growth**	**Schedule Growth**
DB vs. DBB	6% lower	12% faster	33% faster	5.2% less	11.4% less
CMR vs. DBB	1.5% lower	6% faster	13% faster	7.8% more	9.2% less
DB vs. CMR	4.5% lower	7% faster	23% faster	12.6% less	2.2% less

Thomas et al. (2002) had done another empirical study in collaboration with CII. The study explored the relationship between construction projects' performance and their delivery systems. The study used a broad variety of projects submitted by both owner and contractor organizations that used one of two project delivery systems, DB or DBB, to the Benchmarking and Metrics (BM&M) Database of the CII. The database comprises of both domestic and international projects for the period between 1997 and 2000. The study used information about cost, schedule, safety, changes, and rework performance as metrics for project outcomes. The study also included practices considered to be essential in improving project performance. The practices analyzed were pre-project planning, constructability, project change management, design / information technology, team building, and zero accident techniques. The final sample for the study comprised of 326 owner projects (244 DBB and 82 DB) and 291 contractor projects (163 DBB and 128 DB). The study concluded that DB projects gave better schedule, changes and rework performances for owners and better changes performance for contractors, while DBB gave only better schedule performance for contractors. No statistical significance was found for the cost performance at either project delivery system. Ibbs et al. (2003) is another study done in collaboration with CII to compare DB to the more traditional DBB. A total of 67 projects from the CII database were used for the analysis of this study. The study found schedule performance to be more advantageous for the DB over the DBB system. No results under the cost or changes performance were found to be noteworthy by this study. CII have realized the importance of evaluating project delivery system's performance for the advancement of the construction industry and its participants. And that is shown in the previously mentioned studies.

Other studies found in the literature produced, as a result of measuring and relating project performance to project delivery systems, predicting models to act as practical tools for AEC industry participants in predicting their project performances (Jaselskis 1988; Ling et al. 2004; Molenaar 1997). Ling et al. (2004), as one example, studied the performance of DB and DBB projects and its correlation with project delivery characteristics, and in the process attempted to construct models to predict the performance of DB and DBB projects. Eleven performance indicators were found in the literature as dependent variables. Potential explanatory (independent) variables were also found in the literature to construct the predicting models. The study used 87 projects as a data set; 54 were DBB, and 33 were DB. Out of the 11 performance indicators set to predict the DBB and DB projects performance, robust models with good predictability were constructed for only 2 performance indicators for the DBB and 4 for the DB. The authors concluded that the constructed models should be good tools for contractors and owners in deciding what project delivery system to go with to ensure that their projects would produce higher performance.

Some studies in the literature focused on one particular context in their project performance evaluation. The following are examples of these studies. Debella and Ries (2006) tried to objectively measure and compare performances of project delivery systems for one type of owners, school districts.

The project delivery systems included in this comparison were all sub-classification of the traditional hard bid DBB system. The first type is DBB with only one “single prime” contractor, the second type is DBB with “multiple prime”, and the third and last one is the same as multiple prime but with management agent, construction manager. The data for this study came from 94 projects executed in the Northeast portion of the US. The performance indicators for this study were construction speed, unit cost, cost growth, schedule growth, change orders, and number of litigation cases. The study was able to distinguish among the delivery systems in only 3 of the 6 performance indicators. Multiple primes with agent had higher construction speed than the other two, and higher change order percentage. The single prime had lower number of litigation cases than the other two. There was no statistical significance in unit cost, cost growth, and schedule growth among the 3 project delivery variations. Another example is a study done by Rojas and Kell (2008) intended to compare cost growth performance in construction projects using both DBB and CMR delivery systems. Again, the scope of this study was school districts in particular. The data for this study was collected from 297 completed public school projects in the states of Oregon and Washington. The performance measures used were change orders cost growth, and cost growth prior to and during construction. Change order growth was lower on average for CMR projects than DBB projects, without statistical significance. Cost growth for CMR projects was higher on average than DBB projects, with statistical significance. The findings of this study challenge the common assumption that CMR delivery system has better cost control on projects than DBB.

A third example for project delivery system studies performed in a specific context is a study done by Hale et al. (2009) to compare the performance of DBB and DB project delivery systems in terms of cost and time. The scope of the study was military construction projects. The sample used for this study was from military building with similar nature, and two groups of samples were formed accordingly for each delivery system. The DBB sample contained 39 projects and DB sample contained 38. Statistical analyses were used to compare the samples and determine if one project delivery system was better than the other.

The result of this study indicates that the DB system is superior to DBB: DB projects will take less time to complete and have less time and cost growth.

Some more recent studies in the literature have added sustainability goals among the outcomes of project performance affected by project delivery systems. The sustainability goals were mostly in the form of acquiring the Leadership in Energy and Environmental Design (LEED) certification. Molenaar et al. (2009) delivered a study that explored how different project delivery systems influence owners' ability to achieve their sustainability goals in their construction projects. Data for this study was collected from 92 completed projects from both public and private owners. The study found that all project delivery systems (DBB, CMR, and DB) were used to deliver sustainable objectives represented in all LEED certifications. However, success in achieving these sustainable goals differed from one delivery system to another. Korkmaz et al. (2010) delivered another study that contributed to the relationship between the project delivery systems and attributes and project performance, especially those for high-performance green buildings. The data was collected from 40 projects, and concentration of the data pool was from green office building projects, projects that had LEED rating. The project delivery systems included in the analysis of this study were CMR, DB, and DBB. One of the main conclusions of this study was that timing of the contractors' involvement in projects was a strong process indicator affecting most of the performance outcomes. This is more evident in DB projects than in DBB projects.

All these previously mentioned studies are relevant to the subject of this study. However, two most recently published studies are more relevant to this study in terms of including the recently evolved Integrated Project Delivery (IPD) system. Cho and Ballard (2011) wanted to discover a relationship between IPD, Last Planner (LP) which is a scheduling method also called pull scheduling, and project performance represented in cost and schedule reduction. The delivery system comparison in this study was between IPD versus non-IPD projects. The data for this study was collected from 49 projects using a survey. Three hypotheses were tested for this objective: (1) whether implementing more LP results in better project performance, (2) whether IPD projects performance is different from those with non-IPD, and (3) whether LP was implemented more with IPD projects than with non-IPD projects. The first hypothesis was statistically supported by a regression model. The data failed to statistically support the second and third hypotheses. The authors admit the limitation of their study in terms of quality of data and sample size. El Asmar (2012) is a more recent and more comprehensive study in the form of a PhD thesis titled *Modeling and Benchmarking Performance for the Integrated Project Delivery (IPD) System*. Although the sample size El Asmar used does not qualify to be significant with only 35 projects, the quality of the data collected qualifies the study to produce more comprehensive conclusions. The responders of the survey El Asmar used in his study were solely contractors and the project delivery systems included in the study were DBB, CMR, DB, and IPD. The study concluded that IPD achieves statistically significant improvements in 14 metrics across five performance areas: building quality, project schedule, project changes, communication among stakeholders, and financial performance.

The paragraphs above presented the construction literature about the effect of project delivery system on project outcomes. Three main points can be taken from these studies. First, studies in the literature about the effects of project delivery system on project outcomes are many. They vary in scope, objectives, and number of delivery systems included. Finally, they clearly show a direct effect of the project delivery system on project outcomes which was indicated in the conclusions of the studies. *Table 6* below summarizes the studies presented in the above paragraphs. The table highlights the focus areas used in the literature presentation such as the delivery systems compared in each study, the scope and context of data collected, and the number of projects used for the analysis. The last column of *Table 6* shows what is included in this study effort compared to the previous studies.

Table 6: Literature Summary of the Effect of Project Delivery System on Project Outcome

	Zeitoun and Oberlender (1993)	Pocock, Liu, and Tang (1997)	Molenaar (1997)	Molenaar and Songer (1998)	Sanvido and Konchar (1998)	Chan et al. (2001)	Thomas et al. (2002)	Ibbs et al. (2003)	Ling et al. (2004)	Debella and Ries (2006)	Rojas and Kell (2008)	Hale et al. (2009)	Molenaar et al. (2009)	Korkmaz et al. (2010)	Cho and Ballard (2011)	El Asmar (2012)	Boodai (2014)
Systems Compared																	
DBB	●	●	●		●		●	●	●	●	●	●	●	●		●	●
DB	●	●	●	●	●	●	●	●	●			●	●	●		●	●
CMR					●						●		●	●		●	●
CMA	●																●
Other		●						●		●					●	●	●
IPD															●	●	●
Data Collected																	
Quantitative	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Qualitative	●		●	●	●	●			●				●	●		●	●
Projects Sector																	
Public	●	●	●	●	●	●	●		●	●	●	●	●	●		●	●
Private	●				●		●		●				●	●		●	●
Projects Location																	
US	●	●	●	●	●		●	●		●	●	●	●	●		●	●
Foreign						●	●	●	●								
Num. of Projects	106	209	N/A	122	351	19	617	67	87	94	297	77	92	40	49	35	34

Organization of the table is adopted from Sanvido and Konchar (1998)
Studies are organized chronologically by the publishing year

2.4 Integration in the Project Delivery Improves Project Outcome

The effect that a project delivery system has on project outcomes (i.e. cost, schedule, or quality) has been well established and explored in the literature as evidenced in the previous section. This section is intended to go beyond what was accomplished in the previous section and prove that not only project outcomes are strongly associated with project delivery system, but that *better project outcomes* are strongly associated with *more integrated* project delivery systems. Numerous studies in the literature showed that projects with more integrated delivery systems had better outcomes (El Asmar et al. 2013; Hale et al. 2009; Ling et al. 2004; Pocock, Liu, and Tang 1997; Pocock and Liu 1996; Sanvido and Konchar 1998).

As mentioned earlier in this study (*Section 1.5.2)* integration involves the following: integrating resources, efforts, information, and experiences among project participants as early as possible in the execution of a construction project. Nam and Tatum (1992) used the term Integration to describe the integration effort between design and construction. The literature also shows that this integration does not mean participation only, it needs to be active, and in early stages of a project (Azari-Najafabadi et al. 2011; FMI Management Consulting 2010). The term integration, which is sometimes interchangeably used with collaboration, represents a change or a shift from traditional project delivery systems (see *Table 1*, *Chapter 1*). It could be found as small as voluntary acts among project participants, and as extreme as contract obligation.

Since the early 1990' and especially with the emergence of the DB delivery system, AEC industry participants started to realize the benefits of integrating project participants' efforts as early as possible in a project. Published studies were found to recommend collaboration and team setting among project participants. Sanvido et al. (1992) defined in their study a set of factors or conditions critical to project's success. These factors or conditions, the authors argue, ensure a successful project performance when thoroughly and completely satisfied. One of these factors is "a well-organized, cohesive facility team to manage, plan, design, construct, and operate the facility." Gibson Jr et al. (1994) were set as a research team to determine the impact of pre-project planning on the success of projects. The study included interviews with 131 professionals representing three different groups of project stakeholders: operations, business, and project management. The three groups of professionals interviewed for this study served as a diversity of opinions about many areas concerning the project success and pre-project planning efforts. After the analysis of the participants' perceptions concerning project success and pre-project planning effort the authors outlined best practices in this area. These outlined best practices included:

1. "*Teamwork* and *communication* are critical to the pre-project planning process.
2. When organizing for the pre-project planning, a *multi-disciplinary team* consisting of appropriately skilled and experienced personnel, to include the project customer, *is required*. This means that operations, business, project management / technical, and, if applicable, key consultant personnel must be closely involved in pre-project planning early in the process."

The authors concluded that a diverse pool of opinions in team-based blending of project participants is the best way to achieve project objectives. In a PhD thesis, Pocock (1996) developed an approximation method to measure project integration through project participant's "Degree of Interaction" (DOI). DOI is defined by the author as *"the extent of interaction among designers, builders, and project team members during a project's planning, conceptual design, detailed design, procurement, construction, and start-up phases,"* and it is calculated using man-hours spent by project team members interacting among each other throughout project phases. In the study, DOI was calculated for 38 military construction projects. The projects were delivered using alternative and improved project delivery systems such as Partnering, which is a project delivery system that transforms contractual relations into a cohesive team with one set of goals and eliminates any hostility (Larson 1995), and DB that have higher DOI than project delivered using the traditional project delivery system, DBB. The study showed that DOI has a direct impact on project performance with a clear positive relationship: better performance outcomes with higher DOI. Another more recent thesis that proved better project performance comes with more integration among participants is what El Asmar (2012) did as discussed in the previous section.

Del Puerto et al. (2008) studied the need for integration from an owner's perspective which is in-line with the objectives of this study. Del Puerto and others studied what owners believe is important to achieve their project goals using DB project delivery system. The study used the owners' evaluation criteria for DB proposal plans. The authors found that *"builder involvement in the design process"* was one of the main reasons owners opted to use DB delivery system.

This section presented studies found in the literature that showed the relationship between integration in the project delivery system and better project outcomes. The newly evolved Integrated Project Delivery (IPD) system is predicated around integrating project participants' efforts in project execution, hence the name. The following section will explore what was found in the literature about IPD, and whether these claims of IPD providing better integration among project participants are supported.

2.5 Integrated Project Delivery (IPD)

Chapter 1 of this thesis contained an introduction about the IPD system. This section presents what was found in the literature about IPD. As mentioned earlier, the inception of IPD was in the last decade, around 2005 (AIA and University of Minnesota 2012; Lichtig 2005). With the increased acceptance momentum in the industry for this new project delivery system, noteworthy efforts in the form of reports or case studies to educate the AEC community about this system were published.

The American Institute of Architects (AIA) – California Council has taken the lead role in educating the AEC community about IPD. Their first two publications in this endeavor came in 2007 (AIA and

AIA-California Council 2007; AIA-California Council 2007). The two reports set forth a definition for the new project delivery system, principles and assumptions needed to implement IPD, and characteristics of IPD projects from choosing the integrated project team to project closeout. *Figure 5* below is from one of the reports mentioned above. It shows how the characteristics of an IPD project differ from a traditional project with the early involvement of project participants and early project goals definitions.

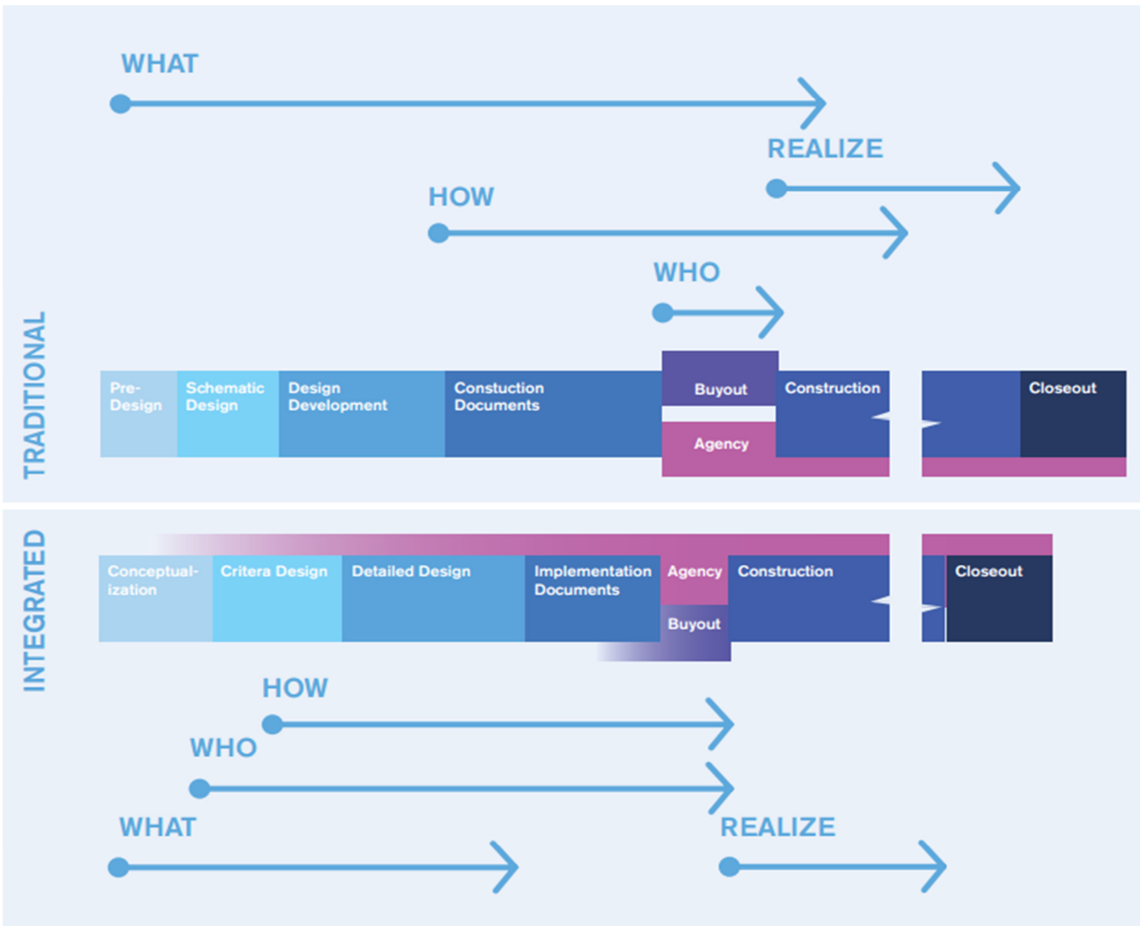


Figure 5: Comparing a Traditional Project Delivery System (DBB) to an Integrated one (IPD) (AIA-California Council 2007)

After setting forth IPD's definition and frame of work, AIA followed with another publication in 2009 that talked about the value proposition of IPD. The report presented a collection of experiences from

IPD project participants (i.e. owners, designers, and contractors) on the value IPD provides in terms of efficiency, cost management, superior results, and flexibility (AIA and AIA-California Council 2009).

A year after, AIA released a publication that showcased six projects to serve as a "proof of concept" for IPD then followed it with another publication in 2012 that showcased another six more projects with the inclusion of the old six. These twelve projects varied in nature from office building to healthcare facility to educational facility. However, they all were executed using the same IPD guidelines identified in previous publications and came out with impressive results (AIA and University of Minnesota 2012; AIA-California Council 2010).

One major point was shared in all AIA publications was the evolution of IPD principles. As the level of experience increased, so is level of defined details for IPD. This can be observed in AIA sequential publications. *Table 7* lists the development of IPD principles in AIA publications. First, they were a group of general principles that sets IPD projects apart from other delivery systems projects (column 1) (AIA and AIA-California Council 2007). These general principles were fine-tuned to more detailed principles, broken down into contractual and behavioral principles with the addition of catalysts or tools for IPD (column 2) (AIA-California Council 2010; NASFA et al. 2010). The development can be seen as follows. "*Mutual respect and trust*" was detailed further to be "*key participants bound together as equals*" by using "*multi-party contracts*," and adding the "*liability waivers between key participants.*" The "*mutual benefit and reward*" was detailed further to specifically be "*shared financial risk and reward*" and "*fiscal transparency between key participants*." The "*appropriate technology*" was specified more to be "*BIM*" and "*lean design and construction*." In their most recent publication, AIA regrouped IPD principles into Markers and Strategies (column 3) (AIA and University of Minnesota 2012). The markers represent general principles that could be applied to any project, even projects delivered using traditional delivery system. The strategies represent the known IPD tools and techniques such as multi-party contract, liability waivers, financial transparency, and co-location. By the time this last publication was issued, AIA's experience with IPD and the AEC participants' perception of IPD was the highest. This final development of IPD principles was done in anticipation of AEC participants' reluctance to commit to the contractual obligations that comes with IPD such as the multi-party contract and liability waivers. For that reason, AIA showed how IPD principles can be implemented with the conventional project delivery systems such as DB, CMR, or even DBB as it appears in their case studies. Some of the case studies' projects had a conventional project delivery system (CMR) with the application of some IPD principles.

A report published in 2010 as a collaboration effort among five professional organizations that represent participants of the AEC industry, and AIA was one of them, gave a new dimension to IPD projects (NASFA et al. 2010). The study categorized collaboration in a project within three levels:

- Level One – Typical collaboration with no contractual obligation
- Level Two – Enhanced collaboration with some contractual obligation
- Level Three – Required collaboration with supporting contract (multi-party contract)

Level one in the report refers to all non-IPD projects. Level two refer to projects that adopt IPD as a philosophy, and can be called IPD-like, IPD-ish, or IPD-lite projects. Level three refer to projects that adopt IPD as a delivery system, and can be called IPD or pure-IPD. *Table 8* was taken from this report and shows the details of these levels of collaboration.

Table 7: Evolution of AIA's IPD Principles

2007	2010	2012
Principles of IPD Mutual Respect and Trust Mutual Benefit and Reward Collaborative Innovation and Decision Making Early Involvement of Key Participants Early Goal Definition Intensified Planning Open Communication Appropriate Technology Organization and Leadership	*Contractual Principles:* Key Participants Bound Together as Equals Shared Financial Risk and Reward Based on Project Outcome Liability Waivers between Key Participants Fiscal Transparency between Key Participants Early Involvement of Key Participants Intensified Design Jointly Developed Project Target Criteria Collaborative Decision-Making *Behavioral Principles:* Mutual Respect and Trust Willingness to Collaborate Open Communication *Catalysts for IPD:* Multi-Party Agreement Building Information Modeling Lean Design and Construction Co-location	*IPD Markers:* Relational Contracts Protection from Litigation Aligned Project Goals (Jointly Developed Project Target Criteria) Informed and Balanced Decision-Making (Collaborative Decision Making) Open Communication Risks Identified and Accepted Early *IPD Strategies:* Key Participants Bound Together as Equals (Multi-Party Agreement) Budget & Create Team for Design Intensive Work Early Contribution of Expertise (Early Involvement of Key Participants) Pre-existing Relationships between Parties Champion/ Facilitator (Leadership by All) Shared Financial Risk and Reward Based on Project Outcome Liability Waivers between Key Participants Fiscal Transparency between Key Participants BIM – Virtual Rehearsal of Construction and Ongoing Constructability Reviews Lean Construction Processes Co-location

Table 8: Levels of Collaboration (NASFA et al. 2010)

	Level One "Typical" Collaboration	Level Two "Enhanced" Collaboration	Level Three "Required" Collaboration
Level of Collaboration	lower	← →	higher
Philosophy or delivery method?	IPD as a Philosophy	IPD as a Philosophy	IPD as a Delivery Method
Also known as...	N/A	IPD-ish; IPD Lite; Non Multi-party IPD; Technology Enhanced Collaboration; Hybrid IPD; Integrated Practice	Multi-Party Contracting; "Pure" IPD; Relational Contracting; Alliancing; Lean Project Delivery System™
Delivery Approaches	CM at-Risk or Design-Build	CM at-Risk or Design-Build	Integrated Project Delivery
Typical Selection Process	Qualifications Based Selection of all team members or Best Value Proposal	Qualifications Based Selection of all team members	Qualifications Based Selection of all team members
Nature of Agreement	Transactional	Transactional	Relational
Key Characteristics	• No contract language requiring collaboration • Limited team risk sharing • CM or DB share in savings	• Contract language requiring collaboration • Some team risk sharing • Co-location of team	• Owner-Designer-Contractor (and possibly other key team members-IPD Subs) all sign one contract that contracts collaboration • Team risk-sharing-incl. A/E • Team decision-making • Optimizing the Whole • Pain / Gain sharing • Limits on litigation • Co-location of the team
Typical Basis of Reimbursement	GMP	GMP	GMP or No GMP (some costs guaranteed)

Other than AIA efforts in articulating IPD and educating the AEC community about it, there have been efforts by other organizations for the same purpose, overviewing IPD and educating the AEC community about this system, however, not to the same magnitude of AIA publications (CMAA 2010; Sive 2009; Thomsen 2009). Kent and Becerik-Gerber (2010) published a study about IPD not to educate the public about IPD, but rather to measure AEC industry's experience and attitude toward IPD. The study collected qualitative data from owners, designers, engineers, construction managers and contractors. Singelton and Hamzeh (2011) published a study to explore the ability to implement IPD principles on the Navy construction projects. Their conclusions were based on few pre-published IPD case studies.

All what has been published about IPD and mentioned above gives quality description about the system and how it is viewed in the AEC industry. However, it is not relevant to this study in terms of methodology. The main objective of this study is to statistically prove the performance superiority of IPD compared to other project delivery systems. Only two studies have been published so far that are relevant to this study in terms of statistically proving the performance superiority of IPD. Both studies have been mentioned earlier towards the end of *Section 2.3*. Cho and Ballard (2011) wanted to discover a relationship between IPD, Last Planner (LP), and project performance represented in cost and schedule reduction. The study found that implementing more LP results in better project performance. However, the study did not find any statistical support to whether IPD projects performance is different from those with non-IPD, or LP was implemented more with IPD projects than with non-IPD projects. El Asmar (2012) is a more comprehensive study in the form of a PhD thesis. The quality of the data collected qualifies the study to produce more comprehensive conclusions. The responders of the survey El Asmar used in his study were solely contractors and the project delivery systems included in the study were DBB, CMR, DB, and IPD. The study concluded that IPD achieves statistically significant improvements in 14 metrics across five performance areas: building quality, project schedule, project changes, communication among stakeholders, and financial performance.

Moreover, two Master theses out of the University of Wisconsin-Madison were also found to include IPD in their scope. Iwanski (2013) assessed IPD performance with Mechanical and Electrical Contractors where he found IPD to give superior performance in quality, communication, and schedule metrics for the said Specialty Contractors. Olsen (2013) surveyed General Contractors other than those in El Asmar (2012) sample to confirm El Asmar’s conclusions at the univariate analysis level where he found IPD to give superior performance in communication, change management, and business performance areas.

A survey of the IPD literature shows a lack of hard-data-based studies to show any type of performance superiority compared to other project delivery systems. Only few studies were based on hard data and statistical analysis of IPD performance. Furthermore, none of these studies put owners' needs or criteria specifically in perspective.

2.6 Summary of the Literature Review

Through the literature review three main goals were achieved. First, all the published studies and research relevant to this study were explored. Second, the literature review explored the methods followed in the relevant studies to this study. And finally, a gap in the literature was identified for this study to fill.

In exploring the literature, several steps were taken. The title of this study is achieving project success through integration in the project delivery system from an owner's perspective. Four keywords guided the literature review: "Project Delivery System", "IPD", "Project Performance", "Project Success", and "Owner Success Criteria". First, the definition of success in construction projects was explored. It was clear from the literature that achieving success in construction projects depend greatly on addressing all project stakeholders' needs. Then, the review focused more on owners' criteria alone out of all the project stakeholders. This produced a list of highly cited owners' success criteria in construction projects. After that, the review turned to the relationship between project delivery system and project outcomes that represent success. The review resulted in a strong correlation between project delivery system and project outcomes. Then the review zoomed on integration in the project delivery system. The review resulted in number of studies that proved how more integration in the project delivery system leads to more success. Finally, the review focus turned to IPD literature. The results of the review showed that IPD literature is still limited in terms of statistically based studies that show the claimed performance superiority of IPD compared to other project delivery systems. *Table 9* below shows the flow of these steps in the literature.

The last point to take from this literature review is the opportunity for this study to fill an available gap in the construction literature. After reviewing the literature relevant to the subject of this study, a gap was identified for this study to fill. The construction literature lacks a study that shows the effect of integration in project delivery system on project success. When talking within this frame, El Asmar (2012) would be the closest study this one. However, El Asmar (2012) was measuring success from a contractor's perspective, and this study focuses on the owner's perspective.

Table 9: Summary of Literature Review Steps

Literature Review Steps	Outcome
What is success in construction?	Success in construction projects depends greatly on addressing different project stakeholders' needs.
⇩	⇩
What is construction success to owners?	A list of highly cited construction success criteria from an owner's perspective.
⇩	⇩
Does project delivery system affect project outcomes?	A strong correlation was found in the literature between project delivery system and outcomes.
⇩	⇩
Would more integration lead to more success?	A strong correlation was found in the literature between integration in a project delivery system and outcomes.
⇩	⇩
Integrated Project Delivery (IPD)	IPD literature is very limited in the hard data based studies to prove its superior performance.
At the end, a gap was identified for this study to fill in the construction literature.	

Chapter 3. RESEARCH VARIABLES

In this chapter, the variables to be studied and analyzed are presented. Determining the study variables is very important, for it provides a clear analysis of the project delivery process and its effects on project outcomes. Both, project delivery attributes and project outcomes are represented in variables: the first is called independent and second is called dependent.

First, the variables representing project outcomes in the form of performance metrics, which also represent dependent variables, will be introduced. Then, the variables representing project delivery characteristics and attributes, which also represent the independent variables, will be introduced. Also, a framework through which these independent variables are categorized will also be presented.

3.1 Performance Metrics (Dependent Variables)

The performance metrics were introduced in the literature review chapter and specifically in *Section 2.2*. The literature was reviewed to explore the historically most cited owners' project success criteria also known as performance metrics. *Table 4* in that section shows a summary of the literature findings. The eight most cited criteria shown in the said table are:

1. Meets Cost Requirements
2. Meets Schedule Requirements
3. Meets Quality Requirements
4. Customers / Users Satisfaction
5. Reduced Claims
6. Expertise of participants
7. Safety during construction
8. Functionality in terms of intended use

The literature findings of the performance metrics from an owner's perspective were also coupled with this study's Executive-Level survey data. Information about the content of this survey and its respondents has been previously discussed in *Subsection 1.6.2.1*. The survey contained a list of owners' success criteria – also known as performance areas – extracted from the literature. Survey respondents were asked to rate the impact of each success criterion in the list in term of its impact on project success, add any necessary criteria not in the list, and also rate it. *Section 4.1* in *chapter 4* will include detailed description of the data collected. Each success criterion, or performance area, determined by the owners has to be associated with a measurable metric in order to determine the level of its accomplishment.

The final list of performance areas contains only the areas for which data was available with the survey responders, and was successfully collected. This makes a total of seven performance areas with 14 measureable performance metrics that satisfy owners' criteria. *Table 10* shows the details of the final performance areas and their measurement metrics used in this study. The first column in the table has the success criteria in the form of general areas of construction performance. The second column has the measurement metric(s) for each performance area. The third column contains a definition for each measurement metric. And finally, the forth column determines the type of variable for each metric and whether it is an objective or subjective measure. Two types of metrics are used here: continuous, and categorical. Two types of categorical variables used here are ordinal (a gradual discrete scale such as Likert), and binary (a dichotomous scale of yes or no). Data was successfully collected for all the 14 measurement metrics in the data collection process.

Table 10: Project Owner-Specific Performance Areas and their Complementing Measurement Metrics

Performance Area (1)	Measurement Metric (2)	What is it? (3)	Type (4)
1. Cost	Cost Change	Cost Change: the difference between the planned and actual project design and construction costs	Continuous (Objective)
2. Schedule	Schedule Change	Schedule Change: the difference between the planned and actual period of project's construction phase	Continuous (Objective)
3. Quality	Turnover Quality	The quality of Start-up, Call backs, and O&M as seen by the owner	Ordinal (Subjective)
	Building Quality	The quality of Structure & Exterior, Layout & Interior as seen by the owner	Ordinal (Subjective)
	Systems Quality	The quality of systems (e.g. lighting, HVAC) and equipment (e.g. labs, processing) as seen by the owner	Ordinal (Subjective)
	Overall Quality	The average score of everything in 3, 4, & 5 above	Ordinal (Subjective)
4. Communication	RFI/Million $	The number of RFI/Million dollars of the total project cost	Continuous (Objective)
	RFI Processing Period	The time (days) it takes to process an RFI as approximated by the owner representative	Continuous (Objective)
	Team Communication	Communication among project team members as seen by the owner	Ordinal (Subjective)
5. Claims	Number of Claims	The issuance of claims in a project	Binary (Objective)
6. Satisfaction	Owner Satisfaction	Owner's level of satisfaction	Ordinal (Subjective)
	User Satisfaction	User's level of satisfaction as seen by the owner	Ordinal (Subjective)
	Overall Satisfaction	The average score of 11 & 12 above	Ordinal (Subjective)
7. Safety	Safety Rating	Safety Standards and Safety Performance of the project rated by the owner	Ordinal (Subjective)

The study Project-Level survey can be found in *Appendix E* where designated question(s) were assigned for each of the measurement metrics in the table above.

3.2 Project Characteristics (Independent and Control Variables)

Previous studies found in the literature have paved the way for this study in determining project delivery attributes and characteristics to analyze (El Asmar 2012; Korkmaz 2007; Korkmaz et al. 2010; Sanvido and Konchar 1998). Some of these studies have previously been mentioned in the literature review chapter, however, this chapter will emphasize on their contribution to the project delivery characteristics and attributes in the form of various variables. These project characteristics fall under two categories: independent and control variables. The independent variables consist of different manageable aspects of the project, whose relationships with the project outcomes are to be determined, such as the project delivery system, project collaboration efforts, contract conditions, etc. The control variables are variables that significantly affect the project outcomes, however, unmanageable / uncontrollable by the project managers such as project type, size, locale, and other external conditions.

Sanvido and Konchar (1998) study, as has been mentioned in the literature review, is considered a significant study in the field of analyzing project delivery systems' performance. The authors broke down project characteristics in order to analyze their effect on project outcomes into groups: project characteristics which included size, location, and type; project delivery system which included the system used and the accompanying commercial terms; and project team characteristics which included team procurement, experience, and communication. Other characteristics such as the level of project complexity and legal constraints surrounding the projects were also included. The study found the following specific characteristics (variables) to have direct effect on project outcomes:

- Project size
- Subcontractors' experience with facility type
- Facility type
- Project delivery system
- Level of new construction
- Commercial terms used
- Percent design complete
- Team communication
- Contract unit cost
- Onerous clauses in the contract
- Project complexity

Korkmaz (2007) and Korkmaz et al. (2010) also studied the influence of project characteristics on project outcomes. The study categorized project characteristics into seven Performance Indicators: owner commitment, project delivery system, project team procurement, contract conditions, design integration, project team characteristics, and construction process. The following specific characteristics (variables) were found to have direct effect on project outcomes:

- Project size
- Owner type
- Project participants' experience with facility type
- Quality of workmanship for the building mechanical and envelope systems
- Completion of contract documents
- Use of construction mockups
- Timing of involvement of contractor and commissioning agent

Project delivery systems (PDS) have been introduced in *Chapter 1* as they define the relationships, roles and responsibilities of project participants; establish the project execution framework by sequencing the different project phases to provide the built facility; and also describe the techniques and methods the project management team uses (Oyetunji and Anderson 2006; Sanvido and Konchar 1998). More recent studies in the literature suggest a different definition of project delivery systems with three basic domains: commercial terms that defines the legal relationships between project participants, an operating system that includes the management techniques followed, and a project organization that unifies the culture for different participants (Cho et al. 2010; CMAA 2010; Smith et al. 2011)

El Asmar (2012) studied project characteristics that influence project outcomes, however with a different approach. The author argues that the delivery characteristics of AEC projects fall into three domains modeled after the triple bottom line suggested by Elkington (1998) : social, economic, and physical. The three domains in El Asmar (2012) are: (1) *Tone* which represents the social aspects of a project, (2) *Terms* which represent the economic aspect of a project, and (3) *Tools* which represent the physical aspects of a project. The author calls this taxonomy the (3Ts). The author justifies the need for this new taxonomy of project delivery characteristics to the changes in the construction industry. Project *terms* are changing from linear / sequential DBB to more integrated systems, started with the DB and now with the IPD. Project social characteristics, or *tone*, are changing from segregated participants to collaborative approaches and teams. Project *tools* are changing due to the technological advancement. An example is the move from two-dimensional drawing to three-dimensional designs with the Building Information Modeling (BIM) technology. *Figure 6* below shows this shift.

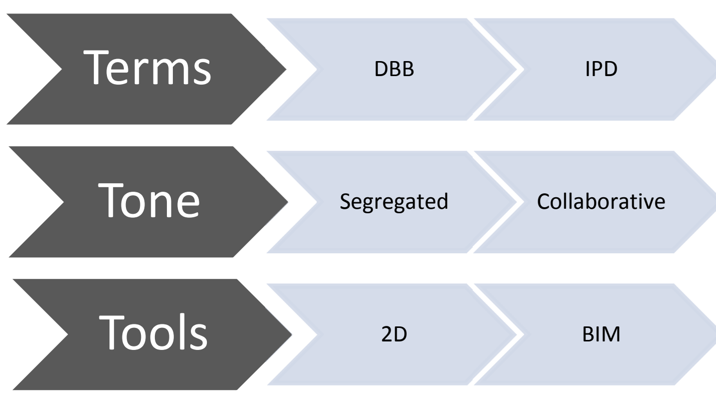


Figure 6: A Changing Industry (El Asmar 2012)

Through statistical analysis, El Asmar (2012) arrived at number of characteristics that influenced superior project outcomes grouped under the 3Ts. Low percent of design complete at contractor's engagement and contractual incentives were influential Terms characteristics. Existence of core leadership team, fiscal transparency, and chemistry among project participants were influential Tone characteristics. Finally, the use of BIM was an influential Tool to better project outcomes.

3.3 3T Project Characteristics (Variables)

Literature was the main source for compiling an initial list of project delivery characteristics. The project characteristics were further refined after the validation process by the professional panel of this study as was explained in the methodology section in *Chapter 1*. Moreover, this study has similar focus to El Asmar (2012) which is IPD except from a different perspective. Therefore, the similar approach in term of using the 3Ts taxonomy for categorizing project characteristics is followed in this study. *Tables 11, 12,* and *13* show a detailed list of the Terms, Tone, and Tools of the project characteristics observed and analyzed in this study respectively. The organization of the tables is adopted from El Asmar (2012) and it includes three levels of the project characteristics. The first column represents the highest level; Terms, Tone, or Tools. The second column represents intermediate level of the project characteristics, main items under which number of sub-items are grouped. The third column represents sub-items of the project characteristics, items directly asked about in this study's survey.

Table 11: 3T Project Characteristics (Terms)

High Level (T) (1)	**Intermediate Level (2)**	**Survey Level (3)**
Contractual Ties: Terms	Project Delivery System (PDS)	Type of PDS (DBB, DB, CMA, CMR, IPD)
		PDS Appropriateness with Project Type
		PDS Appropriateness with Project Size
		If IPD, was a Multi-Party Contract?
		If IPD, Number of Parties Signing Contract
		If IPD, Type of Contract Document
	Contract Characteristics	Use of Liability Waivers
		Use of Risk/Reward Balance
		Collaboration Required by Contract
		Use of Dispute Resolution Process
	Compensation Method Use for Each Project Participant	Architect/Engineer
		Construction Manager
		Contractor
		Design-Builder
	Contract Incentives	Use of Incentives
		Incentive Method Used
		Successfulness of Method
		Use of Financial Transparency (Open-Books)
	Selection Basis of Each Project Participant	Architect/Engineer
		Contractor
		Construction Manager
		MEPs
		Main Subcontractors
		Suppliers
	Insurance Policy	Finding suitable insurance policy
		Satisfaction with insurance
		Use of OCIP

Table 12: 3T Project Characteristics (Tone)

High Level (T) **(1)**	**Intermediate Level** **(2)**	**Survey Level** **(3)**
Social Aspects: Tone	Project Participants' Interaction Characteristics	Prior Experience as a Unit
		Team Communication
		Team Chemistry
		Definition of Participants' Roles/Responsibilities
		Definition of Goals and Measurement Metrics
		Scope Definition and Communication
	Project Participants' Experience with Project Type	Architects/Engineer
		Contractor
		Construction Manager
		Subcontractors
	Project Management Structure	Use of Management Team
		Number of Representatives in Team
		Jointly Developed Project goals & Milestones
		Pre-defined Decision Making process
		Collaborative Decision Making
		Use of Co-location
		Project Integration (IPD, IPD-like, non-IPD)
	Project Participants' Involvement Stage	Contractor
		Subcontractors
		Suppliers
		Owner's Participation

Table 13: 3T Project Characteristics (Tools)

High Level (T) (1)	Intermediate Level (2)	Survey Level (3)
Technology & Functions: Tools	Lean Construction Tools	Network of commitments
		Reliable promising
		Value stream mapping
		Choosing by advantages (CBA)
		Target value design
		Set-Based Design
		Kaizen events
		Waste identification/ elimination
		Shared responsibility
		The five S's
	Pull scheduling	Use of Pull scheduling or Last Planner
	BIM	Use of BIM
		If BIM is used, Interoperability of BIM

Appendix B complements these project characteristics taxonomy tables, and presents the definitions for the terms found in the tables and related to PDS. The definitions were combined from several sources of IPD and PDS literature including AIA-California Council (2007 and 2010); Ballard (2008); Kent and Becerik-Gerber (2010); Liker (2004); NASFA et al. (2010); Nelson (2010); El Wardani (2006); Barker et al. (2005).

In addition to the 3T project characteristics, general information about the project were also collected. These characteristics fall under the control variables introduced and explained at the beginning of the previous section (3.2). *Table 14* below displays these characteristics. The organization of the table is similar to that of the 3T tables above.

Table 14: General Project Information

High Level (1)	Intermediate Level (2)	Survey Level (3)
General Project Information	Project General Information	Project Name
		Project Location
		Project Type
		Construction Type
		Regulatory/Legal constraints
	Project Manager Information	Project Manager Name
		PM Contact Information
	Facility/Design Information	Current Development Stage
		Facility Gross Area, Planned
		Facility Gross Area, Actual
		Sustainability Certificate
		Project Complexity

The variables presented in this section are the independent variables used in this study which are: the project characteristics (3Ts), and the general project information. These variables are used to analyze project performance.

3.4 Combining Variables

Variables presented in the previous sections (3.1 & 3.3) of project characteristics and performance metrics make up a total of 110 variables. Some of these variables are combined (or averaged) together to give a more comprehensive gauge of a specific characteristic in project delivery. An example of a combined variable is from the Terms variables: the *Compensation Method* variable, as shown in *Figure 7*.

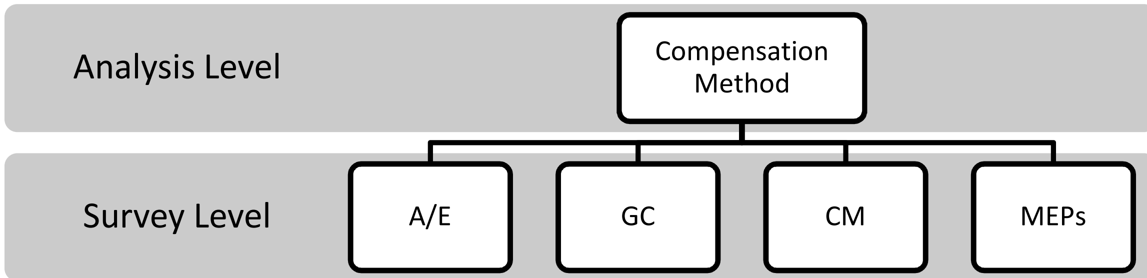


Figure 7: Combined Variable of Compensation Method

The compensation method (e.g. lump sum, cost plus, GMP) of each project participant is acquired in the survey. Compensation methods differ from one participant to another. With so many compensation methods and so many project participants, combining the usage of every compensation method across all main project participants gives more accurate measure to the use of that method. This gives us one combined compensation method variable for each method used in the project. To demonstrate in an example, let us say that a project has five main participants, and that two had lump sum and the rest cost plus compensation. Two combined compensation variables will result: one for lump sum and one for cost plus. The final combined variable is used in the analysis rather than the variable for every individual participant.

Another example of a combined variable from the Tone variables is *The Participant's Past Experience with the Project Type*, as shown in *Figure 8*. The project participants' experience with project type is individually acquired in the survey. However, since the focus of this study is in integrated delivery, the collective experience of the project participants gives better indication rather than the individual experiences. Therefore, in the analysis, the level of experience of every project participant with the project type is combined in one variable in the form of a cumulative score.

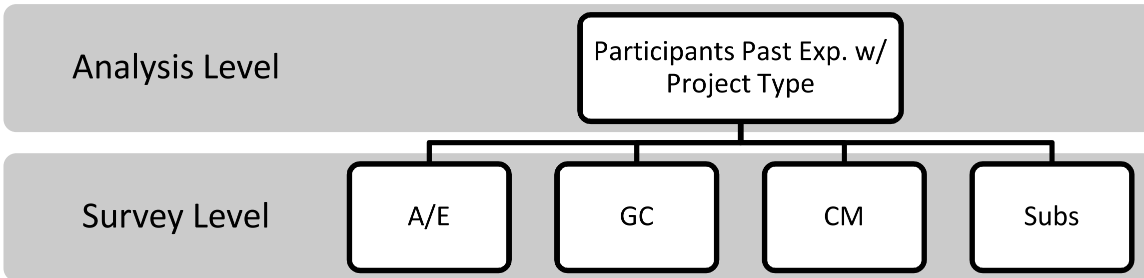


Figure 8: Combined Variable of Project Participants Experience with Project Type

A third example of a combined variable from the Tools variables is the *Number of Lean Tools Used* in the project, as shown in *Figure 9*. Lean tools play a significant role in integrating and effectively using project resources and efforts (Ballard et al. 2007; CURT 2007; Singelton and Hamzeh 2011; Smith et al. 2011). The survey of this study acquires through a question the lean tools used in a project such as Choosing by Advantages (CBA), Target Value Design (TVD), 5Ss, or Set-Based Design (SBD). Definitions of these tools and others can be found in *Appendix B*. El Asmar (2012) showed that using creative tools and techniques (including lean tools) significantly influenced project outcome. Therefore, rather than linking the influence of using each individual lean tool in the project with project outcome, the total number of lean tools employed in the project linked with project outcome would give a more comprehensive picture on the influence of lean tools.

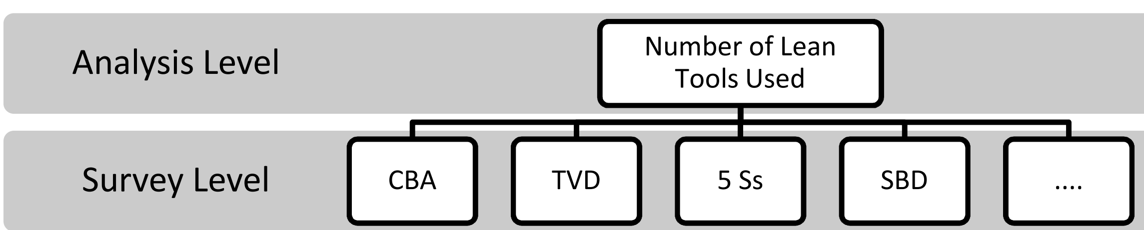


Figure 9: Combined Variable of Lean Tools Used

These are only examples of combined variables used in this study's analysis. Variables in this study were combined when adequate. Other variables were used individually such as the type of PDS used, the use of co-location for project team, and the type of construction of a project (i.e. new building, addition to existing building, or renovation). The following section will show more combinations among this study's variables in addition to how the non-numerical variables are coded for the analysis of the study.

3.5 Coding Non-numerical Variables

The data collected in this study are from two types: numerical and non-numerical. Numerical data are directly used without the need to further being refined. An example of numerical data collected in this study is the percent of cost change in a project. The extracted number from the survey is used in the analysis. The case is different for the non-numerical data where further coding is required to quantify and properly analyze the data. Non-numerical, also known as categorical, data varies significantly from one variable to another. One type of non-numerical data collected in this study is binary. It is basically a yes-or-no answer to a question. This is conveniently converted to one or zero respectively. Other type of non-numerical data collected in this study is nominal. Discrete coding is used to quantify the nominal data for different known types of answers. An example for that type of data is PDS used in a project where each type of PDS is assigned to a number such as "1" for DBB, "2" for DB, "3" for CMA, etc. Other type of non-numerical data collected in this study is ordinal. Discrete coding is also used for the ordinal data. However, the order of the codes matters, unlike nominal data. An example of ordinal data collected would be the level of project complexity. Categories of project complexity ranged from very high, which was coded with a nine, to very low, which was coded with a one. Due to insufficient project data records with this study's responders, the majority of this study's data were categorical. The following paragraphs will explain the coding steps used for key variables used in this study.

There were a lot of questions (variables) in this study survey that had binary yes-or-no answer. The use of co-location, financial transparency, success strategy, risk / reward balance, all had binary answers and were directly used in the analysis. The use of incentives was also used in the analysis as binary answer, although more details about incentives were collected in case the findings demanded more investigation. Collected answers of “yes” or “no” were directly converted to “1” and “0” respectively.

The majority of the variables used in this study had ordinal codes, which translate higher codes with superior results. And since the theme of this study is integrated project delivery, a variable with a higher code translates to more integration. This applies to the following paragraphs.

The selection basis for each project team member was coded as follows: “0” for open bid which is the most competitive selection method, “1” for prequalified bid which is a method with less competition and more focus on qualification, and “3” for negotiated bid which is a method that is based solely on qualification and healthy productive relationship. The selection basis score for all project team members is averaged for a score ranges from 0 to 3. A comprehensive (combined) variable is created for the selection basis with a score that ranges from 0 for all open bid and complete competition to 3 with all negotiated bid and no competition.

The contract limitation variable of a project is a combination of three binary variables: (1) the use of liability waivers, (2) the use of collaboration requirements by contract, and (3) the use of multi-party contract. The use of each one will give a score of “1” and the non-use a score of “0”. If a project is using both collaboration requirements and liability waivers, a score of “3” will be assigned rather than “2”. This is done intentionally to differentiate between integration efforts in the projects, especially contractual integration. If one is used, liability waivers or collaboration requirement, then a score of “1” will be assigned, and if none is used, a “0” will be assigned. After that, the score of the use of multi-party contract, 0 or 1, will be added to the previous score to give the comprehensive score of contract limitation with a range of 0 to 4. A score close to zero would indicate a very limited project contract with small room for integration initiatives, and a score close to 4 would indicate a contract with higher limits for integration initiatives.

The compensation variables represent all major compensation methods: lump sum, cost plus fee, cost plus percentage, guaranteed maximum price, and, cost plus profit sharing. Stakeholders in one project could be compensated differently. Data about the compensation methods is collected for the project key stakeholders: A/E, GC, CM, and Subs. Compensation method for every key stakeholder is treated as a binary variable with responses of “yes” or “no” are converted to “1” and “0”. Then the compensation variables are summed over the major stakeholders so that every compensation method would have one value ranging from 0 to 4. For example, in one project, the A/E and subs were compensated using lump sum, the GC using guaranteed maximum price, and the CM using cost plus fixed fee. The compensation variables would be lump sum with 2, GMP with 1, cost plus fixed fee with 1, cost plus percent fee and cost plus profit sharing with 0.

The variable of stakeholders’ involvement represents at what stage each key stakeholder was involved in the project. The planning, construction, and operation represent the project stages in the survey coded with 3, 1, and 0 respectively. These values were chosen to distinguish early integration efforts in a project. The scores collected for all key stakeholders are eventually averaged to give the final value for the variable ranging from 0 to 3.

Project team variable represents the number of members making the team in a project, and how much that team is empowered. The variable value is a discrete count of project team members. A binary variable is then added to that discrete number for whether the core team approach for a project is applied. The core team term represents how empowered a project team is to take immediate action to any decision the team makes regarding the project. The team members count ranges from 1 to 5, and the core team binary variable is either 0 or 1. The final value of the project team variable has a 1 to 6 range. Higher values translate into more integration and empowerment.

The management structure variable is a combination of number of ratings. Scope definition & communication, definition of participants' roles & responsibilities, definition of goals & measurement metrics, and dispute resolution process are all combined in one score. Every variable of these is being coded according to the following scale: "9" for very good, "5" for good, "3" for adequate, "1" for poor, and "0" for very poor. The average score of these variables is then added to a binary variable score of the use of predefined decision making process. The final score represent the management structure variable.

Stakeholder interaction variable is another combination of number of ratings. Team chemistry, owner's commitment, and team meeting periods are all combined to determine the stakeholder interaction of a project. Team chemistry is coded using the previously introduced 5-point scale from very good with "9" to very poor with "0". Owner's commitment is coded on a 3-point scale as follows: 80-100% commitment with "5", 60-80% commitment with "3", and less than 60% commitment with "1". Team meeting periods is coded on a 4-point scale as follows: daily with "9", weekly with "5", bi-weekly with "3", and monthly with "1". The scores of these three variables are averaged, the score of the binary variable of using jointly-developed project goals and milestones is then added to that score to make up the final comprehensive variable value that represents stakeholder interaction.

Team experience as a unit variable is coded using a 3-point scale. The 3-point scale is as follows: no experience with "0", one to two projects with "1", and more than two projects with

“2”. As for the collective team experience with the project type variable, a 5-point scale is used similar to what was previously explained from very high with “9” to very low with “0”. Each key stakeholder is rated with this scale, and then the rating of all key stakeholders is averaged to give the team experience with project type variable.

Project complexity variable is combined from two ratings: design complexity, and regulatory constraints surrounding the project. Each variable is rated according to the 5-point scale introduced previously from very low with “0” to very high with “9”. Then the two variables are averaged to give the project complexity variable.

The BIM variable consists of two variables: the use of BIM which is a binary variable, and BIM interoperability. A project using BIM would have a score of “1”, otherwise “0”. A project using BIM, and the BIM model is interoperable among project participants would have a “3”. Interoperability of BIM is an advanced state to project participants, especially those seeking more integration. That is why the scale is done as 0, 1 for only the use of BIM, and 3 for the use and interoperability of BIM.

Detailed description of the variables used in this study was presented in this chapter. The chapter began with a description of the types of variables, then listed the variables used, and ended up with the combination and coding of the variables. Variables are considered an essential part in this study and before proceeding into the analysis it is important to have a clear idea about them, for they are the vehicle that drives this study’s conclusions.

Chapter 4. THE CURRENT STATE OF CONSTRUCTION OWNERS ORGANIZATIONS

The data of this study was gathered by two surveys, the Executive-Level and the Project-Level surveys during the year 2013. The purpose of each survey and what entails have been previously explained in *Chapter 1* (*Section 1.6.2*). The following sections give the descriptive statistics for both surveys with more focus on the Executive-Level survey which describes *the current state* of construction owner organizations.

4.1 Executive-Level Survey

The purpose behind the Executive-Level survey of this study is to explore construction owner organizations' attitudes toward the current state of the construction industry. The following subsection will give descriptive statistics of the construction owners' sample participated in the survey. Then, a presentation of construction owners' priorities during construction project execution will follow. After that, there will be a subsection of project delivery systems usage and satisfaction. Finally, obstacles to innovation in the construction industry and suggested solutions will be discussed.

4.1.1 Descriptive Statistics of the Participants

As mentioned earlier in *Chapter 1*, IPD is a newly evolved project delivery system, and plays a main role in this study, and randomizing a sample of the construction owner organization population would be unlikely to include proper number of IPD projects to statistically analyze their performance. Therefore, purposive sampling was used (Babbie 2010), where construction owner organizations that were known to have recently used IPD were combined in a list. The list was then expanded beyond organizations with IPD experience to include regular construction owner organizations to insure a proper number of projects are acquired in order to do a valid statistical analysis. At least one owner organization in every state of the

US was contacted to participate in the survey. More details about the data collection process and method can be found in *Section 1.6.2.3*.

From a total of 106 owner organizations contacted, 36 responded to this study's Executive-Level survey for a response rate of 34%. Participants came from 19 states as is shown in *Figure 10*. Gray shaded states are where participants are from, and the number inside the state represents how many participants from that state in the survey. The majority of the participants (22 organizations) came from the Midwestern states. The rest of the participants were from Western, Southern, Eastern states, and one undisclosed participant.

The participants also came from both public and private sectors. Fifteen participants were from the private sector, and 21 were from the public sector.

Five main types described the businesses of the survey responders as shown in *Figure 11*. Twenty participants were educational institutions, seven were healthcare organizations, four were industrial / manufacturing organizations, two utility companies, one governmental agency, and two other types. As a disclaimer, it should be mentioned that the types of organizations included in this study sample is not representative of the industry, or the construction owner organizations. The reason behind the proportions of business types of owners included in this sample depended mainly on the purposive sampling and availability of contact information for potential participants. Please refer to Section 1.6.2.3. for more details.

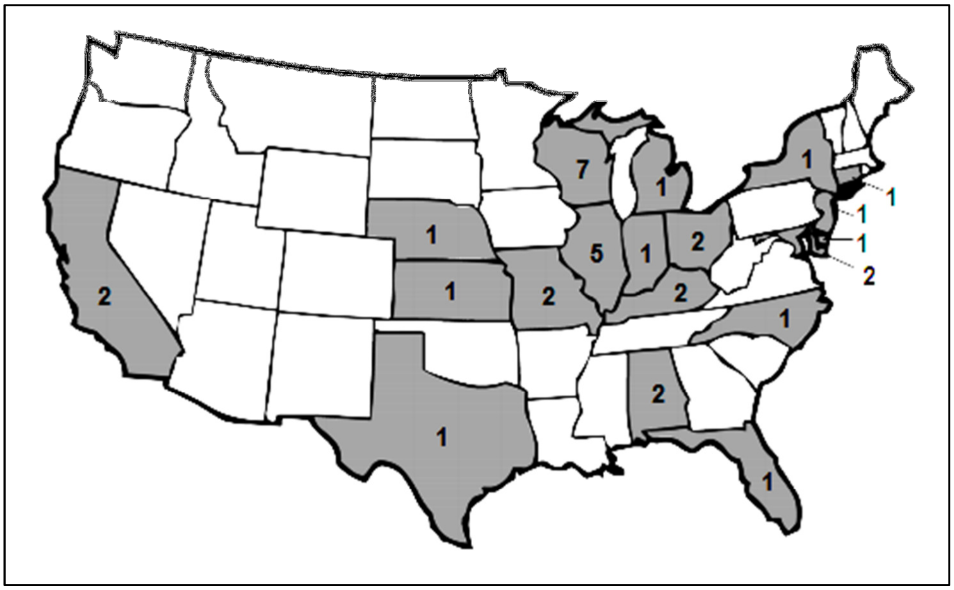


Figure 10: Executive-Level Survey Participants' Locations

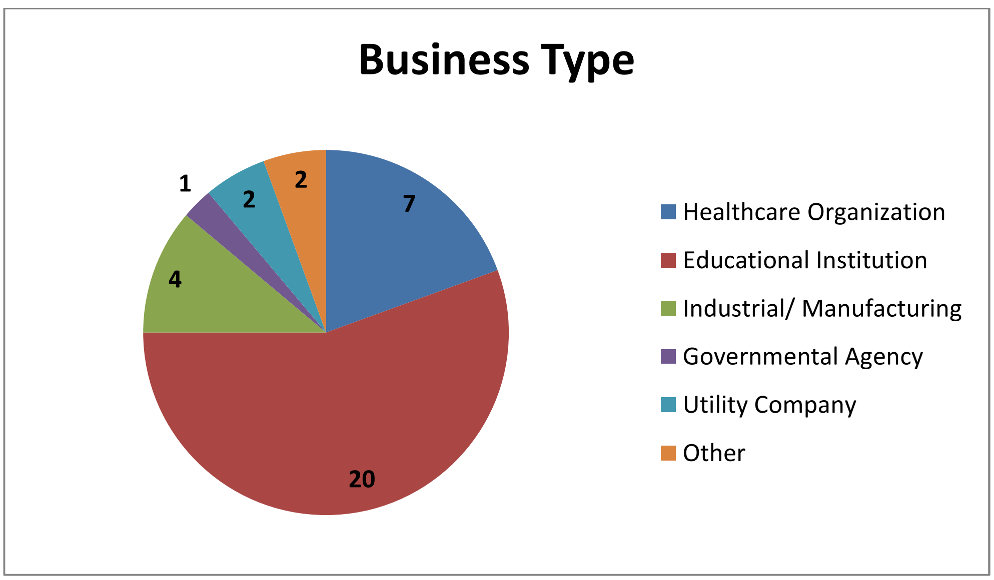


Figure 11: Executive-Level Survey's Participants Business Types

4.1.2 Owners' Success Criteria

Evaluating what current construction owners see as success is one of the main objectives of this study. As was explained first in the methodology in *Chapter 1* of this study on how to approach this objective, and based on the literature finding presented in *Chapter 2* of this thesis, the Executive-Level survey presented 10 performance metrics to responders. These metrics were retrieved from the literature and the professional panel of this study. The survey asked the responders to assign the proper percentage of impact each metric has on the success of capital construction projects as each owner sees them. The responder's choice was a range from 0% to 100% for each metric, and percentages assigned to the metrics do not have to add up to 100%. This would allow responders to give more than one metric the same percentage. The percentages were converted to 10-point scale where a 100% equals to 10, 90% to 9, 80% to 8, etc. The resultant of that question in the Executive-Level survey is shown in *Figure 12* below.

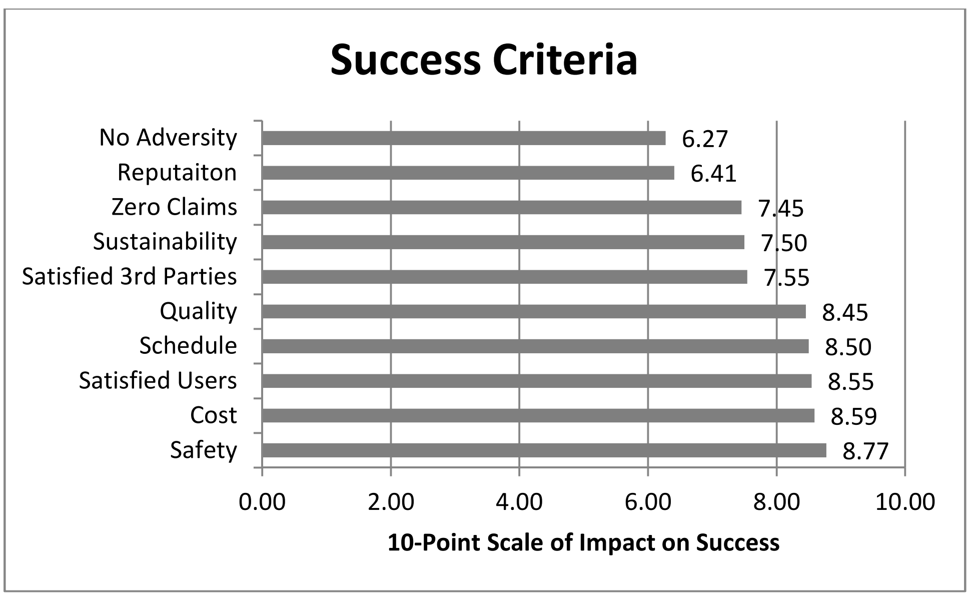


Figure 12: Construction Owners Success Criteria

The top five success criteria according the Executive-Level survey sample of construction owner organization are: (1) Safety, (2) Cost, (3) Users Satisfaction, (4) Schedule, and (5) Quality. As it is shown in *Figure12*, all five criteria are very close in score, ranging from 8.77 to 8.45. The other five criteria had also very close score within each other, ranging from 7.55 to 6.27; however the latter five criteria were relatively distant from the first five. This gives an indication that the first five criteria are seen collectively by construction owners as similarly important.

Prior to this study, another survey was done to construction owners in 2012 conducted by FMI Management and Consulting agency where they surveyed 45 construction owner organizations. It was previously mentioned in the literature review; however, due to the similarity of the two surveys in acquiring owners' success criteria, it is worth mentioning again. The findings of the two studies are lined up with their ranking in *Table 15*.

Table 15: Owners Success Criteria Comparison

This Study's 2013 Survey Findings	FMI Management 2012 Survey Findings
1. Safety	1. Safety
2. Cost	2. Best Value for Low Price (Cost)
3. User Satisfaction	3. Schedule
4. Schedule	4. Quality
5. Quality	5. Efficiency
6. Satisfied 3rd Parties	6. Productivity

The two studies agree on the top priorities for owners in conducting their construction capital projects: safety, cost, schedule and quality. Cost, schedule and quality have been owners' priorities historically as was concluded in *Section 2.2* of the literature review. However, safety is a new concern to owners that have been recently cited as is shown in both surveys results.

4.1.3 Most Important Stage during Construction

This study's survey also asked owners to rank capital project delivery stages according to how much each stage demand owner's attention. The stages in the survey were: Strategic Planning, Design, Construction, and Operation. The ranking of the stages came as they were mentioned. Strategic Planning had an average score of (1.4), Design had an average score of (1.58), Construction had an average score of (1.98), and Operation had an average score of (2.24). It appears from the results that construction owner organizations were concentrating more on strategic planning and design, and relatively less on construction and operation of their capital projects.

4.1.4 Project Delivery Systems (PDS): Usage and Level of Satisfaction

The study survey asked owners about their usage of the different Project Delivery Systems (PDS), and their level of satisfaction with each PDS. The PDS currently used in the US, and are offered in this comparison, were Design-Bid-Build (DBB), Design-Build (DB), Construction Management-Agent (CMA), Construction Management-at Risk (CMR), and Integrated Project Delivery (IPD). Then there was an open field titled other that was left for responders to fill in a PDS they used and was not offered as an option.

For the PDS usage, responders were asked to give every PDS an approximate percentage of their use to that PDS over the last seven years. The total of percentages assigned to all PDSs by a responder has to add up to 100%. The result of that question is shown in *Figure 13* below. DBB came in first place with a percentage of 48%. In second place is CMR with 19% of usage followed by IPD with 14%, DB with 13%, and finally CMA with 7%. These percentages only represent the sample surveyed in this study. Recall that purposive sampling was used for this study with a concentration on owners with IPD experience at the beginning of data collection, and then the participants' circle was widened to include regular construction owners. More details about the data collection process can be found in *Section 1.6.2* in *Chapter 1* of this thesis.

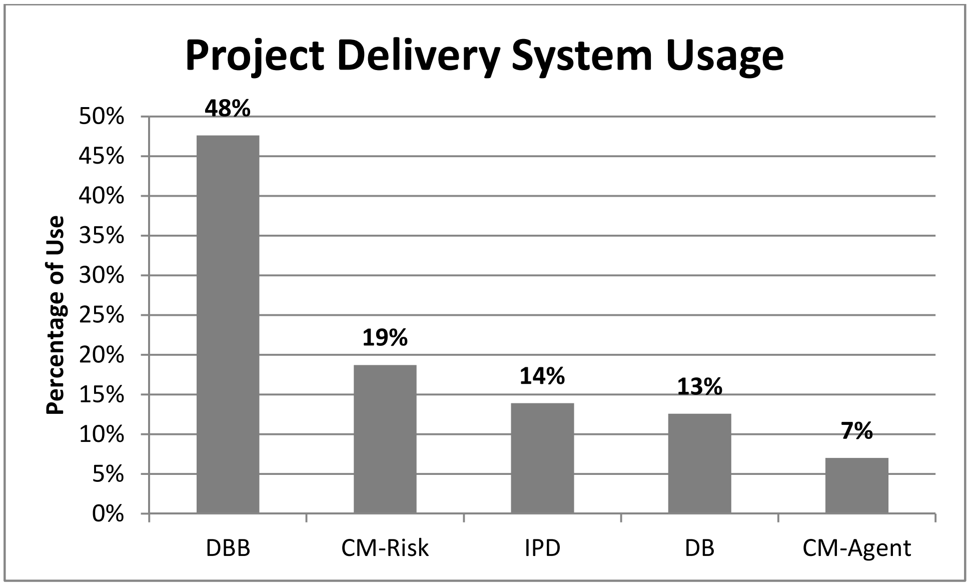


Figure 13: PDS Percentages of Use by Owners over the Last Seven Years

The following question to the PDS percentages of use was about the level of satisfaction of responders with each PDS. The level of satisfaction was gauged using a 7-point likert scale as follows: (1) Very Dissatisfied, (2) Somewhat Dissatisfied, (3) Slightly Dissatisfied, (4) Neutral, (5) Slightly Satisfied, (6) Somewhat Satisfied, and (7) Very Satisfied. The result of this question is shown in *Figure 14* below. IPD came in first with an almost perfect score of (6.92). CMR came in second place (5.91), then DB (5.59), CMA (5.25), and in last place DBB with a score of (5.10). Two comments should be mentioned about these results. First, the score for all PDS were high, above five points (i.e. above slightly satisfied). This suggests owners' contention with whatever PDS they are using, which might also explain an obstacle in the way of adopting new and innovative methods in the AEC industry, which will come in more details later in this chapter. Second, these results only represent the sample surveyed in this study.

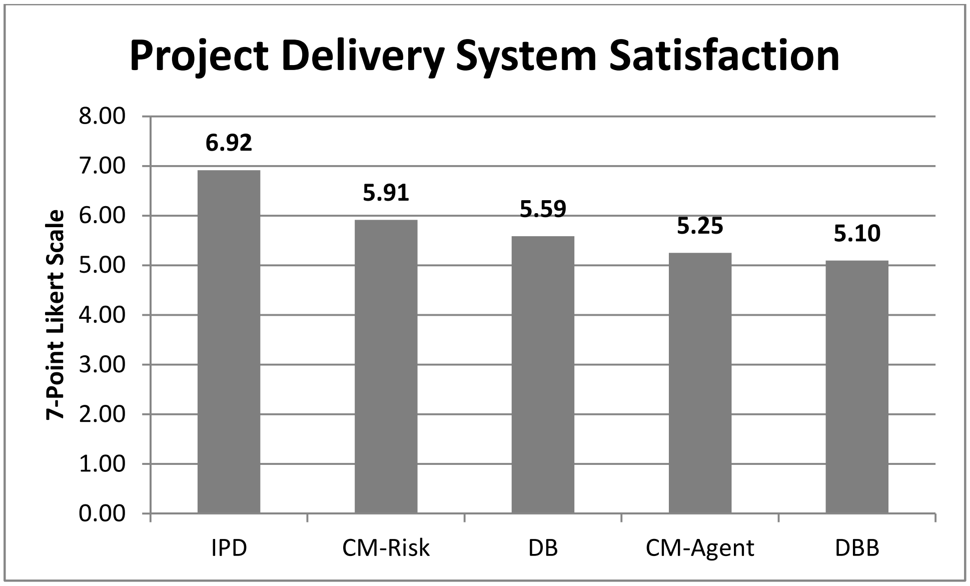


Figure 14: Owners' Level of Satisfaction with PDSs

The level of satisfaction question also offered a space for responders to comment on their reasons for either satisfaction or dissatisfaction with PDSs. The following paragraphs will present a summary of the responders' opinions on each of the main PDSs used currently in the US.

<u>Design-Bid-Build</u>

The overwhelming reason for participants' satisfaction with the DBB is its cost performance, especially the fixed price feature. Ten out of 16 participants who responded to this question have indicated cost as a reason for their satisfaction with the DBB system. As one participant said it, DBB "has produced lowest priced contracts to the university." Another noteworthy reason for satisfaction from the responders is DBB's ability to control the scope of work. One participant translated the scope control as "predictable outcomes." This reason can be tied to the first reason, where the ability to control the scope produces a fixed price contract.

Two overwhelming reasons for participants' dissatisfaction with the DBB were shown in the survey. The first is the cost performance. Responders referred to cost overruns produced by change orders when specifying the cost performance. Five out of sixteen responders have indicated this feature as a reason of dissatisfaction. The second reason is the longevity of the schedule. Four out of sixteen responders have indicated this feature as a reason of dissatisfaction. Other noteworthy reasons from the responders are the quality of final product and vendors, and scope control. The low quality of final product and vendors was referred – according to responders – to the limited number of bidders willing to participate in DBB projects. In addition to being a satisfaction reason to participants for the DBB system, scope control was a reason for dissatisfaction to others, and this could be tied with the first reason for dissatisfaction mentioned above which is DBB cost performance. Responders referred scope control dissatisfaction issues to DBB's inability to cope with change during project execution as it "creates substantial number of change orders" according to one responder. Another responder said that DBB "doesn't cope with change effectively."

Design-Build

One reason had the majority of responders' vote, schedule. Eleven out of 18 responders have chosen schedule as a satisfaction feature with DB system. This result agrees with the available DB literature that describe DB as accelerated delivery or "Fast-track" projects (AIA and AGC 2011; AIA 2008). Another noteworthy satisfaction feature for the DB system was cost. Four responders chose cost as a satisfaction feature for the DB system. Other features of the DB system that were mentioned once by responders were collaboration, risk assignment, and its suitability "for technical or specialized projects" as one responder put it.

Two dissatisfaction reasons were seen equally significant by responders, quality and scope control. Ten responders collectively out of 15 have chosen these two features as dissatisfaction reasons with the DB system. This could be due to the unknown aspect of the final product. Execution of the project in the DB system begins before having a final set of design documents; where at some point during the design process the construction begins. This has its effect on the control of the scope of a project. It could also affect the quality of the final product, especially when cost runs beyond the allocated funds for that project. One responder summed the two features by saying “lack of ability to truly define and control the product.”

Construction Management-Agent

Probably due to its limited use, only four responders commented on satisfaction reasons with CMA system. Two responders chose scope control as a satisfaction reason with CMA system, one responder chose quality, and one responder chose CM expertise provided.

Eight responders have commented on dissatisfaction reasons with CMA system. The main reason for dissatisfaction with responders was cost, with four responses. Another reason for dissatisfaction with CMA system is accountability with two responses. “Lack of accountability and contract chain-of-custody issues”, as one responder has put it in words, would describe the accountability issues with this system.

Construction Management-at Risk

Eleven responders have given their opinion on the satisfaction reasons with CMR system. The satisfaction was evenly distributed among eight different features. Schedule, collaboration, and expertise, each had two responses. Other features were cost, scope control, risk assignment, owner’s involvement, and contractor’s involvement, each had one response. From that, one can conclude that CMR brings good features to owners, albeit no particular feature as a defining satisfaction feature for the sample surveyed.

Out of five responders who have given their comments on this question, three have chosen cost to be a dissatisfaction reason with the CMR system. As one responder has put it in words about this reason, “CM fees sometimes are not competitive,” in reference to the construction management services fees associated with this system, which could be relatively high.

Integrated Project Delivery

Sixteen responders have shared their opinion on IPD system in this question. Seven out of 16 responders have chosen collaboration as a reason for satisfaction with IPD system. One responder referred to the "collaborative, trusting relationships required" in the IPD system. Another responder mentioned that "shared risk leads to greater trust, less adversity" in the IPD system. The other two satisfaction reasons were accountability with four responses, and quality with three responses. One responder described the accountability in an IPD project in its participants' "reliability" on each other. Another responder described the quality in an IPD project as "quality result and process."

As to the dissatisfaction with the IPD system, only one responder gave an opinion. This is in contrast with 16 responders gave their opinion on the satisfaction features of IPD system. And that was probably due to the novelty of IPD system in AEC community. The feature was scope control.

It should be mentioned again that what was presented above only represents the sample surveyed. However, it should give an indication of how owners find different PDSs. A complete list of the answers received by responders can be found in *Appendix F.*

4.1.5 Obstacles to Adopt Innovative Construction Methods

The study survey also asked participants of what they think are the main obstacles in the way of changes to better practices in construction project delivery within the AEC industry. The question offered eight choices extracted from the literature and edited by this study's professional panel. Participants were also given the choice to add any other issues they see as obstacles in the way of adopting new methods in the AEC industry. *Figure 15* below gives the result to this question in how many votes each choice got, and the rank of the obstacles as owners see them. In order to unify the comprehension of all responders of the survey, a list of definitions was attached to the survey that explained what was meant by every choice.

The following paragraphs will give a brief description about each obstacle in their ranked order, and what responders suggest to overcome that obstacle. Single suggestions were grouped when applicable under unifying main topics.

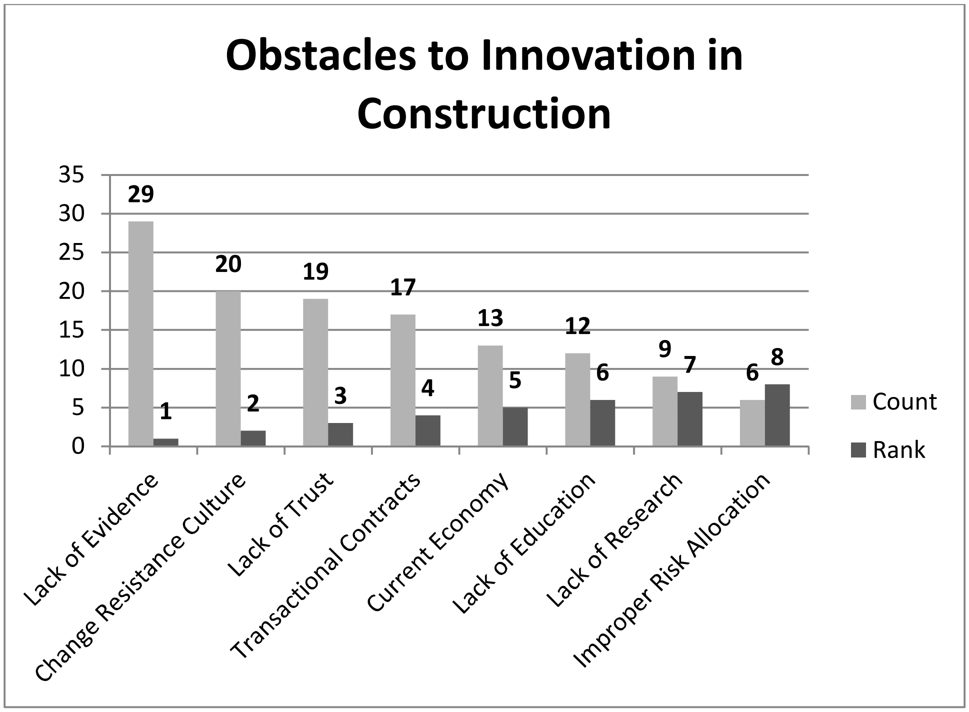


Figure 15: Obstacles to Innovation in Construction According to Owners

1. Lack of enough solid evidence on new methods:

This reason was ranked first among this survey's responders. Twenty nine out of 36 responders have chosen lack of evidence of new methods as an obstacle of establishing new methods in the AEC community. There were also 12 suggestions offered by responders to overcome this obstacle, and they revolve around two issues: more research on new construction methods, and publishing and circulating case studies of new methods, which in-turn would provide evidence for new methods.

2. Change resistance culture

The first obstacle above may lead to the second ranked reason among the survey responders, change resistance culture. Twenty responders out of 36 have chosen the change resistance culture as an obstacle in the way of establishing new methods in the AEC industry. Moreover, there were 16 suggestions offered by responders to overcome this obstacle. The suggestions revolve around two things: again publishing and circulating case studies of new methods, and owners' responsibility to take the lead in forcing changes in the construction conventional ways and methods.

3. Lack of trust

Nineteen responders have chosen the lack of trust as an obstacle in the way of establishing new methods in the AEC industry. Responders also offered 12 suggestions to overcome this obstacle. The suggestions revolve around two issues: Building trust through good relationships, and owner's responsibility in selecting project team members and building trust within the team. By trust, the responders were referring to relationships that take place among project participants. As one responder expressed it as a suggested solution, "develop ideal behavior for all team members to adhere to."

4. Transactional contracts

Seventeen of the survey responders have chosen the transactional contracts (i.e. current conventional construction projects contracts) as an obstacle in the way of adopting new methods in the AEC industry. The responders offered eight suggestions to overcome this obstacle, and they stem from two points: revising and redoing current contracts toward more integration and collaboration among project participants, and more responsible decisions by owners in choosing the right contract.

5. The current economy

Thirteen responders have chosen the current economy as an obstacle in the way of adopting new methods in the AEC industry. Maybe due to its external factors, only two responders offered suggestion to overcome this obstacle. One mentioned time, as time “will eventually normalize” the performance of the economy. Another responder suggested increasing “funding sources.”

6. Lack of education

Twelve responders have chosen lack of education as an obstacle in the way of developing new methods in the AEC industry. The responders offered nine suggestions to face this obstacle in the form of reinventing construction education and training courses. Some of the suggestions were directed to college students during their college education years, and other suggestions were directed to professionals in their post-college training. The suggestions basically were about improving the quality of education and training.

7. Lack of Research

This obstacle was seen by responders to have a direct relation to two of the obstacles mentioned above: the lack of evidence on new methods, and the change resistance culture. Nine responders have chosen lack of research as an obstacle in the way of adopting new methods in the AEC industry. Only four suggestions offered by responders to overcome this obstacle, and they were obviously about performing and funding more construction research.

8. Improper risk allocation

Six responders deferred the inability to adopt new methods in the AEC industry to improper risk allocation. The responders offered suggestions to face this obstacle in four points: better risk management, converting conventional contracts to relational contracts, increase owners’ responsibility in shouldering more risk, and finally by sharing experiences in this area.

9. Other: State Laws and regulations

The majority of responders chose state laws and regulations as an obstacle in the way of establishing new methods in the AEC industry. This obstacle was not offered as an option in the question, it was chosen by responders in the “other obstacles” field in the survey question. Responders described the rigid statutory requirements and “lack of flexibility in procurement laws.” There was a consensus among responders about their suggestion to overcome this obstacle which is changing state laws to allow alternate construction methods.

These obstacles and the suggested ways to overcome them have come from practitioners in the AEC industry; people with many years of experience in construction projects. These notes and suggestions should be considered carefully by participants in the AEC community in order to step forward in the way of improving construction methods.

After overviewing the state of construction owner organizations in construction project delivery, this study also acquired details about specific projects performed by survey responders to achieve the objectives set forth in this study. The following section will give description about the projects data collected in this study.

4.2 Project-Level Survey

Another survey that was sent simultaneously with Executive-Level survey was the Project-Level survey, which was meant to collect details about specific projects executed by construction owner organizations. The Executive-Level survey was first sent to executives in construction owner organizations as an email with a link to the Project-Level survey, and they were asked to forward the Project-Level survey to the right person within the organization to fill in the project management level. Details about the data collection process were previously mentioned in *Chapter 1* (*Section1.6.2*.)

Twenty two responders of the 36 Executive-Level survey responders have participated and submitted data for the Project-Level survey. The 22 Project-Level survey responders provided data for 34 projects. This means that some construction owners have generously provided data for more than one project. The following paragraphs will give descriptive statistics of the participants and the project data submitted for the Project-Level survey. This will include the structure and the business type of the 22 organizations responded to the Project-Level survey. The descriptive statistics will also include the project type, PDS used and construction type of the 34 projects for which data was submitted.

4.2.1 Descriptive Statistics of the Responders

The 22 construction owner organizations participated in the Project-Level survey came from both public and private sectors. The participants were split in half; 11 participants came from the public sector and 11 from the private sector as shown in *Figure 16*.

Participants of the Project-Level survey were broken down into five types of business. Twelve participants were educational institutions, six were healthcare organizations, two were industrial / manufacturing organizations, one was a governmental agency, and one was a utility company as shown in *Figure 17*. These two statistics were extracted from the Executive-Level survey about the organizations responded to the Project-Level survey. In other words, these two statistics were acquired in the Executive-Level survey and recalculated only for the organizations participated in the Project-Level survey.

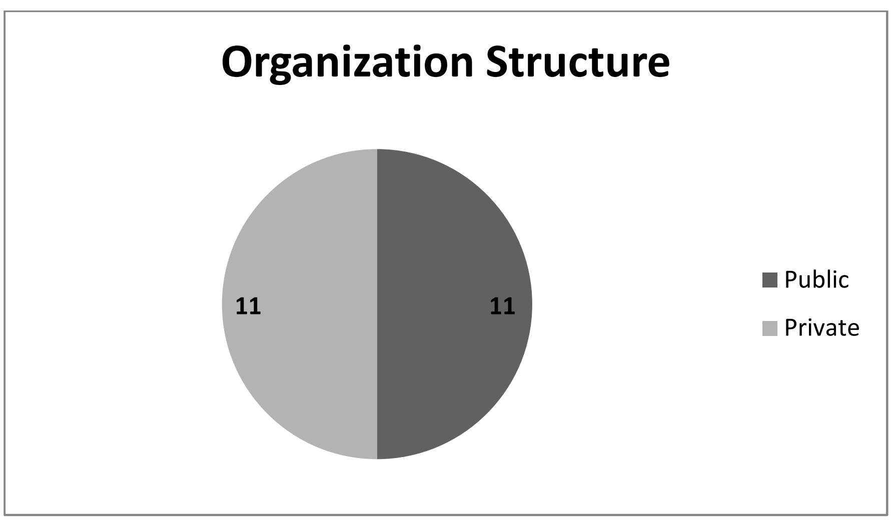


Figure 16: Organization Structure of the Project-Level survey Participants

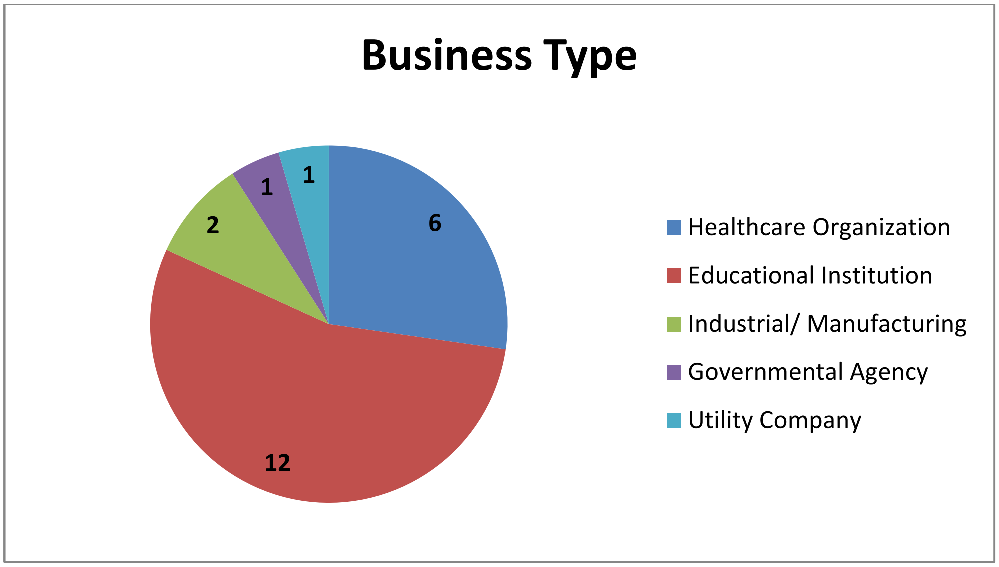


Figure 17: Business Type of Project-Level Survey Participants

4.2.2 Descriptive Statistics of the Projects

Data was collected from 34 projects that were located in 16 different states in the US. *Figure 18* shows a US map with gray shaded states. The gray shaded states are where projects executed and the number in the state represents the number of projects in that state. States with light gray shade represent where IPD projects in the data collection were executed, that also does not necessarily mean that all projects in that state were IPD. Moreover, as can be seen in the map, projects in this study data collection came from Eastern, Western, Southern, and Midwestern states, with a reasonable geographic distribution. However, the majority of the projects (18 projects) came from the Midwest region.

Figure 19 shows the types of construction for data projects. The survey question had three types for responders to choose from: New, Addition to an existing building, or Renovation to an existing building. Projects that are new construction in the data collection were 24, additions to existing buildings were 4, and renovations to existing buildings were 6.

Five main categories were used to categorize the project types included in the data projects. The largest category with 12 projects was educational facilities. Next with 7 projects each were healthcare and commercial facilities. After that are industrial facilities with 6 projects. And finally, athletic facilities were last with 2 projects. *Figure 20* shows these categories.

Figure 18: Locations of Project-Level Survey Projects

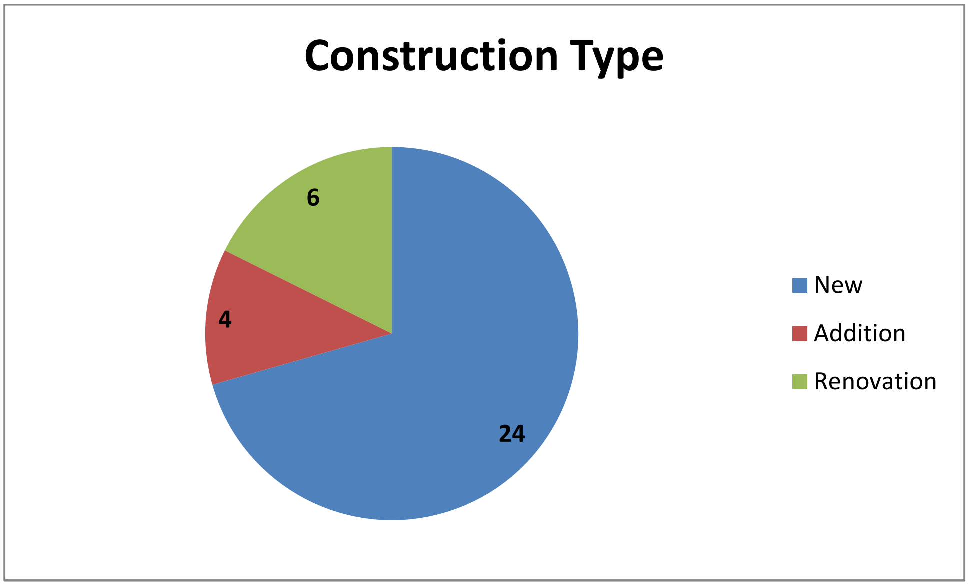


Figure 19: Construction Type of Data Projects

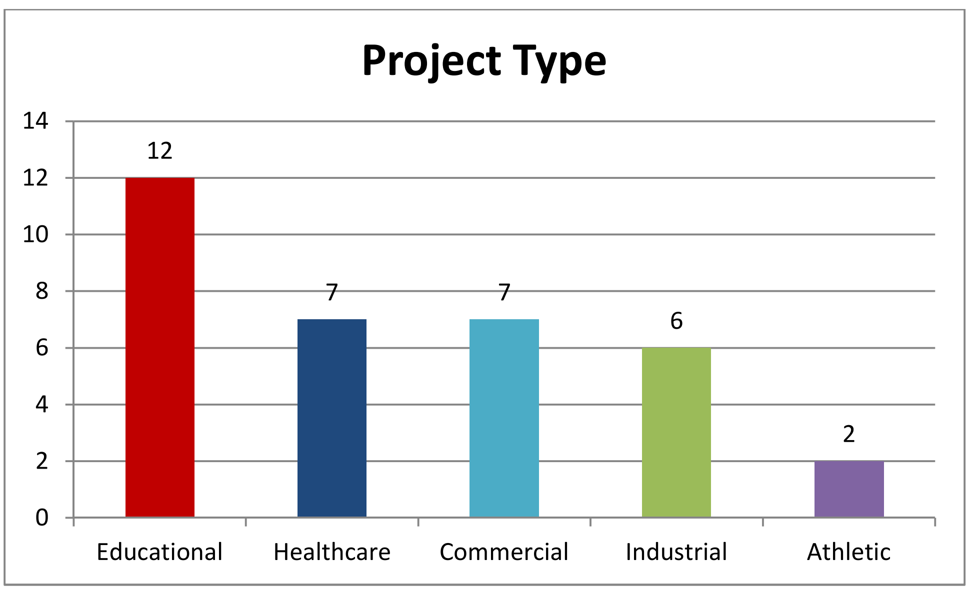


Figure 20: Project Type of Data Projects

The final statistic presented here is the PDS used in the data projects. The result of that statistic is shown in *Figure 21* below. DBB and IPD came in first place with 9 projects for each in the data projects. In second place is CMR with 6 in the data projects. Then come DB and CMA with 3 projects each in the data projects. Finally, 4 projects were categorized as other, for responders have used other name or category to name the PDS used for the project. Other PDS used by this survey's responders are owner EPC model, fast track with CM, alliance cost plus, and GC with fee at schematic design with CM. Another taxonomy of PDSs will be introduced in *Chapter 5* that breaks down delivery systems into: IPD, IPD-like, and non-IPD, and should include all 34 projects. This PDS taxonomy will be used for the analysis of the data.

These numbers represent the sample surveyed in this study and do not reflect the actual use of PDS in the AEC industry. It should be mentioned again that purposive (selective) sampling was used for this study with a concentration on participants with IPD experience at the beginning of data collection, and then the participants' circle was widened to include regular construction owners. More details about the data collection process can be found in *Section 1.6.2* in *Chapter 1* of this thesis.

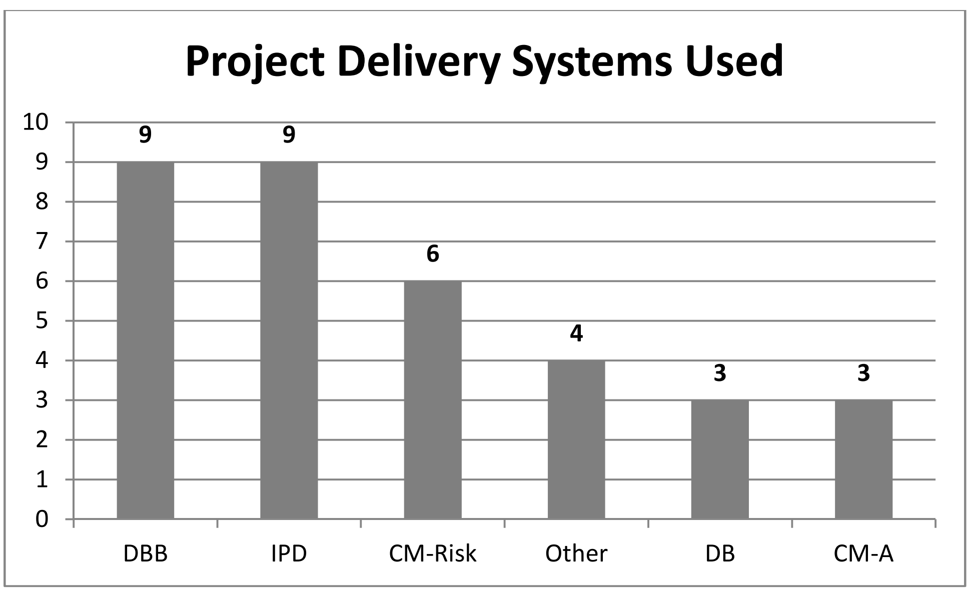


Figure 21: Project Delivery Systems Used in Data Projects

This is a presentation began with a description of the responders to the Executive-Level survey, as it shows the current state of construction owners; how they see success in their capital construction projects, the current methods and systems used by construction owners, and obstacles stand in the way of adopting new and innovative methods in the AEC industry. After that, the Project-Level survey responders and the projects they submitted data for were described.

This presentation of the descriptive statistics of the data collected should be followed in the coming chapter with the analysis performed on data to fulfil the objectives of the study.

Chapter 5. Evaluating Integrated Delivery on Key Project Performance Metrics using Univariate Analysis

The data collected in this study was analyzed to explore the performance of projects with integration (IPD, and IPD-like) compared to traditional projects with little to no integration (non-IPD). The analysis performed in this chapter is univariate: PDSs were tested for each performance metric individually, and PDSs were categorized as IPD, IPD-like, and non-IPD as will be explained in the coming section. The outcome of this chapter will tell whether projects with more integration perform better than projects with little integration, and whether with statistical significance or not.

5.1 IPD, IPD-like, and non-IPD

Recall the title of this thesis is achieving project success through integration in the project delivery system from an owner's perspective. Differences in PDSs are assessed through the level of integration employed. A new categorization method was followed in this study to differentiate PDSs according to integration initiatives employed. This is explained in the following paragraphs.

The literature shows different guidelines used to define an IPD system. AIA-California Council (2010) published a report of IPD case studies that defined projects using IPD (IPD projects) based on *contractual*, such as multi-party contracts and liability waivers and *behavioral*, such as mutual respect and open communication principles. AIA and the University of Minnesota (2012) published another report of IPD case studies. In this report, the authors acknowledged the scarcity of IPD projects in their "pure" form with a multi-party contract. They noticed that multi-party contracts were being customized by owners to eliminate certain contractual obligations such as liability and shared risk / rewards which used to be critical to achieve the "pure" IPD form. Therefore, the authors tried to accommodate the realities of the AEC industry by modifying previous IPD defining principles developed by AIA-California Council

(2010) report into *markers*, and *strategies*. The markers represent characteristics unique to IPD, and the strategies represent IPD's optional variations. For instance, multi-party contract was among the *obligated* contractual principles (AIA-California Council 2010), then became among the *optional* IPD strategies (AIA and University of Minnesota 2012). Other published IPD studies differed in their IPD definitions. Kent and Becerik-Gerber (2010) used three principles to define IPD projects: the use of a multiparty agreement, the early involvement of all parties, and the use of shared risk and reward. El Asmar et al. (2013) defined an IPD project by the use of multi-party agreement and the early involvement of participants in the project, typically before the design starts. Similarly in this study, IPD definition differed from one owner to another. Some of the projects in the data collected were categorized by responders as IPD just because an owner took a different new route in executing that project. However, with a closer look at the project details, one can find that none of IPD's defining principles were applied. On the other hand, some projects were categorized using a conventional project delivery system other than IPD. However, with a closer look at the project details, one can find that it does apply numerous IPD defining principles.

To distinguish IPD projects, this study will use the two defining factors of a project delivery system mentioned earlier in *Section 1.1*, and the defining principles of IPD found in the literature. Therefore, projects will be categorized into IPD, IPD-like, and non-IPD as shown in *Figure 22*. The category of a project is determined according to the level of collaboration among project stakeholders. First, projects are split into two groups: those with *enhanced* collaboration (IPD and IPD-like), and others with none (non-IPD). A project should have at least two of following three characteristics in order to be categorized as having enhanced collaboration: (1) *co-location*, a place where interdisciplinary team members meet to brainstorm and resolve issues on the spot, (2) *financial transparency* which is the right for project participants to review and audit each other's financial records, and (3) the use of the *building information modeling* (BIM) technology (AIA-California Council 2010; NASFA et al. 2010). The group with enhanced collaboration is further split into two groups: those with *obligated* collaboration (IPD), and others with none (IPD-like). The obligated collaboration is contractual with very early contractor's engagement (AIA and University of Minnesota 2012; AIA-California Council 2010; El Asmar et al. 2013). A threshold of 25% of design complete was assigned to gauge the early engagement of contractor in this study. Moreover, a project should have at least two of the following three characteristics in order to be categorized in this group: (1) *multi-party contract* which is a relational contract among a minimum of owner, architect, and contractor that creates a system of shared risk and reward with the goal of reducing overall project risk rather than shifting it between parties, (2) *liability waivers* which are provisions in the agreement that eliminate or significantly reduce the ability of the project parties to sue each other for losses related to the project, and (3) *required collaboration by contract* found explicitly in the contract language (AIA and University of Minnesota 2012; AIA-California Council 2010; NASFA et al. 2010; Sive 2009). After following this method, data collection projects were: 10 IPD, 13 IPD-like, and 11 non-IPD projects.

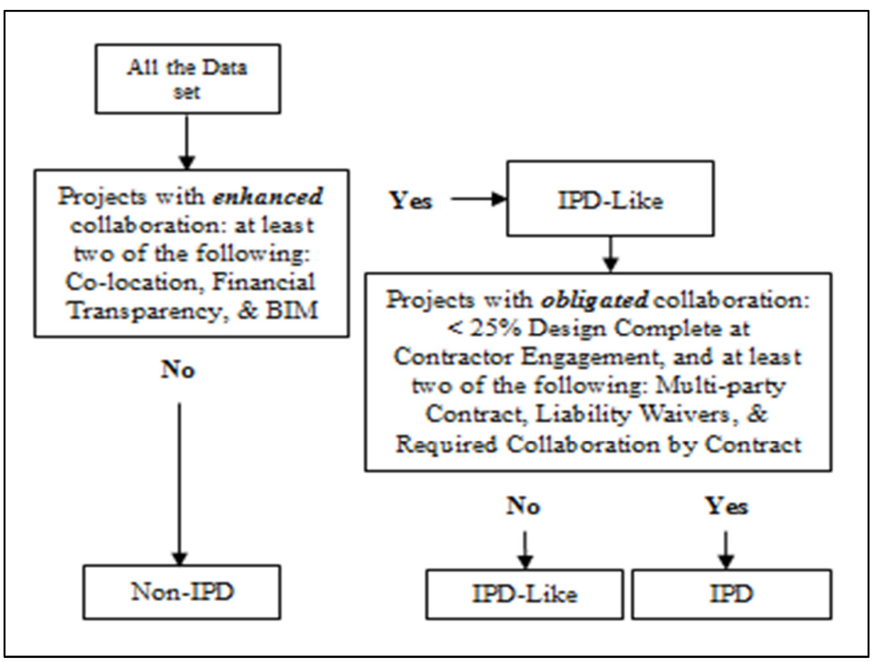


Figure 22: IPD Categorization Method

5.2 Statistical Methods

This part of the analysis for the data collection revolves around statistically proving the superiority of projects with more integration. In other words, the analysis was set to prove the superiority of IPD projects performance, or lack thereof, with a special focus on owners' needs and criteria translated in the performance areas and their complementing measurement metrics combined in a list earlier in *Chapter 3*.

Therefore, univariate analysis revolves around statistically testing the following hypothesis:

H_0: *IPD project performance equals non-IPD project performance*

H_a: *IPD project performance significantly different from non-IPD project performance*

Univariate analysis is used to measure the effect of PDS as a single *independent variable* on project performance. Project performance, represented in the previously established owner-specific performance areas (*Table 10, Chapter 3*), is the *dependent variable*. Project performance will be measured separately for each complementing measurement metric (column 2) according to the lineup in *Table 16* below. *Table 16* is a modified version of *Table 10*. Although "claims" were found to be an important criterion by owners, the data collected was not rich on specifics about claims. The Project-Level survey asked a main question about claims: whether a claim was issued on the projects or not. Answering "yes" to that question would lead to other questions about initiators of claims, reasons, number of claims, dollar amount asked for, and dollar amount paid. However, the majority of the survey responders did not go past the first main question, which left only one, binary, information about claims in the data. The information the majority of responders shared about claims, which is: no claims were issued, did not help or make a difference in the analysis. Therefore, project performance regarding claims was eliminated from the data.

Each performance area will have a following subsection with a hypothesis specific to that area. Two types of statistical tools are used for this univariate analysis in this study, t-test and Mann-Whitney-Wilcoxon (MWW) test. The t-test is a tool that can be used to assess the statistical significance of the difference between two sample means; in the case of this study, this test IPD versus non-IPD projects. The t-test is optimal when used with a normally distributed data. The MWW is a nonparametric statistical hypothesis test used when a sample comes from a population not normally distributed (Sheskin 2003). The normality of the tested data is determined using the Shapiro-Wilk test by testing the hypothesis of whether a sample comes from a normally distributed population or not (Meyers et al. 2006). The hypothesis of each metric will be tested using a two-sided test. This means, when statistical significance is found, both extremes (better or worse) are equally likely applied. Lastly, one performance area, which is satisfaction, will incorporate, in addition to the previous two tests, the chi-squared test where frequencies of success attributes between IPD and non-IPD projects will be statistically tested (Agresti 2007) as will be explained later. All of these statistical tests are performed using the software SPSS®.

Table 16: Owner-Specific Performance Areas and Their Complementing Measurement Metrics

Performance Area **(1)**	**Measurement Metric** **(2)**	**Type of Metric** **(3)**	**Measurement Unit** **(4)**
Cost	Cost Change	Quantitative	Percentage
Schedule	Schedule Change	Quantitative	Percentage
Quality	Turnover, Building, Systems, and overall	Qualitative	5-point likert scale
Communication	Team Communication, Number of RFIs, RFI Processing Periods	Qualitative, Quantitative	5-point likert scale, RFI/Mil$, Days
Safety	Standards and Performance	Qualitative	5-point likert scale
Satisfaction	Owner, User, and overall	Qualitative	5-point likert scale

5.3 IPD Evaluation through Owner-Preferred Performance Areas

IPD performance evaluation is done using univariate analysis for each performance metric which will allow for a clear statistical comparison between IPD versus non-IPD projects. *Table 17* shows both the independent t-test (column 3) and MWW (column 4) that were done for each metric to entertain their values. The proper test to be considered based on the normality test (column 2) was shaded in gray. Values found statistically significant (p-value < 0.05) were made in **bold** font. Values found to be close to being significant were made in *italic* font. The normality test values that are not statistically significant were made in **bold**. A significant normality test value (p-value <0.05) means that the data being analyzed is statistically far from being normal. The following subsections will give more details about the result of each row (performance metric) separately.

Table 17: Statistical Significance Scores for IPD vs. non-IPD Projects Performance

Metric (Unit)* (1)	Normality (Shapiro-Wilk) Test (2)	Mean Score		IPD vs. non-IPD	
		IPD (3)	non-IPD (4)	Independ. T-test (5)	MWW Test (6)
Cost Variance (%)	**0.247**	-0.68	5.46	0.170	0.065
Schedule Variance (%)	0.000	-2.81	4.26	0.096	*0.062*
Turnover Quality	0.020	3.32	3.12	0.466	0.244
Building Quality	0.000	4.50	3.77	0.022	**0.042**
Systems Quality	0.001	4.55	4.00	0.048	*0.066*
Overall Quality	**0.643**	4.01	3.52	*0.054*	0.045
RFI/Million (#RFI/Mil)	0.000	4.01	17.39	0.010	**0.017**
RFI Processing Period (Days)	0.000	3.33	6.50	0.246	0.232
Team Communication	0.000	4.70	4.18	0.044	*0.071*
Safety	0.000	4.40	3.36	0.006	**0.013**
Owner Satisfaction	0.000	4.40	3.73	0.034	*0.067*
User Satisfaction	0.000	4.80	4.09	0.025	**0.049**
Overall Satisfaction	0.001	4.60	3.91	0.016	**0.029**

**Units not indicated are scores of 5-point Likert Scale*

5.3.1 Cost Performance

The cost performance for projects refers to the cost of construction and was measured using one quantitative metric which is cost change. The cost change measured was limited only to the construction cost due to data availability with responders. Cost change in a project was determined by comparing the planned construction cost to the final – actual – construction cost in percentage term. *Figure 23* shows boxplots of the construction cost change of each project group, IPD and non-IPD. The boxplot shows that IPD projects have less construction cost change, represented in lower median, than non-IPD projects. The IPD-like group found in the boxplot is shown for comparison reasons, and was not added to any of the other two groups for the hypothesis test. After conducting the normality test and determining the proper test for the difference between the two sample means, a *p*-value of 0.170 indicates no statistical significance between the two sample means which upholds the main hypothesis of *no difference in the cost change performance between IPD and non-IPD projects.* This *p*-value can be found in row 1 of *Table 17* above. This result comes in accordance with two previous studies done on cost performance of IPD projects where no statistical significance was found in the difference between IPD and non-IPD projects (El Asmar et al. 2013; Cho and Ballard 2011).

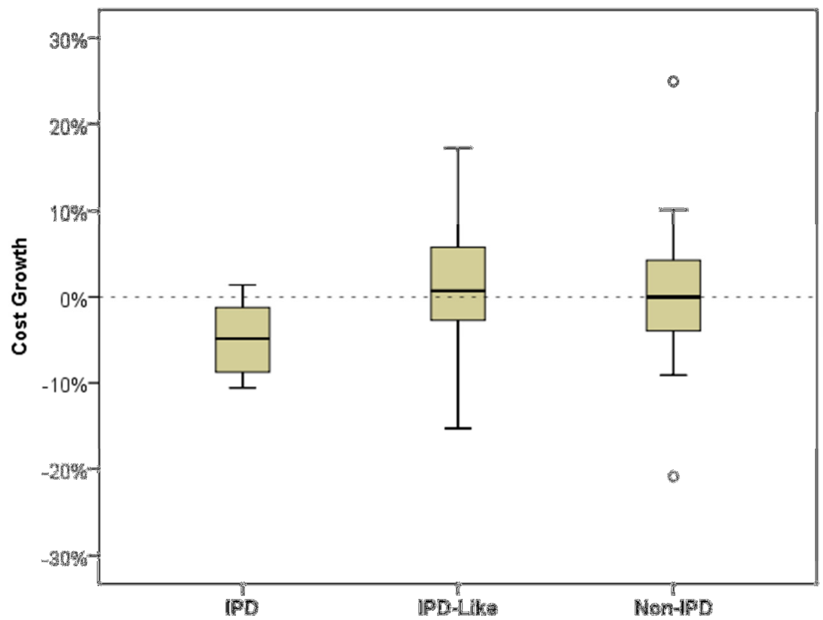


Figure 23: Box Plot of Cost Change

5.3.2 Schedule Performance

The schedule performance for projects refers to the construction phase from the "notice to proceed" to the "substantial completion." The measurement of schedule change was limited to only the construction phase due to the limited data available to responders. The schedule change was measured by comparing the planned schedule to the actual one in percentage term. *Figure 24* shows boxplots of the construction schedule change of each project group, IPD and non-IPD. The boxplot shows lower median for IPD projects than non-IPD projects. After conducting the normality test and determining the proper test for the difference between the two sample means, a *p*-value of 0.062 indicates no statistical significance between the two sample means at the 0.05 level, which upholds the main hypothesis of *no difference in the schedule change performance between IPD and non-IPD projects.* However, the value can be considered significant at the more lenient 0.10 level, which rejects the main hypothesis to the alternative one. This *p*-value can be found in row 2 of *Table 17* above. This result also comes in accordance with the two previous studies done on schedule change of IPD projects (El Asmar et al. 2013; Cho and Ballard 2011).

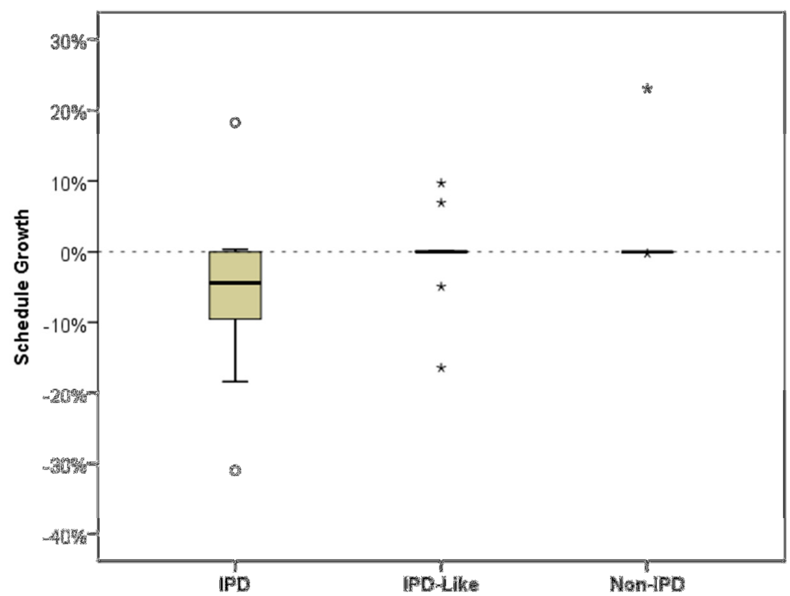


Figure 24: Box Plot of Schedule Change

5.3.3 Quality Performance

Quality performance of IPD projects was measured using three metrics. The first is the facility turnover metric which refers to the difficulty of starting up the built facility, call-backs volume, and operation and maintenance costs. The second is the building quality metric which refers to the quality of the exterior (e.g. structure and façade) and interior (e.g. layout and finishing) of the built facility. The third is the systems quality metric which refers to the quality of any system and / or equipment (e.g. environmental, lighting, processing, etc.) in the built facility.

All three metrics are qualitative / subjective determined according to how owners rate them on a five-point likert scale. An overall quality metric was also used by averaging all metrics. Quality performance was limited to subjective measures due to lack of available quantitative data about quality with owners such as number of deficiencies or latent defects. After running the normality tests and determining the proper statistical test for the difference between the two sample means; the test resulted in a *p*-value of 0.244 for the turnover quality, 0.042 for the building quality, 0.066 for the systems quality, and 0.029 for the overall quality. These values can be found in *Table 17* rows 3- 6 respectively. Except for the facility turnover, *IPD projects show statistically significant difference from non-IPD projects in quality ratings* which rejects the main hypothesis in favor of the alternative one. Although the systems quality is significantly different on the more lenient 0.10 level, it is still considered a difference. El Asmar et al. (2013) concluded quantitatively superior IPD quality performance, and this study arrived qualitatively at the same conclusion.

5.3.4 Communication Performance

Communication among project stakeholders in delivering the project is key to project success (Hanna et al. 2012). Not having clear communication channels could result in wasting project resources. Communication in a project was measured using three performance metrics. Two quantitative metrics used to measure communication are Request for Information (RFI) and RFI processing period (El Asmar et al. 2013; Hanna et al. 2012). The third metric used for communication is a rating by the owner to the communication among project stakeholders. Number of RFIs as a measure was normalized for all projects in the data set by dividing it by the project construction cost in millions to be (RFI/Million$). RFI processing period is measured in days. *Figure 25* shows boxplots of the RFI/Million$ of each project group, IPD and non-IPD. The boxplot shows that IPD projects have lower median for RFI/Million$ than non-IPD projects. After running the normality test and determining the proper statistical test for the difference between the two sample means, a *p*-value of 0.017 indicates statistical significance between the two sample means at the 0.05 level which rejects the main hypothesis in favor of the alternative one. This *p*-value can be found in row 7 of *Table 17* above. This result comes in accordance with El Asmar et al. (2013) where there were also statistical significance in the difference between IPD and non-IPD projects in the number of RFI/Million$.

Figure 26 shows boxplot of RFI processing period where the difference in the groups' medians is not quite clear as the RFI/Million$. RFI processing period had a *p*-value of 0.232 which can be found in row 8 of *Table 17* above. This value does not show statistically significant difference between IPD and non-IPD projects which upholds the null hypothesis, and comes in conflict with El Asmar et al. (2013) study that found statistical significance between the two groups in this metric. The difference in the RFI processing period metric results of this study and El Asmar et al. (2013) could be due to the different populations surveyed for each study (i.e. contractors vs. owners) where processing could very well be carried out differently.

Finally, the subjective rating of team communication had a *p*-value of 0.071 which could be found in row 9 of *Table 17* above. This is considered significantly different in the more lenient level of 0.10 which as well rejects the main hypothesis in favor of the alternative one that *IPD projects show statistically different performance than non-IPD projects in project participants' communication and RFI/Million$.*

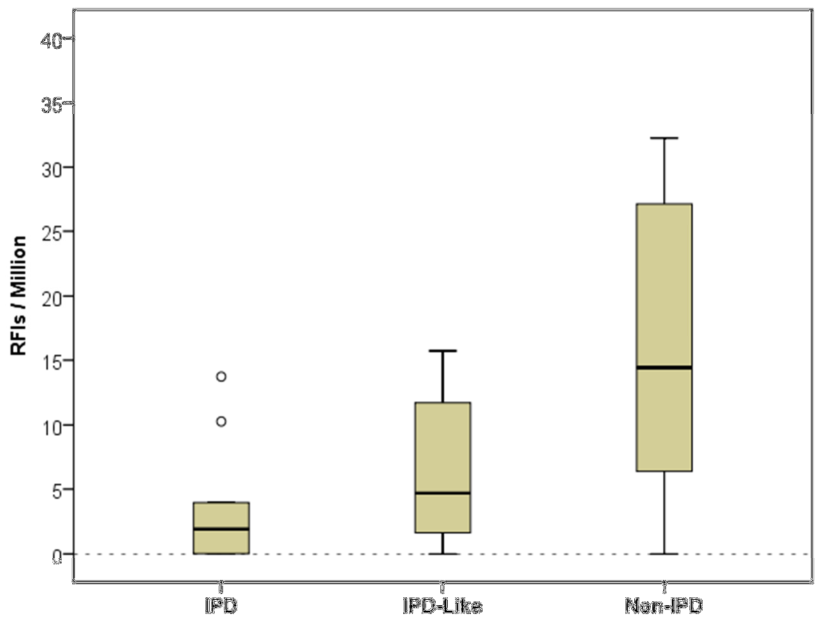


Figure 25: Box Plot of RFIs / Million $

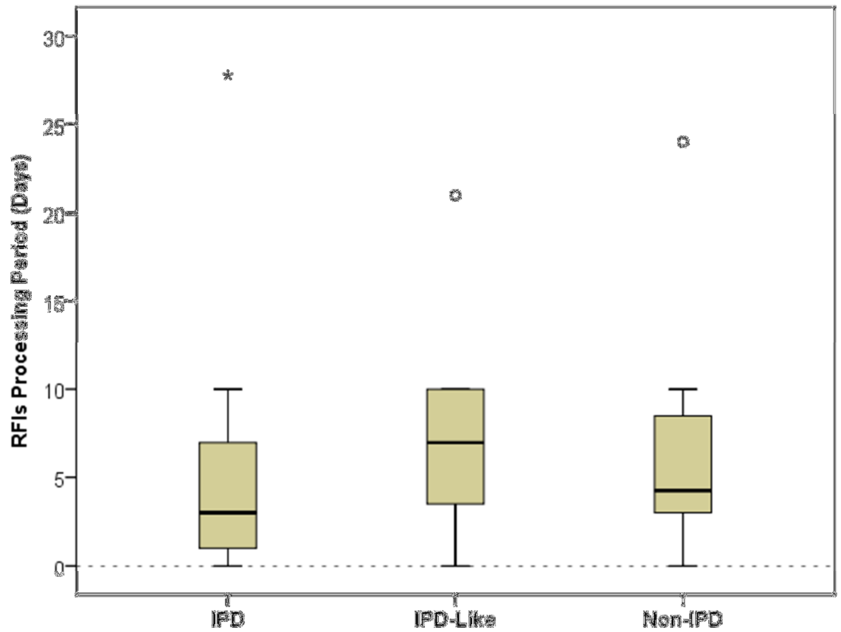


Figure 26: Box Plot of RFIs Processing Period

5.3.5 Safety Performance

Safety performance in projects especially during the construction period is lately becoming more important to owners (CURT 2005; FMI Management Consulting 2012). Recordable-incidents is the proper choice as a quantitative measure for safety performance (El Asmar et al. 2013; Rankin et al. 2008). However, due to data availability with survey responders, only qualitative measure of safety performance was acquired. An average score of two qualitative / subjective metrics was used. The two safety metrics measured safety *requirements and standards* set for the project compared to other similar projects, and safety *performance* compared to other similar projects. After running the normality test and determining the proper statistical test for the difference between the two sample means; the test resulted in a *p*-value of 0.013 for safety performance according to how owners rate it. This *p*-value rejects the main hypothesis in favor of the alternative one that *IPD projects have statistically different safety performance than non-IPD projects*. This value can be found in *Table 17* row 10. El Asmar et al. (2013) concluded no statistical significant difference in safety performance measured in different kinds of recordable between IPD and non-IPD projects. The different conclusion of this study, albeit subjectively measured, shows owners satisfaction with IPD projects in safety performance.

5.3.6 Satisfaction

Satisfaction measure in this study comes from a very reliable source, although subjectively. All project stakeholders' goals ultimately converge to meet owners' satisfaction with the built facility. Therefore, the main source of satisfaction, owners, was surveyed in this study. Satisfaction was measured using two qualitative measures: owner satisfaction, and users' satisfaction. Owner satisfaction refers to the satisfaction of the owner organization with the built facility. Users' satisfaction refers to the satisfaction of the facility users. This study included projects where users are part of the owner organization such as industrial organizations. It also included projects where users are independent of the owner organization; however, have direct contact with it such as educational and healthcare institutions. Therefore, the owner organization would have a valid outlook of users' satisfaction. A third metric called overall satisfaction was used by averaging the previous two. After running the normality test and determining the proper statistical test for the difference between the two sample means for both metrics, the test resulted in a p-value of 0.067 for the owners' satisfaction, 0.049 for the users' satisfaction, and 0.029 for the overall satisfaction. These values can be found in *Table 17* rows 11-13 respectively. A statistical significance between the two groups of projects means (IPD and non-IPD) of satisfaction score exists. The significance was at the 0.05 level for the users and the overall, and was at the more lenient level of 0.10 for the owner satisfaction. This rejects the main hypothesis in favor of the alternative one that *IPD projects have statistically different satisfaction level than non-IPD projects.* The overall satisfaction score which includes the two satisfaction scores should overshadow the less significant owner satisfaction score. This result is unique to this study, since none of the previous IPD project performance studies have directly surveyed the satisfaction of owners toward IPD projects.

Another dimension on satisfaction was explored in this study. Next to the satisfaction questions in this study survey, responders were asked, only in the cases where they had positive satisfaction, to pick from a list of attributes what contributed to the success of the project. The list of attributes included: completed on time (schedule), completed on budget (cost), functionality in terms of serving its purpose, quality in terms of latent defects, and safety in terms of zero incidents during construction. Responders were allowed to pick more than one attribute from the list. *Table 18* below shows the frequency of each attribute picked for this purpose divided into three groups of projects: IPD, IPD-like, and non-IPD. The table also shows percentages of the attributes picked by each project group. For example, the IPD projects group has 10 projects. A 70% at schedule attribute means 7 out of 10 IPD projects picked schedule to be a success attribute for their projects. Moreover, a statistical test can be performed to the *frequencies* in the table to measure any statistical significance in the difference between the project groups in term of choosing a particular attribute. This test is the chi-squared test and it measures against the hypothesis that attributes are distributed evenly across groups (Agresti 2007). A chi-squared value less than the conventional 0.05 threshold means distribution of an attribute is not even among groups, and that one group is statistically different than the others.

Table 18: Frequency of Satisfaction Attributes in Survey Responses

Attribute	Schedule	Cost	Functionality	Quality	Safety
IPD	7 (70%)	7 (70%)	8 (80%)	7 (70%)	5 (50%)
IPD-like	8 (62%)	4 (31%)	11 (85%)	5 (38%)	2 (15%)
non-IPD	5 (45%)	4 (36%)	4 (36%)	2 (18%)	1 (9%)

A chi-squared test to the attributes frequencies shown in *Table 28* for both IPD and non-IPD groups revealed a chi-squared value of 0.256 for schedule, 0.125 for cost, 0.044 for functionality, 0.017 for quality, and 0.038 for safety. This means statistical significance exists on how each group perceived functionality, quality, and safety attributes at the end of their project execution. Another point can be taken from the chi-squared test is that cost and schedule performance is not perceived differently in IPD versus non-IPD projects. This also comes in accordance with the results presented above in this study where there was no statistical evidence of a superior IPD performance in the cost and schedule metrics at 0.05 statistical threshold; however statistically evidenced in the quality, communication, and safety performance. It also comes in accordance with previous studies results (El Asmar et al. 2013; Cho and Ballard 2011) in the same manner. *This finding serves as a strong evidence of owner satisfaction using IPD system* which could also be used as a motivator for other owners to try to experience IPD in their capital projects.

5.4 IPD vs. IPD-like vs. non-IPD

The above subsections demonstrated the performance of IPD projects (i.e. projects with the highest degree of integration and collaboration among project participants) against non-IPD projects. It was also interesting to compare IPD projects with the IPD-like projects (i.e. projects with some degree of integration among project participants, however, not as much as IPD) , and IPD-like with non-IPD projects.

First, IPD (10 projects) were compared to IPD-like (13 projects). The same format in *Table 17* above was followed in *Table 19* below and the results of the statistical tests of this second trial are shown.

Table 19: Statistical Significance Scores for IPD vs. IPD-like Projects Performance

Metric (Unit)* (1)	Normality (Shapiro-Wilk) Test (2)	Mean Score		IPD vs. IPD-like	
		IPD (3)	IPD-like (4)	Independ. T-test (5)	MWW Test (6)
Cost Variance (%)	**0.247**	-5.20	1.38	**0.029**	0.014
Schedule Variance (%)	0.000	-6.38	-0.35	0.169	0.131
Turnover Quality	0.020	3.32	3.21	0.677	0.468
Building Quality	0.000	4.50	4.38	0.629	0.835
Systems Quality	0.001	4.55	4.00	0.037	**0.036**
Overall Quality	**0.643**	4.01	3.78	0.218	0.168
RFI/Million (#RFI/Mil)	0.000	4.01	5.77	0.424	0.483
RFI Processing Period (Days)	0.000	3.33	9.07	0.058	**0.034**
Team Communication	0.000	4.70	4.46	0.273	0.402
Safety	0.000	4.40	4.15	0.535	0.648
Owner Satisfaction	0.000	4.40	4.08	0.262	0.353
User Satisfaction	0.000	4.80	4.54	0.262	0.338
Overall Satisfaction	0.001	4.60	4.31	0.181	0.316

**Units not indicated are scores of 5-point Likert Scale*

Table 19 shows the similarity between IPD and IPD-like group of projects in their performance. The performance metrics did not show statistically significant difference between the two groups except for the cost change, systems quality, and RFI processing period. This similarity in performance encourages the step of combining the two groups as one when compared to non-IPD projects as a succeeding step.

Secondly, IPD-like (13 projects) were compared to non-IPD (11 projects). The same table format was followed in *Table 20* below and the results of the statistical tests of this second trial are shown.

Table 20: Statistical Significance Scores for IPD-like vs. non-IPD Projects Performance

Metric (Unit)* (1)	Normality (Shapiro-Wilk) Test (2)	Mean Score		IPD-like vs. non-IPD	
		IPD-like (3)	non-IPD (4)	Independ. T-test (5)	MWW Test (6)
Cost Variance (%)	**0.247**	1.38	0.85	0.897	0.738
Schedule Variance (%)	0.000	-0.35	2.28	0.353	0.993
Turnover Quality	0.020	3.21	3.12	0.782	0.541
Building Quality	0.000	4.38	3.77	0.049	*0.066*
Systems Quality	0.001	4.00	4.00	1.000	0.851
Overall Quality	**0.643**	3.78	3.52	0.265	0.145
RFI/Million (#RFI/Mil)	0.000	5.77	17.39	0.021	**0.031**
RFI Processing Period (Days)	0.000	9.07	6.50	0.456	0.315
Team Communication	0.000	4.70	4.46	0.235	0.321
Safety	0.000	4.46	4.18	0.031	*0.053*
Owner Satisfaction	0.000	4.08	3.73	0.281	0.269
User Satisfaction	0.000	4.54	4.09	0.156	0.185
Overall Satisfaction	0.001	4.31	3.91	0.167	0.190

**Units not indicated are scores of 5-point Likert Scale*

Table 20 does not show the statistically significant differences between IPD-like and non-IPD group of projects in their performance that *Table 17* (IPD vs. non-IPD) above shows. The only statistically significant difference shown in *Table 20* is in the RFI/Million.

The above two trials of analysis (*Table 19 and 20*) results created an interest in performing one more trial of analysis. A third trial of analysis was done where IPD and IPD-like (IPD/like) projects were combined into one group (23 projects), and this group was compared to non-IPD (11 projects). When compared together, IPD and IPD-like groups of projects showed relatively similar performance, except in three metrics: Cost change, Systems Quality, and RFI processing period. Therefore, when the comparison is done, the score of these three metics will be omitted. The same format in *Table 17* above was followed in *Table 21* below and the results of the statistical tests of this second trial are shown.

Table 21: Statistical Significance Scores for IPD/like vs. non-IPD Projects Performance

Metric (Unit)* (1)	Normality (Shapiro-Wilk) Test (2)	Mean Score		IPD/like vs. non-IPD	
		IPD/like (3)	non-IPD (4)	Independ. T-test (5)	MWW Test (6)
Cost Variance (%)	**0.247**	0.48	5.46	0.342	0.403
Schedule Variance (%)	0.000	-1.42	4.26	0.174	0.331
Turnover Quality	0.020	3.25	3.12	0.582	0.305
Building Quality	0.000	4.43	3.77	0.009	**0.023**
Systems Quality	0.001	4.24	4.00	0.322	0.403
Overall Quality	**0.643**	3.88	3.52	*0.066*	0.046
RFI/Million (#RFI/Mil)	0.000	5.01	17.39	0.015	**0.009**
RFI Processing Period (Days)	0.000	6.61	6.50	0.969	0.991
Team Communication	0.000	4.57	4.18	0.061	*0.098*
Safety	0.000	4.26	3.36	0.003	**0.010**
Owner Satisfaction	0.000	4.22	3.73	0.069	*0.081*
User Satisfaction	0.000	4.65	4.09	0.028	**0.039**
Overall Satisfaction	0.001	4.44	3.91	0.026	**0.040**

**Units not indicated are scores of 5-point Likert Scale*

Statistically significant metrics in *Table 17* (IPD vs. non-IPD) remained significant in *Table 21* (IPD/like vs. non-IPD) for metrics at the 0.05 level. For those significant at the 0.10 level, all the metrics remained except for System Quality. This second trial tests was done to show whether adding IPD-like projects in the IPD group would preserve the statistical significance of performance in comparison to non-IPD projects. This also solidifies the notion that more integration in a project leads to better performance, hence, the first main hypothesis (*Section 1.4*).

5.5 Discussion of IPD Results – Univariate Analysis

IPD definition: IPD definition is still evolving in the AEC industry and differs from one owner to another. Therefore, a method had to be followed in this study to categorize projects as explained in the introduction of this chapter and *Section 5.1*. The result was a balanced division across the three types: IPD, IPD-like, and non-IPD in the data set. This categorization was done to emphasize the role of integration and the defining principles of IPD previously mentioned in *Section 5.1*, which could also be applied to any type of PDS.

Hypothesis test results: The main hypothesis of each performance metric was the equality of performance between two groups of PDS (H_0: IPD = non-IPD), and the alternative hypothesis was inequality of performance (H_a: IPD ≠ non-IPD) with either more or less. The null hypothesis was rejected in favor of the alternative one when using 0.05 as a statistical threshold for five performance metrics as is shown in *Table 17*: safety, RFI/Million $, overall satisfaction, building quality, and user satisfaction. The null hypothesis was also rejected in favor of the alternative one when using the more lenient 0.10 statistical threshold for additional five performance metrics as is shown in *Table 17*: overall quality, schedule change, systems quality, owner satisfaction, and team communication. Moreover, the statistical tests used to compare IPD projects to non-IPD projects were two sided tests, which could be explained with either better or worse performance difference. For every performance metric used, the mean score of IPD projects was always better than non-IPD projects as it appears in columns 3 & 4 of *Table 17* – with and without the statistical significance – which indicates that the difference in performance resulted in this study is to the better side rather than the worse.

Connection with previous IPD studies: When looking at the performance areas where IPD projects found to have statistically better performance than non-IPD projects in this study, one concludes the similarity with the results of previous empirical studies measuring the performance of IPD projects (El

Asmar et al. 2013; Cho and Ballard 2011). Cost change was not found to be statistically significant between IPD and non-IPD projects. On the other hand, quality, communication, and safety were found to be statistically significant between IPD and non-IPD projects. El Asmar et al. (2013) found statistical significance in the exact same performance areas (quality, communication, and safety) quantitatively, as oppose to the qualitative measures used in this study. The qualitative / subjective measures of this study, on top of confirming the quantitative measures done by previous studies, indicate that owners, survey in this study, do perceive the enhanced performance in their facilities delivered using IPD system.

Owners Satisfaction: Owners are the ultimate entity to judge the successfulness of a construction project, for their satisfaction is the focal point of all the other project participants' performance. On top of the hypothesis tested for owner / user satisfaction level between IPD and non-IPD projects, which was statistically significant; success attributes for IPD and non-IPD projects were also statistically measured. Statistical significance was found in the frequencies of the attributes owners chose as reasons for project success: functionality, quality, and safety. IPD projects were found by owners to have more attributes to project success than non-IPD projects. This is a clear evidence of how owners surveyed in this study are satisfied when using IPD in delivering their capital projects.

5.6 IPD Univariate Analysis Conclusion

This chapter provided evaluation of integrated delivery performance (IPD, IPD-like, and non-IPD) from an owner's perspective, and should serve as a stepping stone in the process of approving this newly evolved project delivery system (IPD) within the AEC community. The evaluation areas used are based on owner-specific performance areas in construction projects as perceived from the literature and the professional panel that helped in evaluating this study's survey, and then ranked by responders.

The performance of IPD projects was measured and compared to non-IPD projects. When using a strict statistical significance threshold of 0.05, the study found from the surveyed sample that IPD projects statistically performed better than non-IPD projects in five metrics across four different performance areas: quality, communication, safety, and owner satisfaction. When using less strict statistical significance threshold of 0.10 for the same purpose; IPD projects were found to statistically perform better than non-IPD projects in ten metrics across the same four performance areas with the addition of the schedule performance. This finding confirms the main finding El Asmar et al. (2013) arrived at which was that *"IPD provides higher quality facilities faster and at no significant cost premium."* El Asmar et al. (2013) arrived at this finding from a contractor's perspective, and this study arrives at it from an owner's perspective.

In addition to IPD and non-IPD comparison, IPD-like projects were combined with IPD projects (IPD/like) in the data set as one group and compared to non-IPD projects. Statistically significant metrics in (IPD vs. non-IPD) remained significant in (IPD/like vs. non-IPD) for metrics at the 0.05 level. For those significant at the 0.10 level, all the metrics remained except for Systems Quality. It was interesting to see whether adding IPD-like projects to the IPD group would preserve the statistical significance of performance in comparison to non-IPD projects, which was done in this latter comparison. The second comparison also solidifies the notion that more integration in a project leads to better performance, hence, the first main hypothesis (*Section 1.4*), based on the surveyed sample.

Moreover, this chapter put more emphasis on the satisfaction evaluation. This was due to the fact that owners are the ultimate reference of the level of satisfaction with any construction project, and owners are the only participants in the survey sample for this study. On top of the statistically significant difference between IPD and non-IPD sample means in terms of rating overall owner satisfaction, this study also was able to statistically prove differences in owners' perceptions toward different project attributes contributing to project success. IPD projects, according to the surveyed owners' perceptions, provided more attributes that contributed to project success than non-IPD projects. These attributes presented in functionality, quality, and safety.

Chapter 6. OWNER PROJECT QUARTERBACK RATING (OPQR)

In the previous chapter, comparison between PDS groups was done in a univariate way; by comparing the PDS groups for each single metric of performance. This chapter will introduce a formula to combine all performance areas and their measurement metrics used previously in one single comprehensive number.

6.1 Introduction to OPQR

El Asmar (2012) measured the success of a construction project from a contractor's perspective using a comprehensive measure that combined all construction project success dimensions and called it the Project Quarterback Rating (PQR). The motivation behind the idea of PQR in that study was the rating used by the National Football League (NFL) to gauge their quarterbacks (passers), hence the name. The quarterback rating is a system used by the NFL against a fixed performance standard based on statistical achievement (NFL 2013). The NFL uses four measures to compile the rating: percentage of completions per attempt, average yards gained per attempt, percentage of touchdown passes per attempt, and percentage of interceptions per attempt. Construction projects dynamics are highly complex. Success of construction projects depend on multitude of dimensions, and differ according to many perspectives, as has been explained in *Chapter 2* (*Section 2.1*). Assessing the performance of a construction project is as – if not more – complex than assessing an NFL quarterback performance. Therefore, the need for a similar composite gauge to measure construction projects' performance is indeed present. Examples of dimensions construction projects depend on are: cost, schedule, quality, safety, and satisfaction. These dimensions and others need to be combined into one value that represents the overall performance of a given project. In the previous chapter, project performance was gauged separately to each performance metric. A similar model to the PQR will be established for this study and called the Owner Project

Quarterback Rating (OPQR) model. The model will allow combining all the previously used performance metrics into one comprehensive number that represents and gauges project success.

The OPQR is modeled as a linear function that employs weighted averages of different project performance dimensions. The model can serve as a baseline of projects to which other projects can be compared, and as an aid through which project success can be discussed. The following sections will explain the math behind the OPQR formula, and its validation. Finally, the formula developed will be used as one comprehensive measure of project success to be compared across all PDS groups (i.e. IPD, IPD-like, and non-IPD) in a similar way as was done in the previous chapter.

6.2 Mathematical Formulation

The mathematical concepts behind developing the OPQR are also similar to what El Asmar (2012) has done. *Therefore, the following subsections are adopted – to a large degree – from El Asmar (2012) study.*

The OPQR model combines seven performance areas, or dimensions, specified by the survey responders. The seven areas are: (1) safety, (2) cost, (3) satisfied users, (4) schedule, (5) quality, (6) claims, and (7) collaboration. They were determined earlier as explained in *Section 4.1.2,* and will be later in *Section 6.3.*

The model computes to each project j a corresponding Owner Project Quarterback Rating $OPQR_j$. The OPQR score is based on the above mentioned seven evaluation criteria with different weight assigned to each. The mathematical model that calculates $OPQR_j$ is as follows:

$$\boldsymbol{OPQR_j = \sum_{i=1}^{I} w_i \, s_{ij}},$$

where: j denotes project number j, $1 \leq j \leq J$, $J = 32$,

w_i is the weight of performance area i, $1 \leq i \leq I$, $I = 7$, and

s_{ij} is the composite score of project j for performance area i.

A linear model was used to take advantage of its simplicity, and to be able to add several performance areas. The underlying assumption here is that an overall comprehensive project performance rating $OPQR_j$ exists and only depends on the performance areas i. It is assumed, for simplicity, that the effects of the performance areas i on $OPQR_j$ are linear and independent. That means when the performance area i is fixed, an increment Δs_{ij} will have the same effect on the rating $OPQR_j$ independent of the values that s_{ij} or any other performance metrics are taking, and the effects of more than one increment (i.e. Δs_{ij} and $\Delta s_{ij}{}'$) occurring simultaneously for the same performance area are combined.

In the model, performance score $OPQR_j$ is calculated as the weighted average of the different performance areas s_{ij}. The performance area scores are combined and normalized before making their way to the weighted average formula introduced above. Moreover, scores (s_{ij}) for the seven areas may combine more than one components; for instance, collaboration combines the RFIs/Million$ and team communication rated by the owner. The term X_{ijk} denotes the original scores of performance metrics, with $1 \leq k \leq K$ where K represents the number of metrics combined in each performance area i. In the case of collaboration, $X_{ijk},\ K = 2$, which will be combined into s_{ij} that represents the collaboration performance area.

Figure 27 exhibits three levels that explain what was described above: (1) $OPQR_j$ is the first (top) level; (2) s_{ij} is the second level that includes the seven performance areas that OPQR combines; and (3) X_{ijk} represents the third level that includes any combination of individual performance metrics listed under each of the seven areas. Sub-Items that fall below the third level line represent scores from which the main item (s_{ij}) (i.e. second-level) was averaged. These sub-items are scores of a 5-point likert scale and their main item is an average of them. For example, the satisfaction performance area – in the second level – is an average of the scores of user and owner satisfaction.

Looking at all the metrics in second-level (s_{ij}) of *Figure 27*, a problem becomes evident. There are at least four different units for the metrics on the second-level performance areas, which cannot be added together as they are (e.g. cost change in percent terms cannot be added with RFI processing time in day). Standardization would be a good solution to overcome this problem. Any set of numbers can be transformed to their equivalent values on the standard normal distribution, which will put them in a unified platform for analysis reasons.

Standardization is achieved by subtracting the mean and dividing by the standard deviation. It has significant advantages. First, positive values indicate above average performance and negative values below average performance, while zero indicates the average project performance regarding the specific metric analyzed. This can be done to a combination of metrics that make up one performance area, and also to all the performance areas combined for OPQR as a whole. Second, the combined rating values can be similarly standardized and interpreted in terms of number of standard deviations below or above the average. Basically, the measurement units of the standardized values are the number of standard deviations above or below the average.

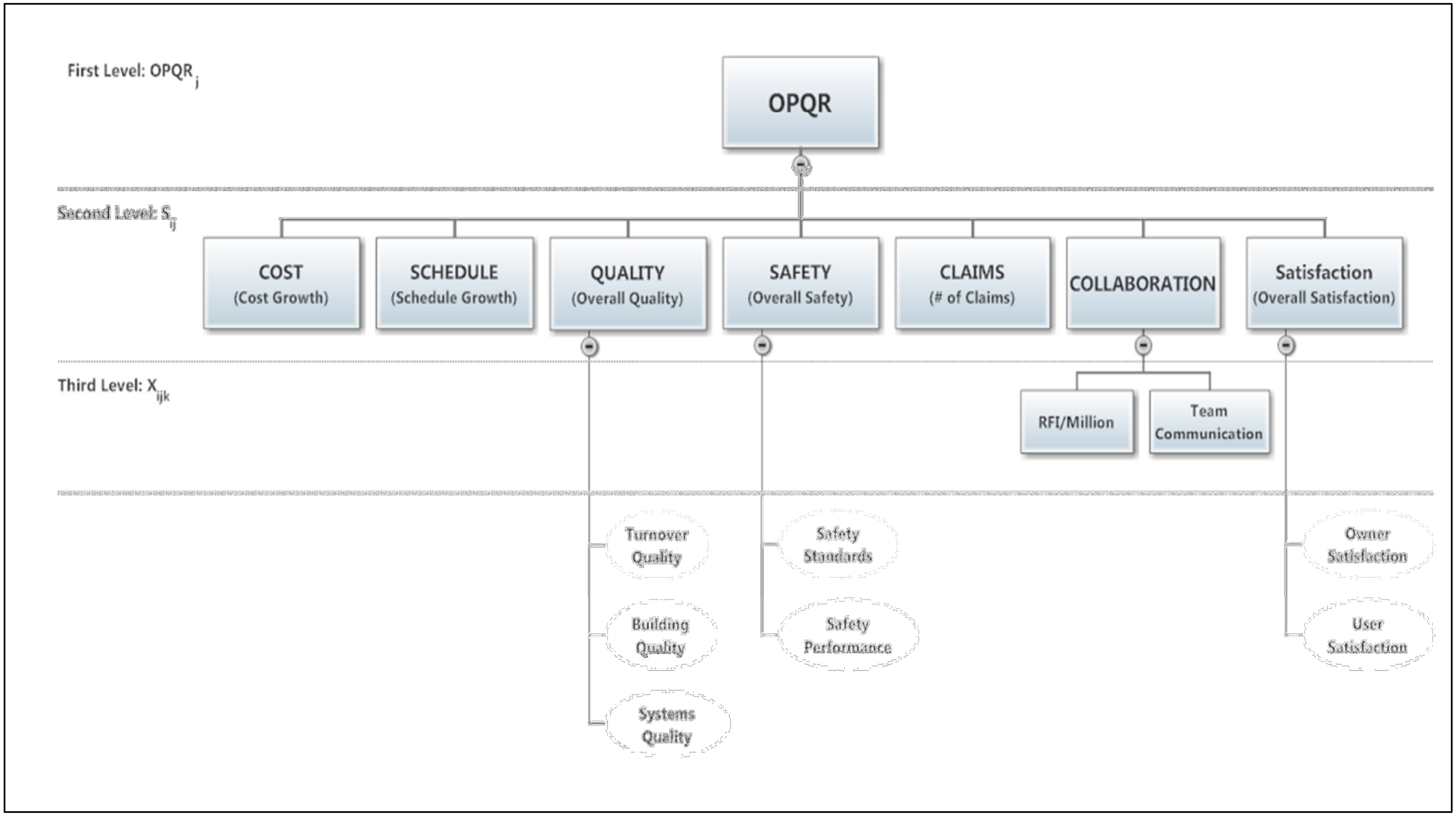


Figure 27: OPQR Structure

Reading the produced formula is as follows: the operation $Av_{ik}(X_{ijk}) = \frac{1}{J}\sum_{j=1}^{J} X_{ijk}$ represents the average of the array X_{ijk} over the index j, while fixing the other indices i and k. The normalization procedure transforms each original score X_{ijk} to its normalized version z_{ijk} as follows: fixing a specific metric k and a performance area i, the mean score and standard deviation are calculated for each performance metric. These are:

$$\mu_{ik} = Av_{ik}(X_{ijk}) \quad \text{and } \sigma_{ik} = \sqrt{Av_{ik}\left(\left(X_{ijk} - \mu_{ik}\right)^2\right)}$$

Where, μ_{ik} is the mean, and σ_{ik} is the standard deviation. The z-scores are then calculated to be $z_{ijk} = (X_{ijk} - \mu_{ik})/\sigma_{ik}$. These z-scores unify the units of different metrics, giving them equal effect on s_{ij}. The scores for each performance area can be calculated using:

$$s_{ij} = \sum_{k=1}^{K} w_{ik}\, z_{ijk}$$

The w_{ik} represents the weight of each metric in a specific performance area i. The z-scores z_{ijk} are centered around zero; therefore, some values become positive and other values negative. In the case of this study, only the performance area of collaboration is made-up of more than one metric. After being used in the weighted average, a similar normalization technique is used to standardize the resulting scores s_{ij}. The mean of all s_{ij} is subtracted from each s_{ij}, then the result is divided by the standard deviation of all s_{ij}, as was completed previously for the original performance metrics scores. The resulting z-scores of s_{ij} will give rather a logical interpretation of the results, similar to what was discussed earlier: a negative score means the project had a lower-than-average performance in the specific area analyzed (e.g. cost or schedule), and a positive score means the project had an above-average performance, while a score of zero means the project had an average performance. In addition, values above or below average can be interpreted as numbers of standard deviations away from that average. For instance, a score of 1.5 means the project was 1.5 standard deviations above the average project for the specific performance area. Similarly, a score of -1.0 mean the project was 1.0 standard deviation below average.

At the end, the standardized scores for all seven performance areas are combined into the OPQR formula, $OPQR_j = \sum_{i=1}^{I} w_i \, s_{ij}$. The resulting scores undergo one last standardization procedure to provide the same interpretation presented above. The next subsection will demonstrate the build-up of this mathematical formulation with actual project data and transform it into a function that can be used to gauge overall project performance.

6.3 OPQR Formula

Before proceeding into building up the OPQR formula, weights of the performance areas should be identified. As mentioned previously, performance areas and their respective measurement metrics were extracted from the literature with the help of the professional panel of this study. Rating for each performance area, which would eventually determine the weight of it, was extracted from the Executive-Level survey. Data for the measurement metrics was collected from the Project-Level Survey. *Table 20* below shows the performance areas (column 1), their respective measurement metrics (column 2), their average score according to the results of the Executive-Level survey (column 3), and their respective weights according to the ranking scores (column 5). The weights were calculated by dividing the average score of each performance area by the total of averages.

Moreover, *Table 20* is also split in two parts. The upper part includes the criteria that data was successfully collected for, and therefore, were included in the OPQR formula. The lower part contains criteria that were included and rated in the Executive-Level survey; however, no data was collected for them, either for data unavailability (Sustainability), or being related to third parties which would be outside the scope of this study (Satisfied 3rd Parties, Reputation). Fortunately, none of the performance areas in the lower part of the table are ranked among the top five in the Executive-Level survey.

Table 22: Performance Areas, Metrics, and their Respected Weights

Performance Area (1)	Measurement Metric(s) (2)	Survey Participants Mean (3)	Survey Participants Rank (4)	Weight (5)
Cost	Cost Change	8.59	2	0.152
Schedule	Schedule Change	8.50	4	0.150
Quality	Overall Quality	8.45	5	0.149
Safety	Overall Safety	8.77	1	0.155
Claims	# of Claims	7.45	8	0.132
Collaboration	75% RFI/Million + 25% Team Comm.	6.27	10	0.111
Satisfaction	Overall Satisfaction	8.55	3	0.151
	Total	**56.59**		**1.00**

Satisfied 3rd Parties	Will not be included in OPQR	7.55	6
Sustainability	Will not be included in OPQR	7.50	7
Reputation	Will not be included in OPQR	6.41	9

Another point that is worth mentioning is the single-measurement metric nature of each criterion in the upper part of *Table 20* except for the “Collaboration”. The Collaboration criterion in a project is being measured by combining two metrics: RFI/Million$ which is an objective measure, and Team Communication which is a subjective measure rated according to owners’ perspective. *The calculating method was also done in a similar manner to that of El Asmar (2012).*

The following paragraphs will explain the details of the values used in the formula. *Cost* and *Schedule Changes* were used for the Cost and Schedule Performances, and were given the same values used in the univariate analysis in *Chapter 5(Sections 5.3.1& 5.3.2)*. The *Overall Quality* score *(Section 5.3.3)*, which is an average of turnover, building, and systems quality scores, was used for the Quality performance. The *Overall Safety* score *(Section 5.3.5)*, which is an average of safety standards and performance rating scores, was used for the Safety performance. The *Overall Satisfaction* score *(Section 5.3.6)*, which is an average of users and owner satisfaction rating scores, was used for the Satisfaction performance. Number of claims was directly used for the Claims performance area. And finally, RFI/Million$ and Team Communication *(Section 5.3.4)* were used for the Collaboration performance. Collaboration was the only performance area with a combination of two measurement metrics. Because of its objectivity, RFI/Million$ metric was given a larger portion (75%) of the combination, with the remainder (25%) assigned to the subjective team communication rating by owner.

The first step in calculating OPQR for a project is standardizing any single measurement metrics in the third-level X_{ijk} . As it appears in *Figure 27*, only Collaboration performance area is made up of more than one metric. Therefore, the first step in this process is creating a new Collaboration variable as follows:

$$Collaboration = (-.075 \times RFI/Million\ \$) + (0.25 \times Team\ Communication)$$

Both metrics in the equation above are normalized before being inserted in the equation for the reasons mentioned in the previous section. The minus sign was given to RFI/Million$ due to its negative effect on this metric. In other words, better collaboration is translated in less RFIs.

The second step is individually normalizing all of the seven performance areas scores: Cost, Schedule, Quality, Safety, Claims, Collaboration, and Satisfaction. The third step is plugging all of the normalized seven performance area scores into the OPQR equation. The final step is normalizing the OPQR score to be able to compare all projects in the data set at a unified scale.

The final OPQR formula looks as follows:

$$OPQR = \frac{\begin{array}{c}(-0.152 \times Cost) + (-0.150 \times Schedule) + (0.149 \times Quality) + (0.155 \times Safety) \\ +(-0.132 \times Claims) + (0.111 \times Collaboration) + (0.151 \times Satisfaction)\end{array}}{0.55}$$

The weight before each metric is taken from *Table 20* above. The minus signs were given to the cost, schedule and claims metrics due to their negative effect on the criterion itself. In other words, better results come with negative cost and schedule changes and less claims. Having a negative cost or schedule change, for example, is more preferred to owner. Plugging a negative number for cost, schedule or claims would produce larger value because of the negative sign before the metric.

6.4 OPQR Validation

The main reason behind the creation of OPQR is measuring the overall performance of a project from an owner's perspective. However, before using the OPQR as a tool for measuring the overall performance of a project, it needs to be validated to assure that it is functioning to its intended use and need.

Factor Analysis (FA) as an independent and unsupervised statistical tool will be used to validate the OPQR by measuring the project performance of the data. FA as a tool models and quantifies latent variables in a data set that cannot be measured (Cox 2005). A practical example of a phenomenon with latent variable is intelligence. Intelligence by itself is difficult to measure; however, several observable measures could contribute to the level of intelligence in a person such as analytical thinking, mathematical ability, and linguistics. FA is a utility through which latent variables of intelligence can be determined in a data set of measurable variables with no preconceptions (Cox 2005). FA creates new variables by combining similar variables that share similar variance in the data, and then rotate them in a way that lines them closely to the original variables. For more information about FA, a reader can refer to Cox (2005) or Hair et al. (1998).

Comparing the previous example (i.e. intelligence) to construction projects success, one can find them similar. Success of a construction project depends on a several variables, and at the same time it is seen differently from different perspectives. Therefore, FA is another tool that can measure construction project success from the measured variables in the data set of this study by creating new latent variables of success. At the same time, FA results of construction project success can be used to compare and validate the results of OPQR equation introduced above.

Using the software SPSS, FA with Oblique rotation was performed on the same performance metrics used to create OPQR. One metric was excluded due to its insignificance effect on the Factor loadings: *Claims*. Going back to the data collected, only two projects in the data set reported that claims had been issued. It could be a sensitive issue to report for responders, and therefore not much was reported. The bottom line is that although it is considered important in construction projects performance to owners, the quality of data collected about claims in this study was very modest. *Table 21* shows the factor loadings from the test output. The test output produced two factors (new variables) explaining 53% of the variance in the data. Many statistical literature have suggested the value of (0.32) to be a threshold for loading in order to achieve practical worth (Meyers et al. 2006). Therefore, loadings less than 0.32 have been deleted from the table to better observe the difference in loadings of the two factors.

Table 23: Factor Loadings on OPQR Performance Metrics

Performance Area (1)	**Factor Loadings**	
	Factor 1 (2)	**Factor 2 (3)**
Quality	**0.853**	
Satisfaction	**0.738**	
Collaboration	**0.454**	
Safety	**0.320**	
Schedule		**0.891**
Cost		**0.791**
Extraction SS Loadings	1.938	1.245
Proportion of Variance (%)	32.30	20.75
Cumulative Variance (%)	32.30	53.04

As mentioned earlier, FA has the ability to define and quantify latent variables in a data set. Factor 1 (column 2) and Factor 2 (column 3) represent two latent variables extracted by this statistical tool. In order to understand these two Factors, one needs to look at what each of these factors represent and describe them accordingly. This can be done by cross-referencing the loading of each factor with the performance areas in column 1 of *Table 21*.

Factor 1 represents mostly subjective measures in the list: Quality, Satisfaction, Collaboration, and Safety. The scores of almost all these performance areas in this study depended on a subjective rating according to owner's perspective as opposed to being based on hard numbers. A proper name for Factor 1 is "Soft Measures". Factor 2 represents two objective measures in the list: Cost and Schedule. Conversely, a proper name for Factor 2 is "Hard Measures" since both metrics rely on hard numbers.

Factor 1 & 2 represent two-dimensional measure of the data. To better understand and visualize this two-dimensional measure, a spread of the data points with respect to these two factors (measures) is needed. *Figure 28* below shows a scatter plot of the data points with respect to both factors.

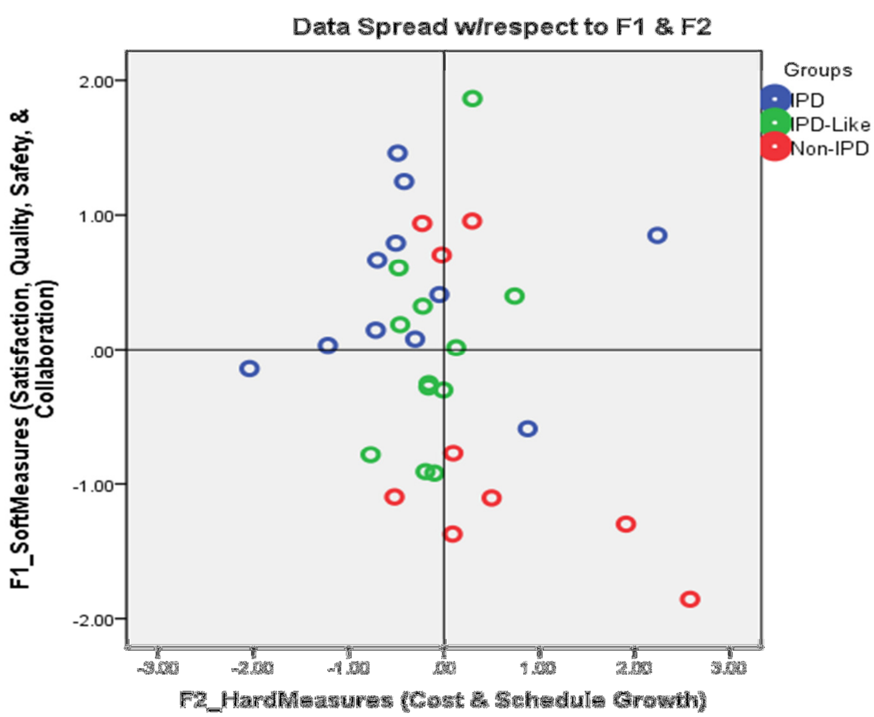


Figure 28: Scatter Plot of Factor 1 & 2

What is shown in this scatter plot reemphasizes what was concluded from the univariate analysis in the previous *Chapter (5)*. With respect to the soft measures (y-axis), there is almost a separation between the IPD (blue) and the non-IPD (red) projects. All but two of the IPD projects fall above the horizontal axis of the Soft Measures Factor which indicates positive number on the factor scale. Similarly, in separate measurement metrics, IPD did show a superior performance to non-IPD projects in Quality, RFIs/Million $, Safety and Satisfaction metrics in the univariate analysis. On the other hand, separation with respect to the Hard Measures Factor (x-axis) is not quite clear. Notice the clustering of the data points around the vertical axis. Although IPD projects fall to the left of the vertical axis and non-IPD projects to the right of it, which indicate positive values to most of IPD projects and negative values to most of non-IPD projects on the Hard Measure Factor scale; the clustering around the vertical axis makes it difficult to statistically separate the performance of both groups of projects, which is similar to what was found in the univariate analysis for the Cost and Schedule metrics.

Now, in order to use the result of FA in validating OPQR, preparation steps need to be done for that result. In a similar concept to what have been done mathematically for OPQR equation, the two-dimensional measure represented by Factor 1 & 2 need to be combined in one-dimension (linear) measure that approximate the overall project performance measured by FA. Both factors were scaled and then the norm of the two scaled factors was created. Scaling transforms the factor to values from 0 to 1 by subtracting all the values from the minimum and then dividing by the maximum. The norm is created by taking the square root of the sum of both scaled factors squared. On the other hand OPQR was also scaled to be compared to the Factor Norm. *Figure 29* shows how the Factor Norm of both factors almost mimics the scaled OPQR with similar highs and lows. The similar results of both scales confirm OPQR and validate it to some degree as an overall measurement tool of construction project performance for owners.

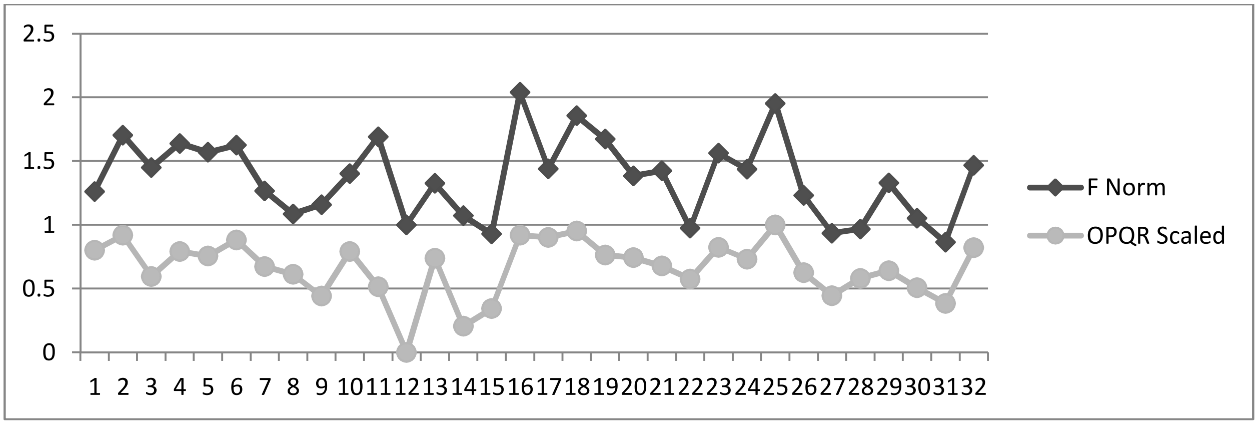


Figure 29: Comparing OPQR to the Norm of Factor 1 & 2

After the OPQR validation process, OPQR results for the overall project performance will be compared for IPD, IPD-like, and non-IPD projects. *Figure 30* shows a boxplot of different PDS groups on the x-axis and their OPQR score on the y-axis. One can see the difference in performance among the three groups, with IPD having the best performance.

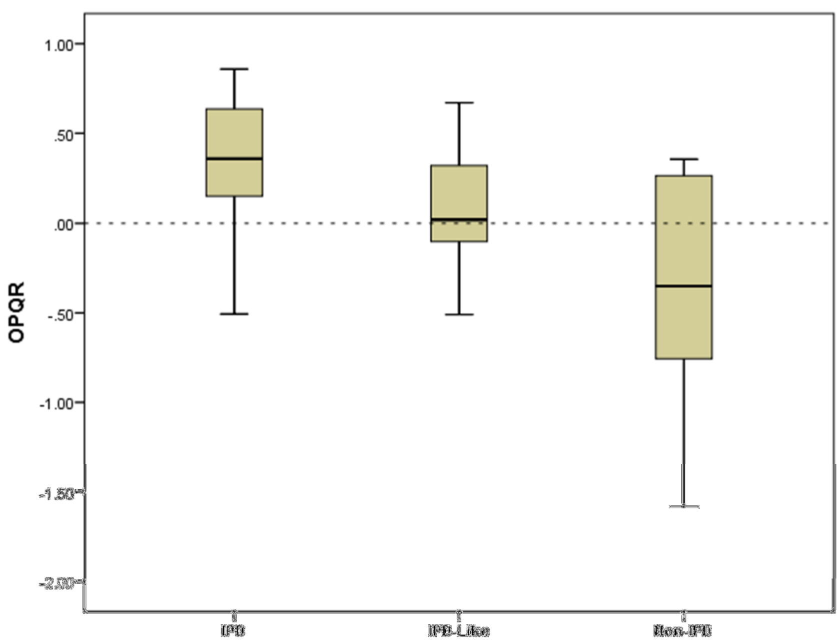


Figure 30: OPQR Boxplot Score for Different PDS Groups

Table 24: IPD vs. non-IPD Comparison of OPQR

Metric (1)	Normality (Shapiro-Wilk) Test (2)	IPD vs. non-IPD	
		Independent T-test (3)	MWW Test (4)
OPQR	**0.095**	**0.009**	0.010

Table 22 shows OPQR comparison between IPD and non-IPD projects. The t-test score in the table proves statistically the superiority of IPD projects' overall performance. *Table 23* shows OPQR comparison between IPD and IPD-like (IPD/like) projects as one group vs. non-IPD projects. The t-test score in the table proves that even with the addition of IPD-like projects to IPD projects, the superiority of IPD/like – the more integrated – projects still holds.

Table 25: IPD/like vs. non-IPD Comparison of OPQR

Metric (1)	Normality (Shapiro-Wilk) Test (2)	IPD/like vs. non-IPD	
		Independent T-test (3)	MWW Test (4)
OPQR	**0.095**	**0.027**	0.015

6.5 Conclusion

This chapter introduced a tool through which a comprehensive project performance evaluation can be achieved. The idea was adopted from a similar tool created for similar study by El Asmar (2012). The chapter introduced the tool and its mathematical derivation. The tool was a linear model based on and calculated as the weighted average of the different performance areas. It was called Owner Project Quarterback Rating (OPQR).

The development of OPQR using the data collection of this study was demonstrated. Standardization was the key in combining different performance areas together in one model. Then OPQR as a project performance measurement tool was validated using the statistical tool factor analysis. OPQR as a project performance measurement tool gives owners a comprehensive and overall view on their capital construction projects lined up as close as possible to success criteria specified by owners. Therefore, OPQR gives a reasonable indication to owners on their capital construction projects performance.

During the univariate analysis in the previous chapter, IPD projects showed superior performance compared to non-IPD projects when the comparison was on each individual measurement metric. Now, measuring the overall project performance using OPQR, IPD projects again showed superiority to non-IPD projects.

Moreover, OPQR, being a comprehensive project performance measure, can serve as a dependent variable when utilizing multivariate analysis to create a predictive model of project performance to owners. A multivariate model comprise of independent variables significantly affect the performance of a project. This is what will be explored in the next chapter.

Chapter 7. EVALUATING INTEGRATED DELIVERY ON A MULTIVARIATE LEVEL

The previous chapter introduced a tool through which a comprehensive project performance evaluation can be achieved. Being a comprehensive project performance measure, OPQR, can serve as a dependent variable when utilizing multivariate analysis to create a predictive model of project performance for owners. A multivariate model comprises of independent variables significantly affecting the performance of a project (i.e. OPQR). This chapter will present the multivariate analysis done with the data collection of this study. First, the variables used for this study regarding construction project delivery will be introduced. Then, two construction project performance models for owners are reached via two multivariate statistical tools: multiple regression, and factor analysis. Each statistical tool is introduced, applied to the variables, and the resulting model is validated.

7.1 Variables of the Study

Before the presentation of any analysis, project delivery characteristics (i.e. variables) measured in this study will be presented. A total of 25 variables measured in this study are presented in *Table 24* below. Recall that the total number of single variables collected in the study's Project-Level survey was about 90 variables. These variables were not used in the analysis as they are. Some variables were combined to give a more comprehensive gauge on a specific characteristic in project delivery; others were taken as they are. *Sections 3.4 & 3.5* explain how variables were combined with each other when applicable. Column 1 of *Table 24* lists the variables, column 2 explains what each variable contains, and column 3 gives the type of variable. The type of variable dictates how that variable will be coded numerically. *Section 3.5* explains types and coding of non-numerical variables for the analysis.

Table 26: Independent Variables of the Study

Variable (1)	What is it? (2)	Variable Type (3)
1. Project Delivery System (PDS)	PDS Type	Nominal
2. Compensation Method, Lump sum	A count of the use of this method by any of the project stakeholders	Discrete
3. Compensation Method, Cost Plus Percent Fee	A count of the use of this method by any of the project stakeholders	Discrete
4. Compensation Method, Cost Plus Fixed Fee	A count of the use of this method by any of the project stakeholders	Discrete
5. Compensation Method, GMP	A count of the use of this method by any of the project stakeholders	Discrete
6. Compensation Method, Cost Plus Profit Sharing	A count of the use of this method by any of the project stakeholders	Discrete
7. Selection Basis	A score for each project stakeholder ranging from open bid to negotiated contract	Ordinal
8. Stakeholders' Involvement	At what stage was each project stakeholder engaged in the project	Ordinal
9. Project Team	The use of management team, and the number of representatives in the team	Discrete
10. Management Structure	Average rating of the following: scope definition & communication, definition of participants' roles & responsibilities, definition of goals & measurement metrics, and dispute resolution process. The use of predefined decision-making process is then added.	Ordinal
11. Team Experience with project type	How experienced are the project team members with the project type. An average score of all the project participants	Ordinal
12. Experience as a Unit	Prior experience of project team members as a unit ranging from non to more than 2 projects	Ordinal
13. Stakeholders' Interaction	Average rating of the team chemistry, Jointly developed project goals, and the team meeting periods	Ordinal
14. Contract Limitation	A count of the following: The use of Multi-party contract, Liability waivers, and collaboration requirements	Ordinal
15. Incentives	The use of Incentives.	Binary
16. Risk/Reward Balance	The consideration of risk/reward balance in the project	Binary
17. Co-location	The use of a co-location to manage the project	Binary
18. Financial Transparency	The use of open-book policy	Binary
19. Lean Tools	A count of the number of lean tools used	Discrete
20. BIM	The use of BIM and its interoperability	Ordinal

Variable (1)	What is it? (2)	Variable Type (3)
21. Success Strategy	The use of a success strategy	Binary
22. Last Planner	The use of Last Planner Scheduling	Binary
23. Project Complexity	An average score of design complexity, regulatory constrains	Ordinal
24. Construction Type	New, addition, or renovation	Nominal
25. Project Type	Type of facility being constructed	Nominal

Variables in the above table are the *independent* variables that will be employed in the multivariate analysis. As for the *dependent* variable, it will be the Owner Project Quarterback Rating (OPQR) introduced and explained in the previous chapter.

7.2 Multiple Regression Analysis

Multiple regression analysis is a statistical tool used in this analysis to model the relationship between the different project delivery characteristics and project performance in an explanatory and predictive way. Multiple regression helps explain the relationship between project performance and how the different project characteristics significantly affect that performance; or in other words, lead to better performance,. Eventually, multiple regression will result in a predictive model that helps predict project performance.

The three popular regression methods widely used in multiple regression practice are: the forward method, the backward method, and the stepwise method (Meyers et al. 2006). The Forward Method is predicated on entering one variable at a time to an empty model. The chosen variable to be entered into the model is the variable that adds the most predictive power at that time to the model. The Backward method works in opposite process to the forward method, hence the name. It starts with a full model with all variables initially entered into the model. Non-significant variables, then, are removed one at a time until arriving at the most predictive model. The Stepwise method combines the two previous ones in one process. It starts with an empty model and enters significant variables one at a time, similar to the Forward method. Once the third variable is entered, the method starts to exclude non-significant variables, similar to the Backward method. This process continues until an optimum model is reached. What will be used in this analysis is the Stepwise regression method.

7.2.1 Stepwise Regression

The stepwise regression procedure was performed using the statistical software SPSS. The model, as explained above, started empty with no variables, then variables were entered and removed based on the following significance thresholds: 0.05 for inclusion and 0.10 for exclusion (SPSS defaults). Coefficient of determination (**R^2**) is then used to assess the resulted model. R^2 can vary between 0 and 1. The higher the value of R^2, the greater the explanatory power of the regression equation (the model), and therefore better prediction of the dependent variable (Hair et al. 1998). The stepwise regression resulted in a final model with three variables and an **R^2** value of **0.692** (adj. R^2=0.659). The variables are: the use of *Financial Transparency*, the project *Management Structure*, and the number of *Lean Tools* used in the project. The model is called OPQR-S, were the S is an indication of Stepwise Regression. The model OPQR-S looks as follows:

$$\mathbf{OPQR - S = -2.670 + 1.461\ Financial\ Transparency + 0.175\ Management\ Structure + 0.082\ Lean\ Tools}$$

An interesting finding in this model is the use of Financial Transparency among project stakeholders. The same variable, however differently measured, was found in a similar study to be within its predictive model (El Asmar 2012). The same observation also goes to the Lean Tools used in a project variable. The limited number of variables (only three) in the model is another finding that is rather concerning about the OPQR-S model. Due to the nature of stepwise regression, lots of variables are omitted by the regression procedure which would limit the model's explanatory ability, and eventually its prospective use by owners in the AEC industry.

The concern about the explanatory power of the model is acknowledged. Yet, this model is the result of the stepwise regression procedure, and should be accepted and assessed as is. *Table 25* below is taken from SPSS output of the final model OPQR-S.

Table 27: Final Regression Model (OPQR-S)

Model Variables (1)	Unstandardized Coefficient B (2)	Unstandardized Coefficient Std. Err. (3)	Stand. Coefficients Beta (4)	t (5)	Sig. (6)	Collinearity Statistics Tolerance (7)	Collinearity Statistics VIF (8)
Constant	-2.670	0.380		-7.023	0.000		
Financial Transparency	1.461	0.309	0.539	4.735	0.000	0.850	1.177
Management Structure	0.175	0.057	0.362	3.072	0.005	0.794	1.260
Lean Tools	0.082	0.039	0.231	2.120	0.043	0.927	1.079

7.2.2 Collinearity in the OPQR-S Model

One of the most important steps in assessing a regression model is checking for the existence of variable collinearity. Collinearity happens pairwise, or with more than two variables which is called multicollinearity, among the independent variables in a model. Collinearity or multicollinearity results in high level of shared variance among independent variables with which determining the individual contribution of each independent variable becomes difficult because the effects of the variables are confounded with each other (Hair et al. 1998). This affects the researcher's ability to understand and present the effects of each independent variable in the regression model.

Two common measures of assessing collinearity and multicollinearity in a regression model are (1) the Tolerance and (2) the Variance Inflation Factor (VIF) which is the tolerance inverse. A common threshold of the tolerance value is 0.10. Tolerance values in the 0.40 range are worthy of concern (Myers 1990) and in the 0.10 range (10 for the VIF value) are considered problematic (Hair et al. 1998; Myers 1990). Column 7 in *Table 25* above lists all the tolerance values of the model's variables. The minimum tolerance value is 0.794 which indicates the nonexistence of collinearity or multicollinearity in the model.

7.2.3 Validity of the Regression Assumptions in the OPQR-S Model

In multiple regression analysis, before drawing any conclusions from the analysis, four assumptions need to be examined. Meeting these four assumptions ensures that errors in prediction are not a result of an actual absence of a relationship among the variables or caused by some characteristics in the data not covered by the regression model (Chatterjee and Hadi 2006; Hair et al. 1998). These four assumptions are as follows:

- Linearity of the data measured
- The error terms are normally distributed
- The error terms have a constant variance
- The error terms are independent of each other

The linearity and normality assumptions can be validated by looking at the normality plot and histogram respectively (Chatterjee and Hadi 2006). The histogram in *Figure 31* below represents a fairly normally distributed data. In addition, the normal plot in *Figure 32* below represents a fairly linearly distributed data. This was indicated by the data points spread along the diagonal axis. The homogeneity and independence of the error terms can be validated by looking at the residual plot (Chatterjee and Hadi 2006) in *Figure 33* below. In *Figure 33*, the residuals (y-axis) are being plotted against the predicted values (x-axis). With the data points being fairly evenly distributed above and below the zero point in the y-axis, this gives a good indication of meeting the assumptions of homogeneity and independence of the error terms. With that, all four assumptions have been met in OPQR-S.

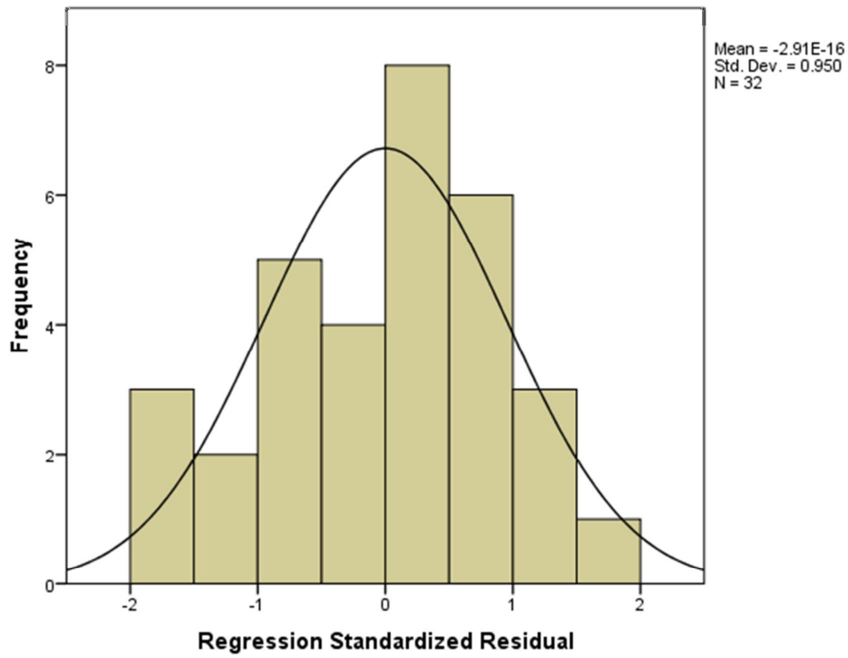


Figure 31: Histogram and Distribution Curve of OPQR-S

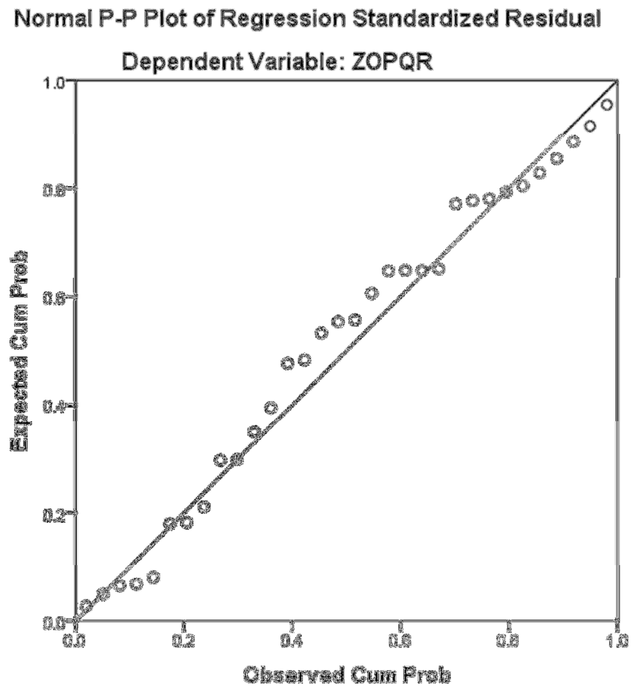


Figure 32: Normality Plot of OPQR-S

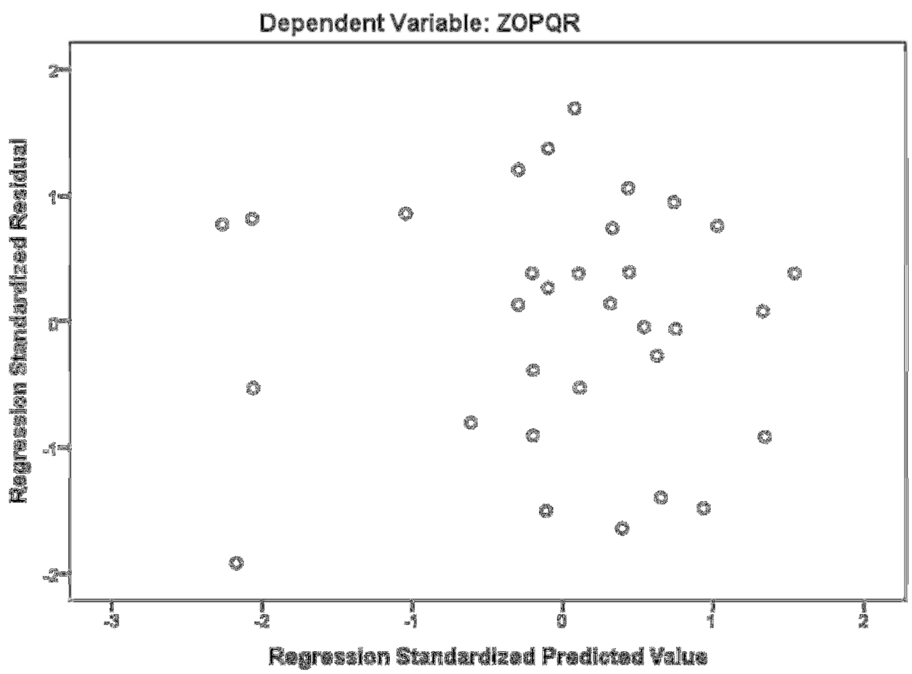


Figure 33: Residual Plot of OPQR-S

7.2.4 OPQR-S Model Validation

The ideal empirical validation process to test a regression model is to collect a new sample from the same population. The regression model then can be used to predict values of the new sample. In the real world, collecting a new sample depends on many factors such as cost, time pressure, and / or availability of responders which are not always to the researcher's expectations. In a case where collecting new data sample has constraints, the researcher may split the collected data randomly into two subsamples. One subsample is for estimating a new regression model, and the other subsample is to validate or "test" the regression model from the first subsample (Hair et al. 1998). This procedure is called cross-validation as it is done in one-way, or double cross-validation when it is done in both ways, as in performing another regression on the other subsample (Meyers et al. 2006). This validation process also includes validating the process through which the model was developed, the stepwise regression. Therefore, the validation models are also developed using the stepwise regression.

First, the available data set of 32 data points (projects) were split randomly into two subsamples. Stepwise regression procedure was done to each subsample with a model developed at the end of the procedure. *Table 26* below has the three models' details (overall and two subsamples) side by side extracted from the SPSS output.

Comparison of the overall model to the two subsamples demonstrates closeness in values of the results in terms of the values of R^2, Adjusted R^2, and the standard error of the estimate as it appears in the last three rows of *Table 26*. Moreover, management structure variable was not entered in subsample 1 (column 3), the same goes to lean tools variable in subsample 2 (column 4). However, the overall model (column 2) included all three variables which indicate that both models are explaining portions of the variance in the data, and that the overall model has more explanatory ability.

Table 28: Double Cross-Validation of the Stepwise Estimation, table organization is adopted from Hair et al. (1998)

Model Component (1)	Overall (n=32) (2)	Subsample 1 (n=16) (3)	Subsample 2 (n=16) (4)
Independent Variables			
Financial Transparency			
Regression Coefficient	1.461	1.425	2.395
Beta Coefficient	0.539	0.621	0.595
t value	4.735	4.473	4.244
Management Structure			
Regression Coefficient	0.175	Not Entered	0.231
Beta Coefficient	0.362		0.465
t value	3.072		3.319
Lean Tools			
Regression Coefficient	0.082	0.143	Not Entered
Beta Coefficient	0.231	0.481	
t value	2.120	3.467	
Model Fit			
R^2	0.692	0.765	0.782
Adjusted R^2	0.659	0.729	0.748
Standard Error of the Estimate	0.584	0.534	0.505

Moreover, another measure can be used to *validate the process of stepwise regression* in obtaining the OPQR-S model is the Mean Squared Prediction Error (MSPE) (Loh 2012). MSPE can be employed on the same data split above. First, subsample 1 model is used to predict the values of subsample 2 and produce a set of ($\hat{y}$). Second, the average value of y in subsample 1 is calculated ($\bar{y}$). Then, two MSPE values are calculated according to the following equations:

$$MSPE_1 = \frac{\sum(y - \hat{y})^2}{16}$$

$$MSPE_2 = \frac{\sum(y - \bar{y})^2}{16}$$

Finally, and R^2 value is calculated from these two new MSPE values to be compared to the model's (OPQR-S) R^2 value. The new R^2 value is calculated using the following equation:

$$R^2 = 1 - (MSPE_1/MSPE_2)$$

The newly calculated $MSPE_1 = 0.616$, $MSPE_2 = 0.987$, and R^2 = **0.37**. This new R^2 is compared to OPQR-S's R^2 which is **0.69**. An R^2 value of 0.37 seems low when compared to the R^2 of OPQR-S model. However, it falls within an acceptable range to what was measured in this study survey: human perceptions. Measuring human perceptions carries high level of variability, and an R^2 value in the range of 0.3 in the context of measuring human perceptions is considered a good value (Pardoe 2013). Almost 80% of this study's content requires subjective answers that are based on the responder's judgment and assessment. Therefore, and R^2 value of 0.37 represents a good validation to the prediction powers of the model OPQR-S.

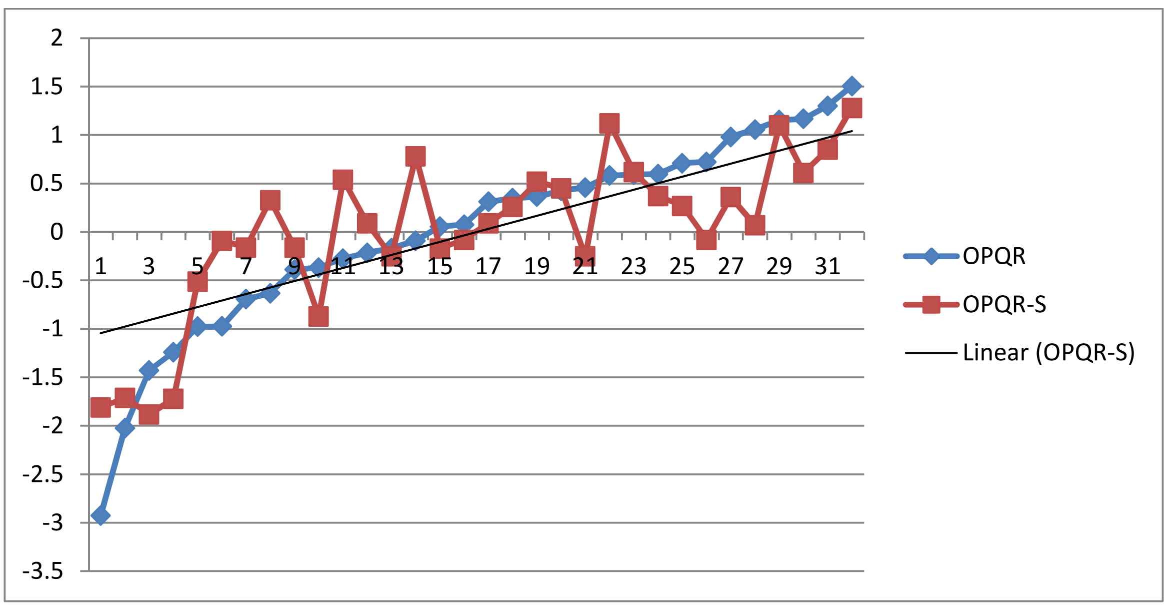


Figure 34: OPQR-S Model Performance Compared to Original OPQR

Figure 34 above shows how the developed predictive model (OPQR-S) trend with the actual OPQR. The y-axis represents the OPQR score, and the data set projects ordered in increasing OPQR score. A linear trend line of OPQR-S has been added to the graph as a way of visually validating the OPQR-S model and how it closely follows the actual OPQR.

A regression model has been developed; assessed for collinearity, multicollinearity, and regression assumptions; and then validated. This is not an implication that this model is perfect. There is still a concern lingering with this regression model, which is its limited explanatory ability with only three predictors. Stepwise regression procedure works in a way that might omit variables that are important in explaining project performance but happen to be correlated with variables already entered in the model.

This raises the need to complement the developed regression model with another explanatory analysis. Factor analysis is considered a potentially good candidate to analyze the data in a way to alleviate the limited explanatory ability of the model.

7.3 Factor Analysis

Factor analysis attempts to find a reduced set of latent – and at the same time driving – variables from within larger set of the observed variables (Cox 2005). This statistical technique searches for the fundamental summarized constructs assumed to underlie the original variables with a minimum loss of information. Unlike multiple regression analysis, factor analysis is an interdependence technique in which all variables are simultaneously considered within the analysis, and new variables are constructed using all variables (Hair et al. 1998). By that, factor analysis technique analyzes the data differently to what took place in the multiple regression analysis, and would truly serve as a complementary explanatory analysis to it. However, before embarking into this new statistical technique, few checks need to be made to decide on the suitability of data set for this statistical technique.

7.3.1 Variables Selection and their Measurements

When selecting variables to be included in the factor analysis procedure, Hair et al. (1998) suggest selecting them based on “conceptual basis”. Hair et al. also further claim that factor analysis is most efficient when conceptually defined dimensions can be defined by the derived factors. The taxonomy that

El Asmar (2012) followed in categorizing the project delivery variables and used in his study would be the most appropriate as conceptual defined dimensions since both studies – El Asmar (2012) and this study – are somewhat similar in scope. El Asmar followed what he called the three tees (3Ts): Terms, Tone, and Tools in dividing the project delivery characteristics variables. The 3Ts have been previously explained and applied to this study's variables in *Section 3.3*. Moreover, *Table 27* below shows how the qualified variables for factor analysis are divided according to the 3Ts taxonomy (column 4). This taxonomy would help in interpreting the outcome of the factor analysis as they are treated as conceptual defined dimensions for construction project delivery.

Hair et al. (1998) also suggest minimizing the number of variables used in factor analysis, but maintaining a reasonable number of variables for each predefined conceptual dimension (3Ts). The number of variables was reduced from what was used in the multiple regression procedure (from 25 to 15) as shown in *Table 27*. Finally Hair et al. (1998) suggest not to use dummy or binary variables (variables coded 0-1) and that they require a special type of factor analysis called Boolean factor analysis. Incentives, Risk/ Reward Balance, Co-location, and Financial Transparency are four binary variables used in multiple regression analysis that represents IPD attributes and are important to include in this analysis. Therefore, it was decided for these four binary variables to be combined in one variable that is a count of these attributes used in a project. The new variable is called IPD Attributes.

Table 27 below is organized similarly as the previously presented *Table 24*. Column 1 of *Table 27* lists the variables, column 2 explains what each variable contains, column 3 gives the type of variable, and column 4 shows how each variable is categorized according to the (3Ts) taxonomy.

Table 29: Factor Analysis Variables

Variable (1)	What is it? (2)	Variable Type (3)	3 T Taxonomy (4)
1. Compensation Method, Lump sum	A count of the use of this method by any of the project stakeholders	Discrete	Terms
2. Compensation Method, GMP	A count of the use of this method by any of the project stakeholders	Discrete	Terms
3. Compensation Method, Cost Plus Profit Sharing	A count of the use of this method by any of the project stakeholders	Discrete	Terms
4. Selection Basis	A score for each project stakeholder ranging from open bid to negotiated contract	Ordinal	Terms
5. Stakeholders' Involvement	At what stage was each project stakeholder engaged in the project	Ordinal	Tone
6. Project Team	The use of management team, and the number of representatives in the team	Discrete	Tone
7. Management Structure	Average rating of the following: Scope definition & communication, definition of participants' roles & responsibilities, definition of goals & measurement metrics, and dispute resolution process. The use of predefined decision-making process is then added	Ordinal	Tone
8. Team Experience with project type	How experienced are the project team members with the project type. An average score of all the project participants	Ordinal	Tone
9. Experience as a Unit	Prior experience of project team members as a unit ranging from non to more than 2	Ordinal	Tone
10. Stakeholders' Interaction	Average rating of the team chemistry, Jointly developed project goals, and the team meeting periods	Ordinal	Tone
11. Contract Limitation	A count of the following: The use of Multi-party contract, Liability waivers, and collaboration requirements	Ordinal	Terms
12. IPD Attributes	A count of the use of the following: Incentives, Risk/Reward Balance, Co-location, and Financial Transparency.	Discrete	Tools
13. Lean Tools	A count of the number of lean tools used	Discrete	Tools
14. BIM	The use of BIM and its interoperability	Ordinal	Tools
15. Project Complexity	An average score of Design Complexity, regulatory constrains	Ordinal	Terms

7.3.2 Number of Factors Extracted

Factor analysis was run using SPSS with the *Principal Axis Factoring* method as an appropriate method (Meyers et al. 2006) and an *Oblique (Direct Obilmin) rotation*. The factor correlation matrix in the SPSS output confirmed the oblique rotation choice with existing correlation between factors greater than 0.30 (Hair et al. 1998). The number of factors extracted in the process was five. The number of factors extracted is decided by eigenvalue, which represents the amount of variance accounted for by a factor, greater than one (Hair et al. 1998; Meyers et al. 2006). *Table 28* below shows that only the first five factors have eigenvalues greater than 1, and that the total variance accounted for by the first five factors is 62.5%. The scree plot in *Figure 35* below also confirms that only five factors have eigenvalues greater than 1.

Table 30: Eigenvalues and Variance Accounted for by the First Five Factors

Factor	Eigenvalue	Extraction Sums of Squared Loadings	% Variance Accounted for	% Cumulative Variance
1	5.428	5.055	33.699	33.699
2	1.909	1.549	10.330	44.029
3	1.313	1.140	7.600	51.630
4	1.238	0.919	6.127	57.756
5	1.088	0.726	4.837	**62.594**
6	0.935			
7	0.630			
8	0.593			
9	0.448			
10	0.360			
11	0.308			
12	0.285			
13	0.198			
14	0.166			
15	0.104			

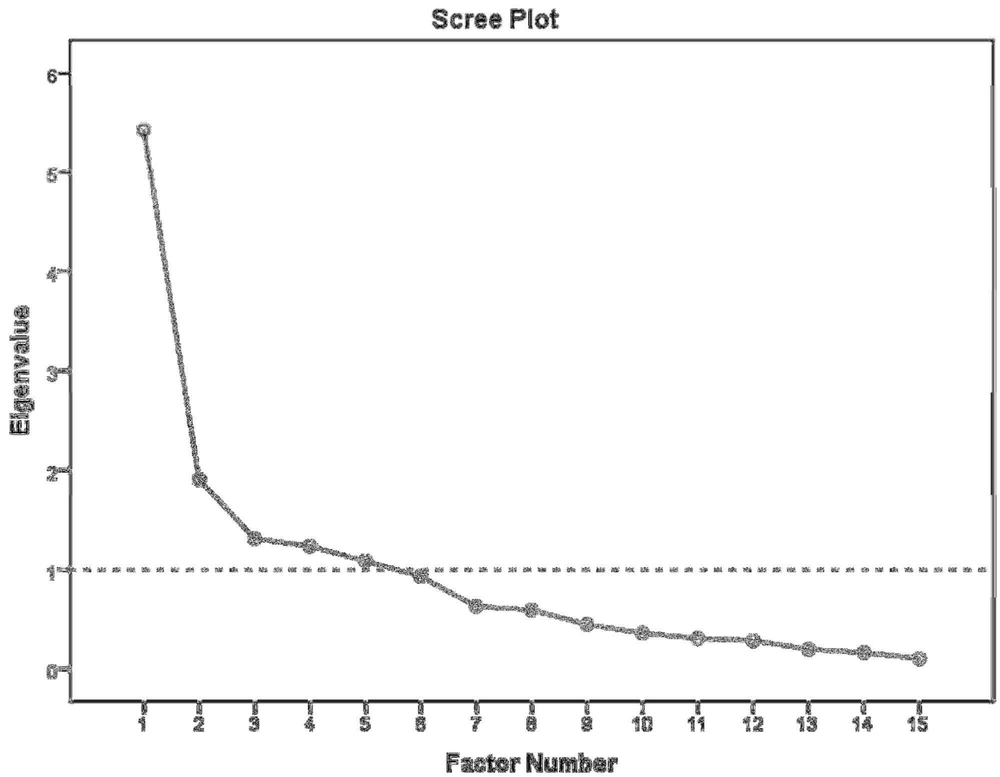


Figure 35: Scree Plot of the Factors

One check needs to be performed before proceeding with the factor analysis; the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and Bartlett's test of sphericity to test the null hypothesis that none of the variables are significantly correlated (Meyers et al. 2006). The KMO measure should be greater than 0.60 in order for the data sample to be acceptable for factor analysis, and the Bartlett test needs to be significant (p-value < 0.05). Both measures need to be met before proceeding (Hair et al. 1998; Meyers et al. 2006). *Table 29* below is extracted from the SPSS output, and it shows acceptable values for both KMO and Bartlett test.

Table 31: KMO and Bartlett Test for Factor Analysis

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy		**0.683**
Bartlett Test of Sphericity	Approx. Chi-Square	219.823
	df	105
	Sig.	**< 0.000**

7.3.3 Deriving Factors and Assessing Overall Fit

The newly extracted factors from the analysis represent the latent variables or the summarized structures underlie the data set. They are formulated according to their loadings as they appear in *Table 30* below. Factor loadings are basically the correlation between each variable and the factor. Loadings greater than ±0.30 are considered to meet minimal requirements, ±0.40 more important, and ±0.50 or greater are considered practically significant (Hair et al. 1998; Meyers et al. 2006). Factor loadings less than 0.30 have been omitted in *Table 30* for easier interpretation since they are non-significant.

The next step after extracting the factors is labeling them based on what each factor is representing with its underlying dimensions (variables). Factor 1 represents high positive loadings of Selection Basis, Stakeholder Involvement, BIM, IPD Attributes, and Lean Tools. All these variables with their high positive loadings represent the Integrated Project Delivery (IPD). Therefore, factor 1 will be called *Integrated Delivery*. Factor 2 represents both the Guaranteed Maximum Price (GMP) and the Profit-Sharing compensation methods, albeit contrasted loadings. GMP is more associated with Construction Management at Risk (CMR) and Design-Build (DB) projects where Profit-Sharing is more associated with IPD projects, however, profits are shared between the owner and contractor in both methods (i.e. GMP and Profit Sharing). Therefore, factor 2 will be called *Profit Sharing Compensation*. Factor 3 only represents the *Contract Limitation* variable; therefore it will be the factor's default name. Factor 4 also only represents the Team *Experience as a Unit* variable; therefore it will be the factor's default name.

Finally, factor 5 contrasts the Lump-Sum compensation method in positive loading, with the Team Experience with Project Type, Project Complexity, Shareholder Interaction, Management Structure, and Project Team, and they are all with negative loadings. Negative loadings indicate that the relationship with the factor is an inverse one (Meyers et al. 2006). Factor 5 reveals the attributes of a traditionally delivered construction project; where there is not much complexity in the project, project team are more experienced with the project type, less stakeholders' interaction with more built-up virtual walls through traditional project organization, and less project team members if there was a team at all. Therefore, factor 5 will be called *Traditional Delivery*.

Table 32: Extracted Factors Loadings

Variables	Factors				
	1	**2**	**3**	**4**	**5**
Selection Basis	**0.805**				
Stakeholder Involvement	**0.742**				
BIM	**0.637**				
IPD Attributes	**0.580**				
Lean Tools	**0.401**				
GMP Compensation		**0.809**			
Profit-Sharing Compensation	0.400	**-0.547**			
Contract Limitation			**0.973**		
Team Experience as a Unit				**0.856**	
Team Exp. Project Type					**-0.894**
Project Complexity			.335		**-0.608**
Stakeholder Interaction	0.383				**-0.605**
Lump-Sum Compensation		0.441			**0.556**
Management Structure	0.384				**-0.425**
Project Team					**-0.419**
Extraction SS Loading	5.055	1.549	1.140	0.919	0.726
% Proportion of Variance	33.699	10.330	7.600	6.127	4.837
% Cumulative Variance	33.699	44.029	51.630	57.756	62.594

7.3.4 Stepwise Regression of the Factors

The five newly derived Factors (or latent variables) provide a good explanatory approach to the project delivery characteristics since they are made of 15 variables combined. These new factors could also be treated as delivery characteristics, and stepwise regression analysis could be employed to further investigate these five factors effects on project performance (OPQR). Stepwise regression has been previously introduced in *Section 7.2.1*. Moreover, Previous studies in the construction industry literature have taken the same route of applying regression analysis on extracted explanatory factors (Chan et al. 2001; Lam et al. 2008).

The stepwise regression analysis will have OPQR as the dependent variable, and the following five newly extracted factors as the independent variables:

- Factor 1: Integrated Delivery
- Factor 2: Profit-Sharing Compensation
- Factor 3: Contract Limitations
- Factor 4: Team Experience as a Unit
- Factor 5: Traditional Delivery

Stepwise regression procedure was performed using SPSS software. The model started empty with no variables, then variables were entered and removed based on the following significance thresholds: 0.05 for inclusion and 0.10 for exclusion (SPSS defaults). The stepwise regression resulted in a final model with three variables and an $\mathbf{R^2}$ value of **0.64** (adj. R^2=0.60). The variables are Factor 1: *Integrated Delivery*, Factor 5*: Traditional Delivery*, and Factor 3: *Contract Limitations*. The model is called OPQR-FA, where FA stands for Factor Analysis, and looks as follows:

$$\mathbf{OPQR - FA = -0.068 + 0.629\ F1: Integrated\ Delivery - 0.393\ F5: Traditional\ Delivery - 0.303\ F3: Contract\ Limitations}$$

This model comes to an interesting finding, which is a validation and approval of this study's main hypothesis that is more success to construction owners comes with more integration in their projects. As seen in the model, better project performance is associated with adopting more integration in the project delivery (F1) and being distant from traditional delivery traits (F5). Another, rather unexpected, finding is the minus sign for the Contract Limitation variable (F3). Previous studies showed that integrated projects are highly correlated with more contract flexibility in employing the likes of multi-party agreements and liability waivers among project participants, and that better project performance is correlated with more contract flexibility (AIA and University of Minnesota 2012; El Asmar 2012). However, the minus sign in the model might indicate owners' reluctance to sign on liability waivers, or shared risks / rewards. AIA mentioned the difficulty of finding an IPD project in its "pure" form. By pure, AIA was referring to using multi-party agreement with what it originally contains. In their case studies of IPD, AIA found that many projects pursuing IPD use custom IPD agreements to eliminate certain aspects of liability waivers or shared risks / rewards (AIA and University of Minnesota 2012). Recall that this model is rather explanatory than predictive. Therefore, this resulting model comes in accordance with the current state of construction owners; it reflects what owners are / are not willing to do. *Table 31* below shows the OPQR-FA model and is extracted from SPSS output.

Table 33: Factors Regression Model (OPQR-FA)

Model Variables (1)	Unstandardized Coefficient B (2)	Unstandardized Coefficient Std. Err. (3)	Standrdzd Coefficients Beta (4)	t (5)	Sig. (6)	Collinearity Statistics Tolerance (7)	Collinearity Statistics VIF (8)
Constant	-0.068	0.112		-0.607	0.549		
F1: Integrated Delivery	0.629	0.139	0.592	4.533	0.000	0.759	1.318
F5: Traditional Delivery	-0.393	0.136	-0.369	-2.885	0.007	0.792	1.263
F3: Contract Limitations	-0.303	0.123	-0.292	-2.470	0.020	0.924	1.082

7.3.5 Validity of the Regression Assumptions in the OPQR-FA Model

The same method followed in verifying the regression assumptions in *Sections 7.2.2* and *7.2.3* are followed in this section. The OPQR-FA model is distant from collinearity as indicated by the tolerance values (column 7) in *Table 31*, the minimum value is 0.759. In addition, all four regression assumptions of the OPQR-FA model are met. The linearity and normality assumptions are met as indicated by the histogram in *Figure 36* and normality plot in *Figure 37*. Homogeneity and independence of error terms assumptions are met as indicated by the residual plot in *Figure 38*.

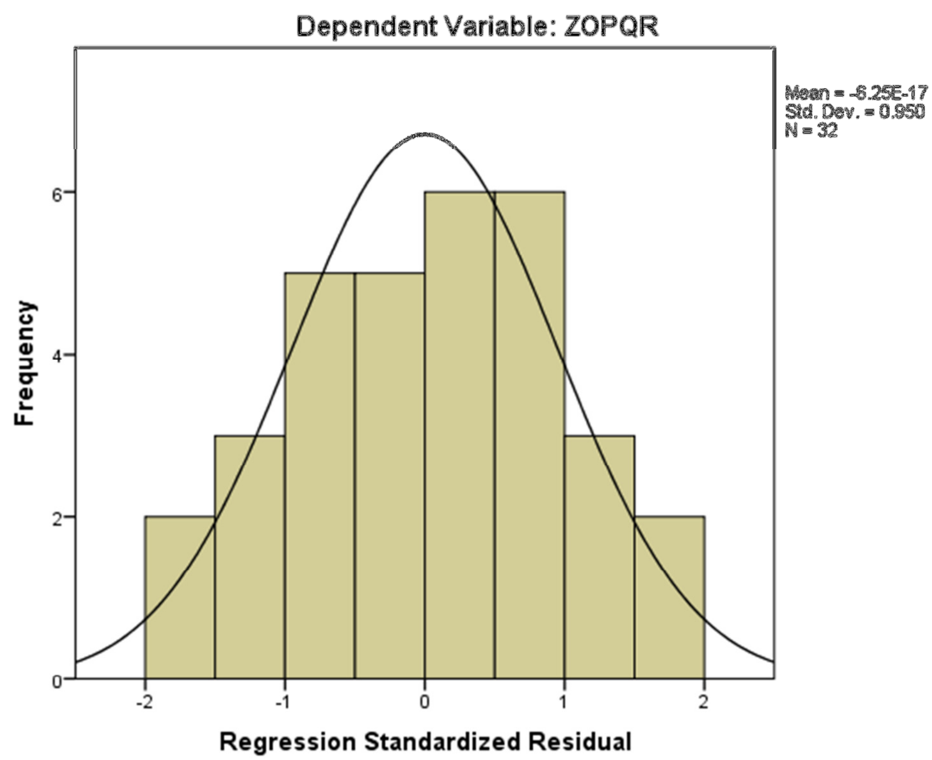


Figure 36: Histogram and Distribution Curve of OPQR-FA

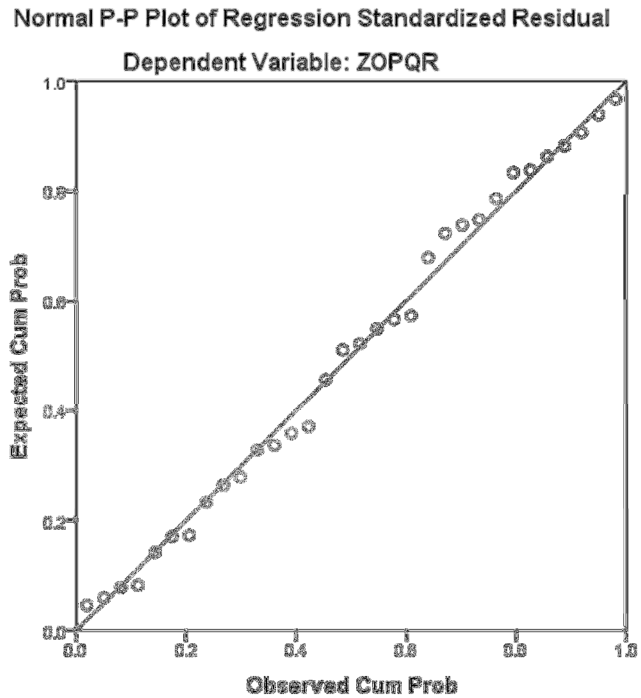


Figure 37: Normality Plot of OPQR-FA

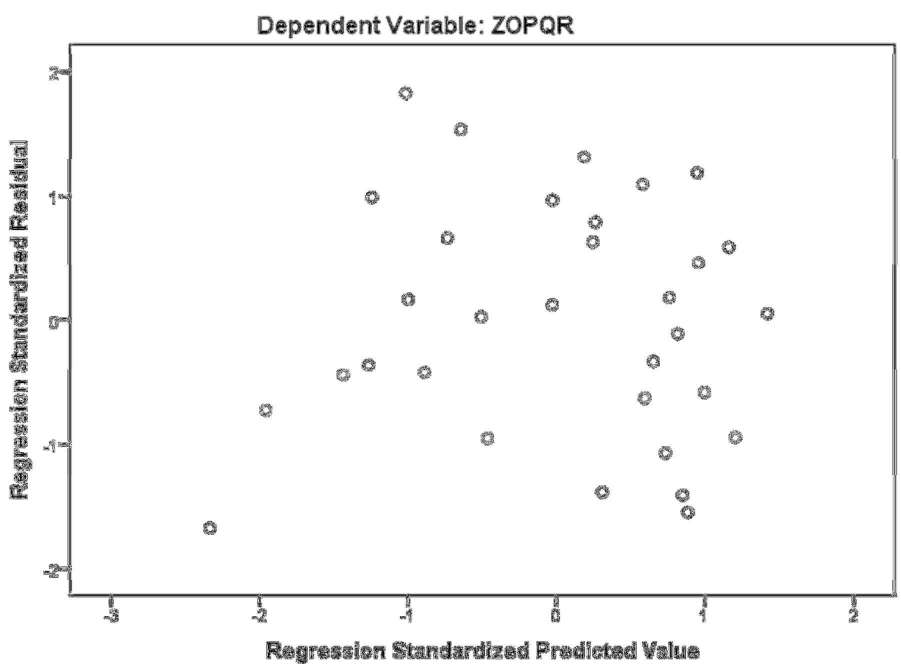


Figure 38: Residual Plot of OPQR-FA

7.3.6 OPQR-FA Model Validation

This newly developed model (OPQR-FA) needs to be validated to ensure its accurate prediction to the study's sample data. The same procedure of validating the process using the MSPE, performed previously in *Section 7.2.4,* will be followed here to *validate the process of stepwise regressing applied to the extracted factors* in obtaining OPQR-FA. First, the data set will be randomly split into two samples: Subsample 1 and Subsample 2. Subsample 1 will be used in a factor analysis process. *Table 32* shows KMO test result for factor analysis of subsample 1. Notice the low KMO value (0.406). This was expected due to lowering the number of data points as a consequence of splitting the data. Bartlett test of Sphericity looks acceptable. *Table 33* shows the factor loadings extracted from subsample 1. The five factors end-up explaining a cumulative variance of 73.5% from the subsample. The step of analyzing and naming the extracted factors will be skipped here since the purpose is obtaining a regression model to arrive at its R^2 value. Then, stepwise regression will be done to the five factors extracted from the factor analysis process to form the model.

Table 34: KMO and Bartlett Tests of OPQR-FA Validation - Subsample 1

Factor Analysis Adequacy Tests		**Subsample 1**
Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy		**0.406**
Bartlett Test of Sphericity	Approx. Chi-Square	171.804
	df	105
	Sig.	**< 0.000**

Table 35: Extracted Factor Loadings of OPQR-FA Validation - Subsample 1

Variables	Factors				
	1	2	3	4	5
IPD Attributes	**0.994**				
Selection Basis	**0.804**				
GMP Compensation		**0.912**			
Profit-Sharing Compensation		**-0.745**			
Lean Tools		**-0.435**		0.380	
Team Experience as a Unit			**0.812**		
Project Complexity			**-0.642**		0.370
Contract Limitation				**0.776**	
BIM	0.374			**0.548**	
Team Exp. Project Type				-0.307	**0.955**
Stakeholder Interaction	0.348				**0.620**
Management Structure				0.376	**0.566**
Stakeholder Involvement	0.462				**0.528**
Project Team	0.321				**0.464**
Lump-Sum Compensation	-0.342	0.333			**-0.453**
Extraction SS Loading	5.458	2.455	1.361	1.005	0.745
% Proportion of Variance	36.384	16.370	9.074	6.699	4.968
% Cumulative Variance	36.384	52.754	61.828	68.527	73.494

The resulting model included both Factors 5 and 1 and is denoted by SS1, as in subsample 1. *Table 33* above shows what each factor is comprised with what variables. The model looks as follows:

$$\mathbf{OPQR - FA\ SS1 = -0.104 + 0.624\ F5 + 0.587\ F1}$$

The model is then used to predict the values of subsample 2 and produce a set of ($\hat{y}$). On the other hand, the average value of y in subsample 1 is calculated ($\bar{y}$). Then, two MSPE values are calculated according to the following equations:

$$MSPE_1 = \frac{\sum(y - \hat{y})^2}{16}$$

$$MSPE_2 = \frac{\sum(y - \bar{y})^2}{16}$$

Figure 39 below explains this process schematically. Finally, an R^2 value is calculated from these two new MSPE values to be compared to the model's (OPQR-FA) R^2 value. The new R^2 value is calculated using the following equation:

$$R^2 = 1 - (MSPE_1/MSPE_2)$$

The newly calculated $MSPE_1 = 0.662$, $MSPE_2 = 1.261$, and $R^2 =$ **0.47**. This new R^2 is compared to OPQR-FA's R^2 which is **0.64**. An R^2 value of 0.47 seems low when compared to the R^2 of OPQR-FA model. However, it falls within an acceptable range to what was measured in this study survey, which is human perceptions (Pardoe 2013). Therefore, an R^2 value of 0.47 represents a good validation to the prediction powers of the model OPQR-FA.

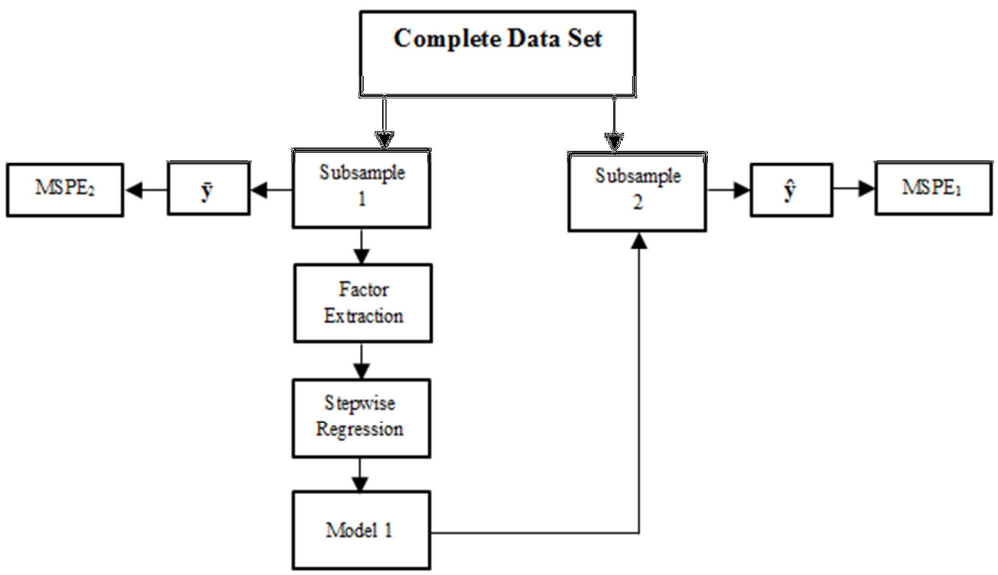


Figure 39: OPQR-FA Validation Process

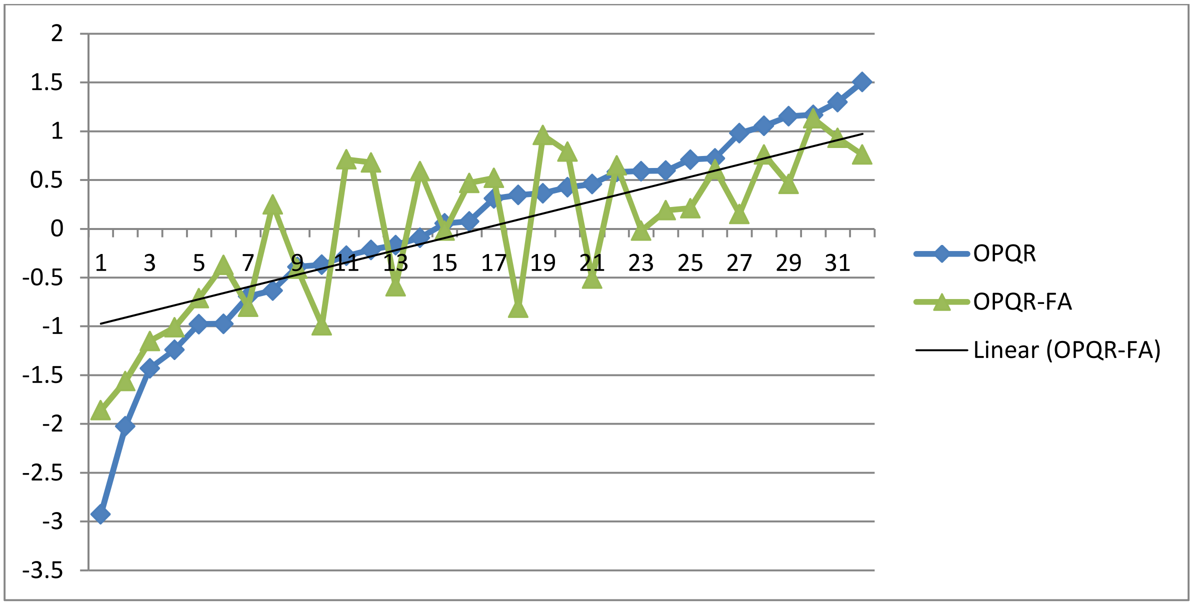


Figure 40: OPQR-FA Model Performance Compared with Original OPQR

Figure 40 above shows how the developed predictive model (OPQR-FA) trend with the actual OPQR. The y-axis represents the OPQR score, and the data set projects ordered in increasing OPQR score. A linear trend line of OPQR-FA has been added to the graph as a way of visually validating the OPQR-FA model and how it closely follows the actual OPQR.

Figure 41 below shows how both models created in this multivariate analysis, OPQR-S and OPQR-FA, trend with the original OPQR of the data set. The figure gives an overview of the results of the multivariate analysis of this study. It is also worth mentioning that the bottom four projects are non-IPD, the middle four projects are IPD-like, and three of the top projects are IPD projects. This shows the OPQR ability of determining the performance of projects in the sample. It also shows the overall superiority of IPD performance compared to IPD-like and non-IPD projects.

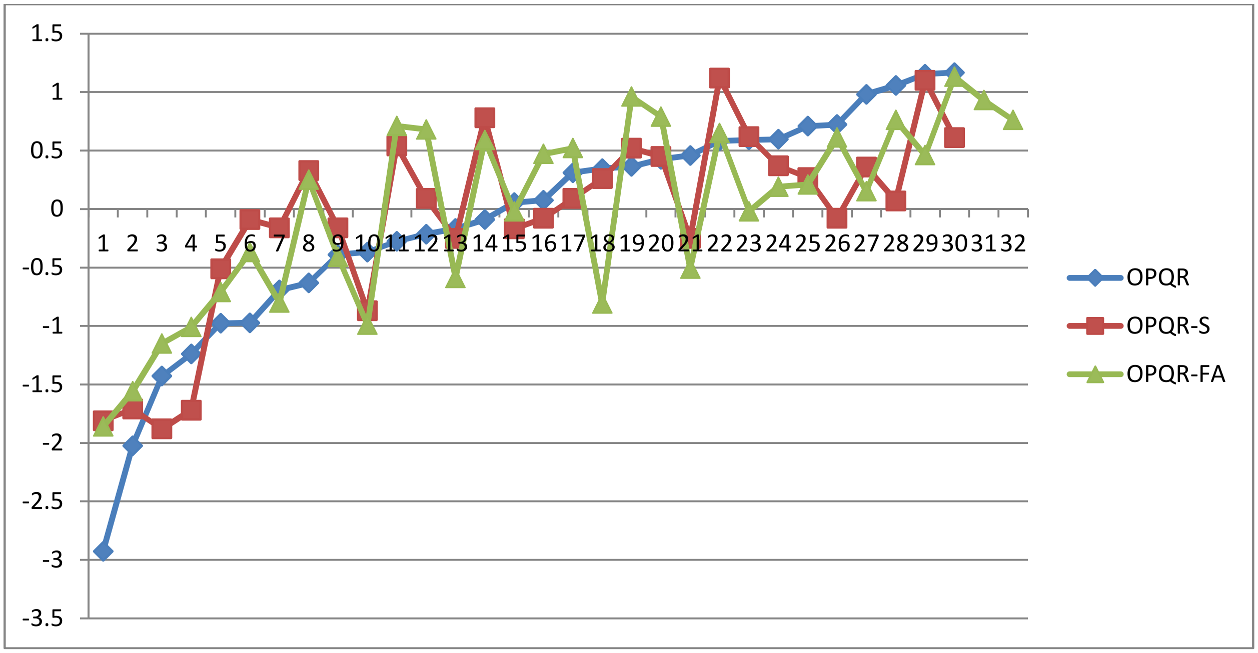


Figure 41: The Trend of OPQR-S & OPQR-FA Compared to the Original OPQR

7.4 Multivariate Analysis Conclusion

This chapter presented the development of two construction project performance prediction models. Predicting the outcome of a construction project represented in OPQR was done using multivariate analysis. All the project delivery variables, for which data was available via this study's survey, were used in this process.

Two statistical techniques were used in the multivariate analysis performed using the statistical software SPSS: Multiple Regression, and Factor Analysis. The process of each technique was validated to ensure the accuracy of predicting the data sample. Each technique produced a prediction model for construction project performance according to owner's perspective.

Multiple regression analysis produced a predictive model that has three variables significantly affect the performance of construction projects. One of these variables is the Management Structure used in the project. This encompasses defining the scope of work and communicates it among project participants, defining the project goals, quality of dispute resolution process, and the use of a decision-making process in the project. The other two variables significantly affecting the performance of construction projects are the use of financial transparency among project participants, and the number of lean construction tools used in the project.

Factor analysis, as another multivariate analysis tool, produced another predictive model that has three variables significantly affect the performance of contraction projects. The arrangement of variables differed from multiple regressions. Some variables were confounded with each other to be suitable for insertion into factor analysis. Factor analysis as a technique also formulates new variables (factors) that include more than one of the originally entered variables. Integrated delivery – that provides more collaboration among project participants – is one of the factors significantly affects project performance. Traditional delivery – that has more rigid relations via virtual walls among project participants – is another factor significantly affects project performance. Contract limitation is also found to significantly affect project performance. Contract limitation includes the use of multi-party agreement, liability waivers, and risk / reward sharing. Factor analysis model showed that the use of less of these would positively affect the project performance, which is contrary to what was found in the literature; however consistent with current owners' reluctance of using such initiatives.

Chapter 8. CONCLUSIONS AND LIMITATIONS

8.1 Summary of Research Methods

This thesis has presented a comprehensive research on achieving success in construction projects through integration in the project delivery system from an owner's perspective. First, the current literature was surveyed and a gap was identified for this study to fill in the body of knowledge. Data was collected from the desired population which is construction owner organizations. Univariate analysis was performed to identify performance variations of different project delivery systems with different levels of integration on separate project performance metrics specified by owners. Then the Owner Project Quarterback Rating was developed as a comprehensive measure of the overall project performance to assess the overall performance of different project delivery systems with different levels of integration. Lastly, multivariate analysis was done to identify and highlight project delivery characteristics that significantly affect the overall project performance.

This research methodology has led to contribution to the body of construction literature. The following sections will provide a summary of this study's results and contributions, limitations around the scope of this study, barriers to implement innovative methods and more integration in construction projects, and close with future research opportunities.

8.2 Summary of Study Results and Contributions

The objectives set at the beginning of this thesis were met, and the following contributions are the result of meeting those objectives:

1. <u>Owner-Specific Success Criteria:</u> A list of owner-specific success criteria for construction projects was accumulated from the literature and assessed and ranked using the study survey. This list is

valuable to AEC participants when executing projects for owners. It is also valuable for researchers to renew and expand on for future research.

2. IPD Definition and the Level of Integration: IPD definition is still evolving in the AEC industry and differs from one owner to another. Therefore, integration level within a project was the differentiating factor among project delivery systems. A method had to be followed in this study to categorize projects according to the level of integration implemented: IPD, IPD-like, and non-IPD, as has been explained in *Section 5.1*. This categorization was done to emphasize the role of integration and the defining principles of IPD, which could also be applied to any type of project delivery system.
3. IPD superiority: This research delivers two main contributions in proving superior performance of IPD as a construction project delivery system. First, it confirms the results of previously published empirical studies of IPD performance, however, from strictly an owner's perspective. Owner-specific performance areas were designated with their complementing measurement metrics through which project performance was measured. The results of statistical significant differences within the available sample of this study between IPD (project with higher integration) and non-IPD projects performance were found in the *quality, communication, safety, and owner satisfaction* areas which support the claims of superiority of IPD performance, especially from an owner's perspective. The second contribution is the measure of owner satisfaction level in this study sample with IPD projects. This study had the opportunity to directly ask owners about their satisfaction with IPD and other project delivery systems and measure their satisfaction level. The results revealed *very satisfied owners with IPD projects*.
4. OPQR Development: A comprehensive overall project performance measure was developed and validated, that combines performance metrics specified by construction owner organizations. The Owner Project Quarterback Rating (OPQR) allowed for an overall project performance measure as oppose to the previous contribution of measuring performance on separate performance metrics. On

the overall performance measure of OPQR, projects with higher integration level (IPD) showed better performance than projects with little-to-no integration (non-IPD). This tool should provide proper guidance to owners in measuring performance in their capital projects. It should also provide guidance to contractors in knowing what owners see as success in construction projects.

5. Key Project Delivery Characteristics: Through the multivariate analysis done in this study, key project delivery characteristics were proven to significantly affect the overall project performance. One of these characteristics is the Management Structure used in the project. This encompasses defining the scope of work and communicating it among project participants, defining the project goals, quality of dispute resolution process, and the use of a decision-making process in the project. The other two characteristics significantly affecting the performance of construction projects are the use of financial transparency among project participants, and the number of lean construction tools used in the project. These characteristics were the result of performing multiple regression analysis. Factor analysis was also performed to delivery characteristics and produced a model with more explanatory ability. The arrangement of variables differed from multiple regressions. Integrated delivery – that provides more collaboration among project participants – is one of the factors (characteristics) that significantly affect project performance. Traditional delivery – that has more rigid relations via virtual walls among project participants – is another factor that significantly affects project performance.

6. Performance Models: Two performance models were developed in this study to help the AEC community in general, and owners specifically, forecast and assess the performance of their construction projects. The predictive model was based on project delivery characteristics employed in a given project, and the project performance is assessed according to owner-specific criteria. An explanatory model was also developed based on the underlying, yet driving, dimensions of project delivery categorized using the 3Ts, and by using factor analysis. The two performance models

complement each other. They also both highlight the importance of integrating project resources to get better results.

7. Recommendations: The results of this study serve as a stepping stone in proving superior performance of IPD and the importance of integration in construction projects. The results of this study also serve as benchmarks for owners to improve their methods of construction project execution. Moreover, integrating resources, efforts, information, and experiences among project participants as early as possible in a construction project has been proven through the sample of this study to produce better results to owners. Owners are encouraged to take the lead in implementing new integrated and innovative methods in their capital construction projects for they are the leaders of the AEC industry.

The shift to more integration in construction projects doesn't require giant leaps by owners; it could start with baby steps of applying integration initiatives such as co-location, and financial transparency to their projects. In addition, "what gets measured gets improved" (Sharma 2006). Embracing the habit of retaining good quality records of construction projects will help owners in benchmarking and improving the outcomes of their projects. This was one of this study's limitations, and hopefully more owners will start keeping records of their construction projects.

8.3 Study Limitations

The scope of this study was to investigate project delivery characteristics and measure the level of integration incorporated in a project delivery, and the effect of this on the project outcomes. Although the AEC industry has many key participants, the population sought after in this study was only owners.

The majority of owner organizations participated in this study did not have quality data records. Therefore, due to the limited data available with responders, the analysis in this study was limited to the construction phase of a project. Efforts exerted during the planning of a project or operation of the facility was not included in the analysis of this study. In addition, the majority of the data collected was subjective as opposed to being based on hard numbers.

Because IPD system is newly evolved in the AEC industry, owners that were known to be using innovative project delivery systems such as IPD were targeted among other owners that were willing to participate in this study in order to include IPD projects in the mix. Therefore, the pool of participants was not representing the whole industry, and the data collection for this study was from 34 projects only. Moreover, due to the prior knowledge of the type of projects IPD system was used for, which were institutional complex projects, only owners of said project types were targeted in this study within the US.

8.4 Obstacles to Implement IPD and Innovative Methods in Construction

A whole section (*4.1.5*) in this thesis was dedicated to study obstacles in the way of changes to better practices in construction project delivery within the AEC industry. Opinions were collected from executives in construction owner organizations. Following are the obstacles found in their ranked order, and what responders suggested to overcome them.

1. <u>Lack of enough solid evidence on new methods:</u> There were two main suggestions offered by responders. The first is doing more research on new construction methods, and the second is publishing and circulating case studies of new methods, which in-turn would provide evidence for new methods.
2. <u>Change resistance culture:</u> This obstacle had two main suggestions offered by responders. The first is, again, publishing and circulating case studies of new methods, and the second is owners' responsibility to take the lead in forcing changes in the construction conventional ways and methods.

3. Lack of trust: Two main suggestions were offered by responders for this obstacle. The first is building trust through good relationships, and the second is owner's responsibility in selecting project team members and building trust within the team.
4. Transactional contracts: There were also two main suggestions offered by responders for this obstacle. The first is revising and redoing current contracts toward more integration and collaboration among project participants, and the second is making more responsible decisions by owners in choosing the right contract.
5. The current economy: Maybe due to its external factors, only two responders offered suggestions to overcome this obstacle. One responder mentioned time, and how it will eventually normalize the performance of the economy. Another responder suggested increasing funding sources.
6. Lack of education: Some of the suggestions were directed to college students during their college education years, and other suggestions were directed to professionals in their post-college training. The suggestions basically were about improving the quality of education and training.
7. Lack of Research: Suggestions to this obstacle by responders were about performing and funding more construction research.
8. Improper risk allocation: Four points were offered by responders to overcome this obstacle. They are better risk management, converting conventional contracts to relational contracts, increased owners' responsibility in shouldering more risk, and finally shared experiences in this area.
9. State Laws and regulations: There was a consensus among responders about their suggestion to overcome this obstacle which is changing state laws to allow alternate construction methods.

These obstacles and the suggested ways to overcome them have come from practitioners in the AEC industry; people with many years of experience in construction projects. These notes and suggestions should be considered carefully by participants in the AEC community in order to step forward in the way of improving construction methods.

8.5 Future Research

This study offered evidence about the superiority of integrated project performance according to the owners' perspective. This study complements previous studies that served similar objective with different perspectives.

This study needs follow-up studies to build up upon its findings. A very limited pool of participants was used in this study due to rarity of IPD projects. Therefore, a potential future research to follow would be to widen the pool of participants, and to include more facility types in the analysis. Another branch from this study would be to do two separate studies, one for the public sector and another for the private sector. This is, of course, with the assumption that IPD and integrated projects are going to be more widely used and available with more projects executed using this system. Another potential follow-up study is to include the phases in the project that were not included in this study: planning and operation. The same data collection tool used in this study can be used in future studies with little modifications to suite the purpose of the study. Moreover, the selection of projects to include in this study was left to owners. This way, which was the only way possible, lets owners select their best projects to be presented and included in the study. Having the option to randomly select projects from owner organizations would give a more realistic view of project performance.

These potential future studies would lead to better understanding of the IPD and integration initiatives in construction projects in general. They will serve not only owners, but all the AEC community as well.

8.6 Final Remarks

IPD and more integration in the project delivery in general offer better results than project delivery with less or no integrations. This study offers key contributions for owners and the AEC community to employ. First, a list of prioritized owner success criteria in construction projects was gathered. The categorization method this study offers to differentiate projects according to IPD principles and integration initiatives is another contribution. The study also provided proof of IPD superiority to non-IPD projects in five performance metrics across four different owner-specific performance areas: quality, communication, safety, and owner satisfaction. Finally, the study provided a comprehensive tool to gauge project success and was employed to build-up predictive and explanatory models to assess the performance of project delivery according to owners' needs by differentiating significant project delivery characteristics.

These contributions should serve as a stepping stone in proving IPD as a construction project delivery system, and integrated projects in general, to the AEC community and most notably owners. The result of this study should ensure owners to invest more in IPD and integration in their projects. That does not imply that IPD is the new found solution to all the AEC industry's inefficiencies; however, it tells that implementing IPD and more integration is a step in the right path for AEC industry participants.

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APPENDIX B – LIST OF DEFINITIONS AND ABBREVIATIONS

This list of definitions of terms was accompanying the survey of this study. It also includes terms and abbreviations used in places of this thesis.

Term	Definition
AEC	Architectural / Engineering / Construction
AIA	American Institute of Architects
Balance Between Risks/Rewards	Usually established by the contract, an incentive compensation system of which project team anticipated profit is put at risk. If project goals are met, project team will share the profits jointly.
Based on Value – Incentive	Incentive method for the project team members by offering a bonus linked to adding value to the project.
BIM	Short for Building Information Modeling. A digital representation of the physical and functional characteristics of a facility.
Call Backs	The incidents where the contractor is called back to the facility to fix any defects.
CCIP	Contractor Controlled Insurance Program
Choosing by Advantages (CBA)	A method for decision-making process that is based on the importance of the advantages available with each option.
CII	Construction Industry Institute
Co-location	A shared office space the project management team uses to collectively manage the project. This is usually within the vicinity of the project.
Construction Management at Risk (CMR)	In CM@R the owner contracts with a design company to provide the design services for the facility. The owner separately selects a contractor – who is the construction manager – to perform construction management services and construction work in accordance with the plans and specifications for a fee. The contractor usually has significant input in the design process and generally guarantees the maximum construction price.
Construction Management-Agent (CMA)	Under CM-Agent, the owner contracts separately with the construction manager, design professional and a general contractor or various prime contractors. The construction manager has a contractual relationship only with the owner. The construction manager in this method is generally not responsible for the means or methods of construction and does not guarantee construction cost, time or quality aspects of the work.

Term	Definition
Core Management Team	A project team that represents at least the main project participants. The team collectively manages the project and makes all the necessary decisions required to construct the facility.
CURT	Construction Users Roundtable
Design-Bid-Build (DBB)	DBB is a traditional process in the construction industry where the owner contracts separately with a designer and a contractor. The owner normally contracts with a design company to provide “complete” design documents. The owner or his agent then solicits fixed price bids from contractors to perform the work. One contractor is usually selected and enters into an agreement with the owner to construct a facility in accordance with the plans and specifications.
Design-Build (DB)	DB is an agreement between an owner and a single entity to perform both design and construction under a single design build contract. Portions or all of the design and construction may be performed by the signing entity or subcontracted to other companies.
Dispute Resolution Process	Steps to be taken within the construction project boundaries and members to resolve any conflict before litigation.
FA	Factor Analysis
Facility Startup	The process of starting up the facility with all its equipment, machines, and systems to fully function at the beginning of owner occupancy.
Financial Transparency	Either a contractual or voluntary right for project participants to review and audit each other’s financial records. This ‘open-book’ financial system is also for the compensation structure so each party’s interest and contributions are similarly transparent.
Five Ss	5Ss is a basic, systematic approach for productivity, quality and safety improvement in a business. They are: Sort, Set in Order, Shine, Standardize, and Sustain. It is used to establish a visual workplace that has a visual order, organization, cleanliness and standardization.
Functionality	The efficiency of the facility when running the functions for which the facility was constructed.
IFOA	Short for Integrated Form of Agreement. It is a form of a Multi-party contract.
Incentive Pool	Incentive method that reserves a portion of the project team’s fees into a pool that can increase or decrease based on various agreed upon criteria before being divided up and distributed to the team.
Innovation – Incentive	Incentive method in which the project team is awarded for creativity

Term	Definition
	in work.
Integrated Project Delivery (IPD)	IPD integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction. It includes tight collaboration between the owner, the architect, and the contractor who ultimately responsible for construction of the project, from early design to project completion. This system could vary from a typical delivery system with more-than-usual collaboration all the way to pure type of IPD which has the contractual agreement of "Multi-Party" between a minimum of the owner, design professional, and builder, where risk and reward are shared and stakeholder success is dependent on project success. It is also called Integrated Lean Project Delivery (ILPD) or Lean Delivery.
Integration	Integrating resources, efforts, information, and experiences among project participants as early as possible in a construction project.
Interoperable	The ability of various construction project participants to easily share building data. This means BIM system is accessible to all participants in the building construction. Participants can input their data and at the same time can see others' inputs in the model.
Jointly developed project goals	Project goals and targets, such as level of finishes in the facility or schedule milestones, are jointly developed by all project team members.
Kaizen Events	Events during which ideas and thoughts of quality and performance improvement are being explored and discussed.
Liability	Burdens usually carried out with construction projects. (e.g. onerous contract clauses, excessive labor)
Liability Waivers	When parties enter a single contract for an IPD project, they use liability waivers to waive liabilities toward each other as a single team, which is to waive their rights to sue each other except for intentional negligence.
Multi-Party Contract	In a Multi-party contract all the primary project participants execute a single contract specifying their respective roles and liabilities. It creates a temporarily organization to realize a particular project.
MWW	Mann-Whitney-Wilcoxon
Negotiated Contract	The owner selects a winner through a request for qualification (RFQ) for the project and often negotiates a contract directly with the most qualified bidder to a reasonable price.
Network of Commitments	Planning and managing the project would be as a network of commitments. Quality must be controlled at the source where the

Term	Definition
	work is being performed and by those performing the work.
OCIP	Owner Controlled Insurance Program
Open Bid	In an open-to-pubic bid, the owner selects the lowest bidder.
Operation / Maintenance Cost	The costs to operate and maintain the facility.
OSHA	Short for “Occupational Safety and Health Administration”.
Performance Bonuses – Incentive	Incentive method which provides an award based on quality and hard work.
Predefined Decision-Making Process	A predefined process in making project decisions, especially those decisions that don’t have enough ready information to confidently make them.
Prequalified Bid	The owner prequalifies a group of bidders based on number of factors such as qualifications and past experience. From that group then the owner selects the winning bidder.
Profit Sharing – Incentive	Incentive method in which each party’s profit is determined collectively rather than individually.
Project Delivery System (PDS)	The system that determines the relationships among parties of the contract and the time of engagement of each.
Project Goals and Measurement Metrics	These are the goals and measurements that determine the success level of the project. Examples of these goals are project schedule goals and milestones, construction production rate, quality controls, etc. Also, determinations of some baseline measurements.
Project Success Strategy	The strategy an organization employs to help lead to successful project outcomes for the organization. An example for this strategy is optimizing the project by pieces (e.g. procurement or construction) or by optimizing the project as a whole.
Pull Scheduling	Project scheduling system in which end of work sequence outcomes are identified and then work items are pulled to the current state. The schedule must be based on collaborative planning by all project team members who will perform in that phase. Pull scheduling should be used to make things happen rather than monitoring.
Quality of the Environmental Systems	The quality of the systems that are functioning in the building (e.g. Heating Ventilating Air Conditioning, lighting, etc.)
Regulatory / Legal Constraints	Regulatory and/or legal constraints in an organization’s governance and the signed contract. Private organizations usually have fewer constraints than public ones.
Relational Contract	Construction contracts that focus on communications and relationships between the parties as well as their specific rights, obligations and deliverables.
Reliable Promising	Each Project team member agrees to help develop the reliability of work flow across the entire project period by trying to make and

Term	Definition
	keep reliable promises.
RFI	Request for Information. A method used to confirm and interpretation of a detail in the drawing or to secure a documented directive order from the architect or the client.
RFP	Request for Proposal. A solicitation method done by an organization often through bidding process to procure a commodity or a project.
Risk	Unforeseeable events or circumstances in construction projects.
Selection Basis	The basis followed to select core management team members.
Set-Based Design	Designers communicate and think about sets of design alternatives. They gradually narrow these sets by eliminating inferior alternatives until they come to a final solution
Shared Responsibility	Project team members have the sense of collectively sharing the responsibility of meeting the project goals.
Target Value Design (TVD) process	The process of establishing early financial targets for the project, and designing to an associated detailed estimate rather than estimating a detailed design.
Transactional Contract	Static contracts where exchanges are make for goods and services. The explicit terms in the contract govern the parties' obligation to each other. This is the traditional way of contracting in construction. This is in opposite type to Relational Contracts that have dynamic nature to them, where emphasis is made on relationships and trust among parties. The explicit contract terms are still there, however there are other implicit terms and understandings that determine and control the behavior of parties.
Value	Value determined subjectively according to an organization's interest and business type. Some could see the value in money savings, others in time savings. Some could seek it in energy efficiency or functionality, others in social gains or sustainability.
Value stream mapping	A method in which all the steps involved in bringing a product or group of products from requests or orders to finished products is collected, arranged, and mapped.
Waste Identification/ Elimination	Recognizing and eliminating waste throughout the delivery of the project

APPENDIX C – LETTER OF INVITATION TO THE SURVEY

COLLEGE OF ENGINEERING
UNIVERSITY OF WISCONSIN-MADISON

Department of Civil & Environmental Engineering

2318 Engineering Hall
1415 Engineering Drive
Madison, WI 53706-1691

Phone: 608/890-3276
Fax: 608/262-5199
Email: menassa@wisc.edu

Construction Users Roundtable (CURT) Members

Dear CURT member,

The University of Wisconsin – Madison is conducting a study to compare the main construction project delivery systems currently used in the U.S.: Design-Bid-Build, Design-Build, Construction Management-Agent, Construction Management at Risk, and the Integrated Project Delivery. The purpose of the study is to evaluate the best and most efficient construction project delivery system to serve current owners' needs. Your assistance is needed to acquire the proper quantitative and qualitative information for completed or partially completed projects.
The study consists of two surveys.

The first survey is the "Executive-Level Survey" and should be filled once by an organization from a person at the executive level. Please use the following link to fill this survey (**password: owners**):
https://uwmadison.qualtrics.com/SE/?SID=SV_bHDsFbwsQOilFxa

The second survey the "Project-Level Survey" and should be filled by a project level person in the organization such as a project manager or engineer (i.e. a person who worked on that project and knows all related technical details well). The Project-Level Survey should be filled for as many projects as possible by a particular organization. Please use the following link to fill this survey (**password: owners**):
https://uwmadison.qualtrics.com/SE/?SID=SV_ea4ZpfotEXNcwYs

Your participation in this survey will be greatly appreciated. If you have any questions about these remarks or the research in general, please do not hesitate to email the research team at boodai@wisc.edu , or menassa@wisc.edu.

Sincerely,

Carol Menassa

Carol C. Menassa, PhD.

M. A. Mortenson Company Assistant Professor in Construction Engineering and Management
Department of Civil and Environmental Engineering
University of Wisconsin - Madison

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APPENDIX D – EXECUTIVE-LEVEL SURVEY

PROJECT DELIVERY SYSTEMS COMPARISON FROM THE OWNERS' PERSPECTIVE

THE UNIVERSITY WISCONSIN MADISON

A Study Conducted by the Department of Civil and Environmental Engineering
at the University of Wisconsin-Madison

INTRODUCTION:

The University of Wisconsin – Madison is conducting a study to compare the main construction project delivery systems currently used in the U.S.: Design-Bid-Build, Design-Build, Construction Management-Agent, Construction Management at Risk, and the Integrated Project Delivery. The purpose of the study is to evaluate the best and most efficient construction project delivery system to serve current owners' needs. Your assistance is needed to acquire the proper quantitative and qualitative information for Capital Projects. Your participation in this survey will be greatly appreciated.

Respondent confidentiality in this research is guaranteed. All collected data will be used in a form that will make it impossible to determine the identity of the individual responses. The survey responses will not be analyzed, or reported in any way in which the confidentiality of the survey responses is not absolutely guaranteed.

SECTION I: ORGANIZATION INFORMATION

1. Please provide the following general information about your organization:

Organization: ______________________________

Location of the main office: ______________________________

Representative's full name: ______________________________

2. Structure: *Please mark all the appropriate fields*
   - ☐ Public
   - ☐ Quasi-Public (a mix of public/private)
   - ☐ Private
   - ☐ For Profit
   - ☐ Not for Profit

3. Business Type: *Please mark all the appropriate fields*
   - ☐ Educational Institution
   - ☐ Commercial Developer
   - ☐ Industrial/Manufacturing
   - ☐ Governmental Agency
   - ☐ Healthcare Organization
   - ☐ Retail/Shopping
   - ☐ R&D Organization
   - ☐ Other:___________

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SECTION II: SUCCESS AND VALUE FROM CAPITAL PROJECTS EXECUTION

4. The success of a Capital Project represents subjective judgment which differs from one owner to another. Please assign the proper percentage of impact each Metric has on the success of Capital Projects as you see them (*Percentages do not have to add up to 100%*):

Metric	Percentage of Impact on Project Success										
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Delivering a project within the assigned **Budget**	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Delivering a project within the scheduled **Time**	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Delivering a final product (facility) with High **Quality**	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Delivering a project **Safely** with zero incidents	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Delivering a project with **No Adversity** among project parties	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Delivering a facility with **Zero Claims**	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Delivering a facility with Highly **satisfied users**/ occupants	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Delivering a facility with Highly **satisfied third parties** affected by the facility (community, consumers, etc.)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Delivering Sustainable and **environment friendly** facility	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Delivering a Socially Recognized/**Reputable** facility	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other (*Please specify*):	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other (*Please specify*):	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

5. The delivery process of Capital Projects passes through a number of stages. Which of the following stages requires the most attention from an owner in order to achieve a successful project? *Please rank them using (1-4) scale, where 1 represents the stage that requires most attention and 4 represents the least.*

Stage	Rank
Strategic Planning (Organizational Objectives)	
Planning/Design (Pre-Construction)	
Construction	
Operation/Occupation (Post-Construction)	

SECTION III: EVALUATION OF CURRENT PROJECT DELIVERY SYSTEMS

6. What is the approximate use, as a percentage, for each of the following project delivery systems in your organization's Capital Projects execution over the last seven years? *(Your inputs should add-up to 100 percent.)*

Delivery System	Percentage of Use
Design-Bid-Build	%
Design-Build	%
Construction Management-Agent	%
Construction Management at Risk	%
Integrated Project Delivery*	%
Other: *(Please specify)*	%
Total	**100 %**

7. How satisfied is your organization with the following project delivery systems? If you are satisfied and/or dissatisfied with any of the delivery systems mentioned in the table, please list one main cause of satisfaction (S) and/or dissatisfaction (D) for each delivery system.

Delivery System	Very Satisfied	Somewhat Satisfied	Slightly Satisfied	Neutral	Slightly Dissatisfied	Somewhat Dissatisfied	Very Dissatisfied	Causes of Satisfaction/ Dissatisfactions
Design-Bid-Build	☐	☐	☐	☐	☐	☐	☐	S: D:
Design-Build	☐	☐	☐	☐	☐	☐	☐	S: D:
Construction Management – Agent	☐	☐	☐	☐	☐	☐	☐	S: D:
Construction Management at Risk	☐	☐	☐	☐	☐	☐	☐	S: D:
Integrated Project Delivery*	☐	☐	☐	☐	☐	☐	☐	S: D:
Other: *(Please specify)*	☐	☐	☐	☐	☐	☐	☐	S: D:

**Integrated Project Delivery (IPD) is also called Integrated Lean Project Delivery (ILPD) or Lean Delivery*

SECTION IV: OBSTACLES TO OVERCOME

8. What do you think are the main obstacles in the way of changes to better practices in construction project delivery? *Please check from the available and/or add from your experience:*

Obstacle	Yes	No	Suggestions to overcome the obstacle
Change Resistant Culture	☐	☐	
Lack of Trust	☐	☐	
Transactional Contracts	☐	☐	
The Current Economy	☐	☐	
Lack of Education	☐	☐	
Lack of Research	☐	☐	
Lack of enough solid evidence on new methods	☐	☐	
Improper risk Allocation	☐	☐	
Other: *(Please specify)*	☐	☐	
Other: *(Please specify)*	☐	☐	

You have completed the survey.

We appreciate your time given to fill out this survey. Thank you.

APPENDIX E – PROJECT-LEVEL SURVEY

PROJECT DELIVERY SYSTEMS COMPARISON FROM THE OWNERS' PERSPECTIVE

A Study Conducted by the Department of Civil and Environmental Engineering
at the University of Wisconsin-Madison

INTRODUCTION:

The University of Wisconsin – Madison is conducting a study to compare the main construction project delivery systems currently used in the U.S.: Design-Bid-Build, Design-Build, Construction Management-Agent, Construction Management at Risk, and the Integrated Project Delivery. The purpose of the study is to evaluate the best and most efficient construction project delivery system to serve current owners' needs. Your assistance is needed to acquire the proper quantitative and qualitative information for completed or partially completed projects. Your participation in this survey will be greatly appreciated.

Respondent confidentiality in this research is guaranteed. All collected data will be used in a form that will make it impossible to determine the identity of the individual responses. The survey responses will not be analyzed, or reported in any way in which the confidentiality of the survey responses is not absolutely guaranteed.

SECTION V: PROJECT INFORMATION

Please provide us with information about a Capital Project your organization executed within the last seven years, starting 2005.

1. Project name: ____________________ 2. Location: _________________________
3. Project type: ________________________ (e.g. Hospital, Dormitory, Research Facility, etc.)
4. Construction type:
   - ☐ New Construction
   - ☐ Addition/Expansion
   - ☐ Renovation/ Retrofit
5. Project manager name: ____

   Contact Information: ____
6. At what stage of the project development the project is currently standing?
   Please mark all the completed stages with the percent complete when applicable.
   - ☐ Design _______%
   - ☐ Construction________%
   - ☐ Operation ________Months
7. Building gross area (sq.ft) , Planned: ______________ sq.ft Actual:_______________sq.ft

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Project Cost:

8. Building total construction cost, Planned:______________$ Actual:________________ $

Please provide the percent change with the appropriate sign (+ or _) from the original cost estimate for the following:

Item	Percent Change %
9. Design Costs	
10. Construction Costs	
11. Project Management Costs, if separate construction manager is hired (i.e. Construction Management-Agent)	
12. Equipment Cost (only if the building equipment was a large item in the building cost estimate.)	

13. If the project experienced changes that required a cost increase, who initiated the change? And what was each initiator's approximate percent of change in the project? *(Please mark all that applies. The percentages of change assigned have to add-up to 100% of the total cost increase)*
    - ☐ The owner ________%
    - ☐ The contractor ________%
    - ☐ The designer ________%
    - ☐ Other: ___________ _______%

Project Schedule:

Please provide the following information about the project schedule:

Stage/Date	Planned (mm /yy)	Actual (mm /yy)
14. Design Start Date (Notice to Proceed)		
15. Design End Date		
16. Construction Start Date (Notice to Proceed)		
17. Construction End Date (Substantial Completion)		
18. Commissioning End Date		
19. Date of Occupancy		

20. If there was a time extension on the project, what were the reasons for that time extension? And what was the percentage of the total time extension for each reason? *(Please mark all that applies. The percentages assigned have to add-up to 100%)*
    - ☐ Change initiated by the owner _____ %
    - ☐ Change initiated by the contractor _____ %
    - ☐ Change initiated by the designer _____ %
    - ☐ Other: ___________________ _____ %

Project's Overall Outcome:

21. What is the Owner's level of satisfaction with this project?
   - ☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low
22. What is the Users' level of satisfaction with this project?
   - ☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐ Don't Know
23. If there is a high level of satisfaction, what was the most substantial feature that made this project successful to the owner?
   - ☐ Completed on Time
   - ☐ Completed on Budget
   - ☐ Functionality in terms of serving its purpose
   - ☐ Quality in terms of apparent and latent defects
   - ☐ Safety in terms of zero incidents during construction
   - ☐ Good collaborative non-adversarial delivery process
   - ☐ Reputation/ Social Gains
   - ☐ Other: ________________________
24. Please elaborate more on the success this project gave to your organization.

____
____

Project Delivery System:

25. What is the project delivery system?
   - ☐ Design-Bid-Build
   - ☐ Design-Build
   - ☐ Construction Management – Agent
   - ☐ Construction Management at Risk
   - ☐ Integrated Project Delivery *(also called Integrated Lean Project Delivery (ILPD) or Lean Delivery)*
   - ☐ Other: __________________
26. How is the delivery system appropriateness for the project type?
   - ☐ Very Good ☐ Good ☐ Adequate ☐ Poor ☐ Very Poor
   - If poor or very poor, what was the main reason for that ______________________________
27. How is the delivery system appropriateness for the project size?
   - ☐ Very Good ☐ Good ☐ Adequate ☐ Poor ☐ Very Poor
   - If poor or very poor, what was the main reason for that ______________________________

28. Mark the appropriate box for the contract financial terms used between the owner and the following entities: *(If Cost plus, please state fee type whether it is a fixed or percent in the blank provided)*

Architect/Designer
- ☐ Lump Sum
- ☐ Cost Plus _______ Fee
- ☐ Other ________________________

Construction Manager (if applicable)
- ☐ Lump Sum
- ☐ Cost Plus _______ Fee
- ☐ Other ________________________

Contractor
- ☐ Lump Sum
- ☐ Cost Plus _______ Fee
- ☐ Guaranteed Maximum Price
- ☐ Other ________________________

Design-Builder (if applicable)
- ☐ Lump Sum
- ☐ Cost Plus _______ Fee
- ☐ Guaranteed Maximum Price
- ☐ Other ________________________

MEPs Subcontractors (mark all applicable)
- ☐ Lump Sum
- ☐ Cost Plus _______ Fee
- ☐ Guaranteed Maximum Price
- ☐ Other ________________________

Product (project) Quality to-date:

Mark the appropriate box to evaluate the quality of the facility as it appears to the owner:

29. How do you rate the difficulty of facility **startup**?
☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐ Don't Know

30. How is the number and magnitude of **call backs** for the facility compared with other similar facilities?
☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐ Don't Know

31. How is the **operation and maintenance** cost for the facility compared with other similar facilities?
☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐ Don't Know

32. How is the quality of the building **structure and exterior**?
☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐ Don't Know

33. How is the quality of the building **interior space and layout**?
☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐ Don't Know

34. How is the quality of the **environmental systems** (e.g. lighting, heating vent, & air conditioning, etc.)?
☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐ Don't Know

35. How is the quality of the facility **equipment** (e.g. production, process, laboratory, etc.)?
☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐ Don't Know

36. How is the quality of the **overall** facility performance?
☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐ Don't Know

Project Sustainability:

37. Did the project apply for a sustainability certificate (e.g. LEED, Green Globes, etc.)?

☐ Yes ☐ No

38. If yes, what rating system is used, and what is the corresponding rating earned for this project?

The Rating System: ____________ The Rating Planned: ____________ The Rating Earned: ____________

39. What is the intended life span of the facility? _______ Years

Management Team:

40. Was there a core management team for the project?
This team collectively manages the project and makes all the necessary decisions required to construct the facility.

☐ Yes ☐ No

If no, please proceed to the next subsection (Project Management).

41. If yes, please identify team members, their selection basis, and the stage of involvement in the team for each member in the table below:

Team members			Selection Basis				Stage of Involvement		
	Yes	No	Open Bid	Prequalified Bid	Negotiated Contract	Other:	Planning/ Design	Construction	Operation/ Occupation
Owner	☐	☐					☐	☐	☐
Architect	☐	☐	☐	☐	☐	☐	☐	☐	☐
Contractor	☐	☐	☐	☐	☐	☐	☐	☐	☐
Construction Manager	☐	☐	☐	☐	☐	☐	☐	☐	☐
MEPs	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other Main Subs	☐	☐	☐	☐	☐	☐	☐	☐	☐
Suppliers	☐	☐	☐	☐	☐	☐	☐	☐	☐
Others:	☐	☐	☐	☐	☐	☐	☐	☐	☐

42. What was the percent complete of design when the contractor was engaged in the project?

☐ 0-10% ☐ 10-25% ☐ 25-50% ☐ 50-75% ☐ >75%

43. What was the percent complete of design when the MEP contractors were engaged in the project?

☐ 0-10% ☐ 10-25% ☐ 25-50% ☐ 50-75% ☐ >75%

44. How often does the management team meets?

☐ Weekly ☐ Bi-weekly ☐ Monthly ☐ Other: ____________

45. What is the management team's prior experience as a unit?

- ☐ > 2 Projects ☐ ≤ 2 Projects ☐ None

46. How is the management team's communication?
    - ☐ Very Good ☐ Good ☐ Adequate ☐ Poor ☐ Very Poor
47. How is the management team's chemistry?
    - ☐ Very Good ☐ Good ☐ Adequate ☐ Poor ☐ Very Poor
48. How committed is the owner to the management team?
    - ☐ 80-100% Participation in team mtgs ☐ 60-80% Participation in team mtgs ☐ < 60%
49. Were the project goals and milestones each developed jointly by the management team?
    - ☐ Yes ☐ No
50. Was there a co-location (one main office) for the management team to manage the project from?
    - ☐ Yes ☐ No
51. Was there transparency (open-books) among management team financials?
    - ☐ Yes ☐ No
52. Was there a predefined decision-making process for the management team?
    - ☐ Yes ☐ No
53. If yes, could you provide a brief explanation of this decision-making process?

____

____

Project Management:

54. How do you rate the level of experience of the architect/designer for this type of project?
    - ☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low
55. How do you rate the level of experience of the contractor for this type of project?
    - ☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low
56. How do you rate the level of experience of the construction manager for this type of project?
    - ☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low
57. How do you rate the level of experience of the subcontractors for this type of project?
    - ☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low
58. What is the level of complexity of the project?
    - ☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low
59. How do you rate the level of regulatory/legal constraints in executing this project?
    - ☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low
60. How do you rate the definition of participants' roles/responsibilities in this project?
    - ☐ Very Good ☐ Good ☐ Adequate ☐ Poor ☐ Very Poor
61. How do you rate the definition of goals and measurement metrics in this project?

☐ Very Good ☐ Good ☐ Adequate ☐ Poor ☐ Very Poor

62. How do you rate the definition and communication of project "scope" among the project participants?

☐ Very Good ☐ Good ☐ Adequate ☐ Poor ☐ Very Poor

63. Did the project contract require any kind of collaboration among project participants?

☐ Yes ☐ No

64. If yes, how do you rate the level of collaboration required by the contract?

☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low

65. Was there any difficulty in finding a suitable liability insurance policy?

☐ Yes ☐ No

66. What was the type of insurance policy used for this contract?

☐ OCIP ☐ CCIP Other: ___________

67. What was your level of satisfaction with the coverage and price of the insurance policy used for this contract?

☐ Very High ☐ High ☐ Average ☐ Low ☐ Very Low

68. How was the dispute-resolution process for this contract?

☐ Very Good ☐ Good ☐ Adequate ☐ Poor ☐ Very Poor

69. How many RFIs were issued in this project and what was the average processing period for an RFI?

Number of RFIs: ______________ Average RFI processing period: __________ Days

Innovation in the Project:

The following questions investigate the extent of innovation initiatives used in this project:

70. Was BIM technology employed in this project?

☐ Yes ☐ No

71. If yes, was the BIM medium interoperable among all project participants?

☐ Yes ☐ No

72. How much of the liabilities are waived between the owner and the contractor?

☐ All ☐ Some ☐ None

73. Were there any considerations for the balance between risk and reward in this contract?

☐ Yes ☐ No

74. Was a multi-party contract used?

☐ Yes ☐ No

75. If yes, who are the parties signed the contract?

☐ Owner ☐ Architect/Designer ☐ Contractor ☐ Main Subs ☐ Other: ______

76. If yes, what was the contract document form?

☐ IFOA
☐ AIA Contracts

- ☐ Consensus DOCS 300
- ☐ Other: __________

77. Was there a compensation method used to incentivize performance/collaboration among participants?

☐ Yes ☐ No

78. If yes, what was the incentive method used?

- ☐ Based on value
- ☐ Incentive pool
- ☐ Profit sharing
- ☐ Performance bonuses
- ☐ Innovation
- ☐ Other: ___________________

79. Was the chosen method successful?

☐ Yes ☐ No

80. If yes, briefly explain why it was successful?

____

____

81. The following is a list of Lean/Innovative tools that are usually used with project delivery systems. Please mark from the following or add any of the innovative tools used in this project:

- ☐ Network of commitments
- ☐ Reliable promising
- ☐ Value stream mapping
- ☐ Choosing by advantages (CBA)
- ☐ Target value design
- ☐ Set-Based Design
- ☐ Kaizen events
- ☐ Waste identification/ elimination
- ☐ Shared responsibility
- ☐ The five S's
- ☐ Pull scheduling or Last Planner
- ☐ Other: _______________
- ☐ Other: _______________
- ☐ Other: _______________

82. Was there a project success strategy employed for this project?

☐ Yes ☐ No

83. If yes, briefly explain this strategy?

____

Project Claims:

84. Was there any claims issued by parties of this contract?

☐ Yes ☐ No, Please continue to the next subsection (Project Safety)

85. Who were the initiators of the claims?

☐ Owner
☐ Architect/ Designer
☐ Contractor
☐ Subcontractor: ______________
☐ Other: ___________

86. What were the main reasons for the claims?

☐ Design deficiency
☐ Different site conditions
☐ Delay
☐ Other: ___________

87. If claims were issued by parties of this contract, please provide information about those claims in the table below. If no claims were issued, please continue to the next subsection (Project Safety)

Party Issued the Claim	Number of Claims		
Owner			
Architect/ Engineer			
Contractor			
Subcontractors			
Others:			

Project Safety:

88. How do you rate the safety requirements and standards set for this project compared to other projects?

☐ Higher ☐ Average ☐ Lower

89. How do you rate the safety performance and results at the end of this project compared to other projects?

☐ Above average ☐ Average ☐ Below average

90. If available, please provide the following construction safety records for the project:

OSHA Recordable Incident Rate (RIR)	
DART Rate (Days Away/Restricted or Job Transfer Rate)	
Lost Time Case Rate (LTC)	
Lost Work Day Rate (LWD)	

APPENDIX F – EXECUTIVE-LEVEL SURVEY SHORT ANSWERS

Satisfaction / Dissatisfaction with Project Delivery Systems:

Following are the actual short answers responders to the Executive-Level Survey supplied. Listed next to the reason of satisfaction / dissatisfaction is the category assigned to the reason in the analysis effort of this study.

DBB			
Satisfaction		**Dissatisfaction**	
Reason (actual answer)	Category	Reason (actual answer)	Category
Scope Control	Scope Control	Time	Schedule
Cost	Cost	Cost	Cost
Predictable outcomes	Scope Control	Quality	Quality
Price	Cost	Uncertainty	Scope Control
Product	Quality	Cost over-run	Cost
Has produced lowest priced contracts to university	Cost	Cost, schedule, least amount of value to owner	Cost / Schedule
Good competition	Competition	Distrust	Adversity
cost	Cost	High price and poor quality	Cost, Quality
cost	Cost	Does not cope with Change effectively	Scope Control
Cost control	Cost	Quality of vendors	Vendor Quality
Cost	Cost	Time	Schedule
Fixed cost	Cost	Lack of contractor pre-qualification	Vendor Quality
Cost and ability to prequalify General Contractors	Cost	Takes too long	Schedule
Works well for public procurement	Law	Limited bidders	Vendor Quality
Proven delivery	Scope Control	Creates substantial number of change orders	Scope Control
Cost	Cost	Bid costs	Cost

DB			
Satisfaction		**Dissatisfaction**	
Reason (actual answer)	Category	Reason (actual answer)	Category
Speed	Schedule	Scope Control	Scope Control
schedule	Schedule	Cost	Cost
Schedule	Schedule	Variable contractor performance	Quality
Price	Cost	Lack of ability to truly define and control the product	Scope Control
Cost	Cost	Flexibility	Scope Control
Speed	Schedule	Quality	Quality
Collaborative approach	Collaboration	Quality	Quality
Fast track, One entity contracting	Schedule	Wrong incentives	Vendor Quality
Economical	Cost	Unsatisfactory design requirements	Quality
Time	Schedule	Product	Quality
Quicker delivery	Schedule	Not as competitive	Vendor Quality
Great for technical or specialized projects	Complex Projects	Loss of control	Scope Control
Schedule	Schedule	Owner representation	Owner Involvement
Cost	Cost	Lack of control of final design	Scope Control
Risk assignment	Risk Assignment	Doesn't work for most projects	Limited Use
Fast delivery	Schedule		
Quick and easy	Schedule		
Speed	Schedule		

CMA			
Satisfaction		**Dissatisfaction**	
Reason (actual answer)	Category	Reason (actual answer)	Category
Scope Control	Scope Control	Cost	Cost
Product	Quality	Risk kept by Owner	Risk Assignment
Provides services our in-house staff cannot provide	Expertise	Cost and value	Cost
Cost control	Scope Control	Cost	Cost
		Cost	Cost
		Doesn't improve schedule enough	Schedule
		Lack of accountability and contract "chain of custody" issues	Accountability
		CM has no "skin" in the game.	Accountability

CMR			
Satisfaction		**Dissatisfaction**	
Reason (actual answer)	Category	Reason (actual answer)	Category
Risk Control	Risk Assignment	Cost	Cost
Contractor Ownership	Contractor Involvement	Cost and value	Cost
Value	Cost	Contractors not fully understanding GMP process	Scope Control
Copes with change effectively	Collaboration	CM fees sometimes are not competitive	Cost
Known way of doing business	Scope Control	Owner representation	Owner Involvement
Provides services our in house staff can't provide; shortens schedule	Expertise / Schedule	Too early to tell	
Schedule	Schedule		
Coordination and planning	Expertise		
Schedule management	Schedule		
Relationship and transparency.	Collaboration		
Owner involvement	Owner Involvement		

IPD			
Satisfaction		**Dissatisfaction**	
Reason (actual answer)	Category	Reason (actual answer)	Category
Program optimization	Efficiency	Cost unpredictability	Scope Control
Overall better projects	Quality	Resource commitment	
Reliability	Accountability	Still learning	
Relationships	Collaboration		
Collaborative, trusting relationships required	Collaboration		
Trust, value	Accountability		
Shared risk leads to greater trust, less adversity	Collaboration		
Overall better projects	Quality		
Reliability	Accountability		
Relationships	Collaboration		
Collaborative, trusting relationships required	Collaboration		
Trust, value	Accountability		
Shared risk leads to greater trust, less adversity	Collaboration		
Is nothing more than CM at risk with a collaborative team.	Collaboration		
Quality result and process	Quality		
Reduced capital costs - elimination of waste	Cost		

Obstacles in the Way of Innovation in the Construction Industry:

Following are the actual short answers supplied by the Executive-Level Survey responders for suggestions to overcome obstacles in the way of innovation in the construction industry. Listed next to the suggestion is the category assigned to the suggestion in the analysis effort of this study.

Lack of Enough Solid Evidence on New Methods:	
Suggestion (actual answer)	Category
Practical solutions	
Industry Research	Research
Communities of Practice	Showcase studies
More sharing of experiences	Showcase studies
CEO and board education	Research
Need to establish more data to prove where deficiencies are.	Research
Research on costs, returns and outcomes	Research
Better education for all parties	Research
Publish new methods	Showcase studies
One must make a decision to try new things.	Research
Process/results	Research
Better ways of quantifying savings from IPD Projects	Research

Change Resistant Culture:	
Suggestion (actual answer)	Category
Look at business case for change	Showcase studies
Education, success stories	Showcase studies
Industry Research	Showcase studies
Incentives/Comparisons	Showcase studies
Pick the right contractor	Owner's resp.
Owners need to take the lead	Owner's resp.
Develop ideal behaviors and expectations prior to project commencement	Owner's resp.
Keep talking about it. Show results.	Showcase studies
Owner assumes most of financial risk	Owner's resp.
State policies and procedures	
Process has been in place for many years, resistance to changing processes	
Training, case studies, education	Showcase studies
Have to try it	Owner's resp.
Better upfront education	Showcase studies
Publish new methods	Showcase studies
Take small incremental steps	Owner's resp.

Lack of Trust:	
Suggestion (actual answer)	Category
Work on building relationships - alliance contracting	Build trust through relationship
Owners can create great teams along with project information transparency	Owner's resp.
Deferential treatment when resourcing	Build trust through relationship
Pick the right contractor	Owner's resp.
Fully develop teams early and focus on relationships	Build trust through relationship
Develop ideal behaviors for all team members to adhere to	Build trust through relationship
Use consistent partners to develop trust	Build trust through relationship
Owner assumes most of financial risk	Owner's resp.
Experience working together, reported results, development of effective practices and working relationships	Build trust through relationship
Have to try it	Owner's resp.
Educate on new methods	
Select who you trust	Build trust through relationship

Transactional Contracts:	
Suggestion (actual answer)	Category
Qualitative comparisons	Owner's resp.
Pick the right contractor	Owner's resp.
Owner adoption of relational contract models	Owner's resp.
Create IPD contract	Revised contract
Usually the biggest liar wins. Make sure that awardee is not at financial risk.	Owner's resp.
State policies and procedures	
Open book accounting	Revised contract
Revisions to contracts	Revised contract

The Current Economy:	
Suggestion (actual answer)	Category
Time, it will eventually normalize	Time
Extreme competition makes hard bid projects more economically attractive	DBB more attractive
Increase funding sources	Increase funding

Lack of Education:	
Suggestion (actual answer)	Category
Architects do not get the right "days in school" on research, business, law, etc.	Pre-graduation education
Quality courses developed by practitioners	Pre-graduation education
Teach IPD in schools	Pre-graduation education
If it wasn't for C students in high school we couldn't build anything.	Pre-graduation education
State policies and procedures	
Training and educational resources	Post-graduation education
More classes for employees	Post-graduation education
Educate on new methods	Post-graduation education
Better education for owners/architects and contractors	Post-graduation education

Lack of Research:	
Suggestion (actual answer)	Category
We need a national foundation to focus on funding industry research	More research
Owner, Trade Associations, Higher Education Partnerships	More collaboration
More use of institutions to perform research	More research
Additional research on benefits of IPD	More research

Improper Risk Allocation:	
Suggestion (actual answer)	Category
Allocation is the wrong word...it should be risk management	Better management
Development of better contract forms	Relational contracts
Select the appropriate contracting method	Relational contracts
The more risk the owner is willing to shoulder, the more collaboration takes place and the better overall project execution.	Owner's responsibility
More experience	More experience

Obstacle: (Other)		
Obstacle (actual answer)	Suggestion (actual answer)	Category
Lack of computation of real value	Industry research	
Geographic variances	Studies differentiating	
State laws	Change state laws to allow alternate construction methods	Change State Law
State Regulations	Change state laws to allow alternate construction methods	Change State Law
Lack of flexibility in procurement laws	Change state laws to allow alternate construction methods	Change State Law
Statutory requirements	Change state laws to allow alternate construction methods	Change State Law

APPENDIX G – UNIVARIATE ANALYSIS SPSS SELECTED OUTPUT

Included in the output are the t-tests and the MWW tests tables for all the performance metrics:

1. Cost Change
2. Schedule Change
3. Turnover Quality
4. Building Quality
5. Systems Quality
6. Overall Quality
7. RFI/Millions
8. RFI Processing Period
9. User Satisfaction
10. Owner Satisfaction
11. Overall Satisfaction
12. Safety
13. OPQR

<u>Cost Change:</u>

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Cost_Grwth	1	9	-5.2031%	4.25344%	1.41781%
	3	10	0.8462%	11.97824%	3.78785%

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
Cost_Grwth	Eq. var. assumed	2.487	.133	-1.432	17	**.170**	-6.05%	4.223%	-14.9%	2.860%
	Eq. var. not assumed			-1.496	11.446	.162	-6.05%	4.045%	-14.9%	2.810%

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
Cost_Grwth	IPD	9	7.44	67.00
	Non-IPD	10	12.30	123.00
	Total	19		

Test Statistics[a]

	Cost_Grwth
Mann-Whitney U	22.000
Wilcoxon W	67.000
Z	-1.878
Asymp. Sig. (2-tailed)	.060
Exact Sig. [2*(1-tailed Sig.)]	.065[b]
Exact Sig. (2-tailed)	**.065**
Exact Sig. (1-tailed)	.033
Point Probability	.006

a. Grouping Variable: Groups

b. Not corrected for ties.

Schedule Change:

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Schdl_Grwth	1	9	-6.3765%	13.51946%	4.50649%
	3	10	2.2828%	7.29858%	2.30801%

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
Schdl_Grwth	Eq. var. assumed	2.083	.167	-1.763	17	**.096**	-8.66%	4.910%	-19.0%	1.701%
	Eq. var. not assumed			-1.710	12.013	.113	-8.66%	5.063%	-19.7%	2.371%

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
Schdl_Grwth	IPD	9	7.56	68.00
	Non-IPD	10	12.20	122.00
	Total	19		

Test Statistics[a]

	Schdl_Grwth
Mann-Whitney U	23.000
Wilcoxon W	68.000
Z	-1.899
Asymp. Sig. (2-tailed)	.058
Exact Sig. [2*(1-tailed Sig.)]	.079[b]
Exact Sig. (2-tailed)	**.062**
Exact Sig. (1-tailed)	.031
Point Probability	.006

RFIs Per Million $

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
RFI/Mil	IPD	10	4.0142	4.59888	1.45429
	Non-IPD	9	17.3895	11.98774	3.99591

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
RFI/Mil	Eq. var. assumed	11.572	.003	-3.279	17	.004	-13.375	4.079	-21.982	-4.769
	Eq. var. not assumed			-3.145	10.102	**.010**	-13.375	4.252	-22.837	-3.913

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
RFI/Mil	IPD	10	7.10	71.00
	Non-IPD	9	13.22	119.00
	Total	19		

Test Statistics[a]

	RFI/Mil
Mann-Whitney U	16.000
Wilcoxon W	71.000
Z	-2.372
Asymp. Sig. (2-tailed)	.018
Exact Sig. [2*(1-tailed Sig.)]	.017[b]
Exact Sig. (2-tailed)	**.017**
Exact Sig. (1-tailed)	.009
Point Probability	.002

RFI Processing Period

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
RFIs_Prcs_Prd	IPD	9	3.333	3.3166	1.1055
	Non-IPD	9	6.500	7.1589	2.3863

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
RFIs_PrcsPrd	Eq. var. assumed	1.642	.218	-1.204	16	**.246**	-3.167	2.630	-8.742	2.409
	Eq. var. not assumed			-1.204	11.283	.253	-3.167	2.630	-8.938	2.604

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
RFIs_Prcs_Prd	IPD	9	7.94	71.50
	Non-IPD	9	11.06	99.50
	Total	18		

Test Statistics[a]

	RFIs_Prcs_Prd
Mann-Whitney U	26.500
Wilcoxon W	71.500
Z	-1.246
Asymp. Sig. (2-tailed)	.213
Exact Sig. [2*(1-tailed Sig.)]	.222[b]
Exact Sig. (2-tailed)	**.232**
Exact Sig. (1-tailed)	.116
Point Probability	.012

Turnover Quality

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
TO_Qlt	IPD	10	5.6333	.86709	.27420
	Non-IPD	11	5.2424	1.43829	.43366

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
TO_Qlt	Eq. var. assumed	1.829	.192	.744	19	**.466**	.391	.525	-.708	1.490
	Eq. var. not assumed			.762	16.639	.457	.391	.513	-.693	1.475

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
TO_Qlt	IPD	10	12.70	127.00
	Non-IPD	11	9.45	104.00
	Total	21		

Test Statistics[a]

	TO_Qlt
Mann-Whitney U	38.000
Wilcoxon W	104.000
Z	-1.225
Asymp. Sig. (2-tailed)	.221
Exact Sig. [2*(1-tailed Sig.)]	.251[b]
Exact Sig. (2-tailed)	**.244**
Exact Sig. (1-tailed)	.122
Point Probability	.014

Building Quality

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Bldg_Qlt	IPD	10	8.0000	.94281	.29814
	Non-IPD	11	6.5455	1.63485	.49293

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
Bldg_Qlt	Eq. var. assumed	5.507	.030	2.462	19	.024	1.455	.591	.218	2.691
	Eq. var. not assumed			2.525	16.240	**.022**	1.455	.576	.235	2.674

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
Bldg_Qlt	IPD	10	13.80	138.00
	Non-IPD	11	8.45	93.00
	Total	21		

Test Statistics[a]

	Bldg_Qlt
Mann-Whitney U	27.000
Wilcoxon W	93.000
Z	-2.050
Asymp. Sig. (2-tailed)	.040
Exact Sig. [2*(1-tailed Sig.)]	.051[b]
Exact Sig. (2-tailed)	**.042**
Exact Sig. (1-tailed)	.019
Point Probability	.004

Systems Quality

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Systs_Qlt	IPD	10	8.1000	.99443	.31447
	Non-IPD	11	7.0000	1.34164	.40452

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
Systs_Qlt	Eq. var. assumed	.001	.977	2.116	19	**.048**	1.100	.520	.012	2.188
	Eq. var. not assumed			2.147	18.309	.045	1.100	.512	.025	2.175

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
Systs_Qlt	IPD	10	13.55	135.50
	Non-IPD	11	8.68	95.50
	Total	21		

Test Statistics[a]

	Systs_Qlt
Mann-Whitney U	29.500
Wilcoxon W	95.500
Z	-1.909
Asymp. Sig. (2-tailed)	.056
Exact Sig. [2*(1-tailed Sig.)]	.072[b]
Exact Sig. (2-tailed)	**.066**
Exact Sig. (1-tailed)	.035
Point Probability	.015

Overall Quality

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Quality	IPD	10	7.2444	.80431	.25434
	Non-IPD	11	6.2626	1.34097	.40432

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
Quality	Eq. var. assumed	2.228	.152	2.008	19	**.059**	.982	.489	-.042	2.005
	Eq. var. not assumed			2.055	16.593	.056	.982	.478	-.028	1.991

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
Quality	IPD	10	13.80	138.00
	Non-IPD	11	8.45	93.00
	Total	21		

Test Statistics[a]

	Quality
Mann-Whitney U	27.000
Wilcoxon W	93.000
Z	-1.974
Asymp. Sig. (2-tailed)	.048
Exact Sig. [2*(1-tailed Sig.)]	.051[b]
Exact Sig. (2-tailed)	**.049**
Exact Sig. (1-tailed)	.024
Point Probability	.002

Users Satisfaction

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
User_Stsfc	IPD	10	8.60	.843	.267
	Non-IPD	11	7.18	1.662	.501

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
User_Stsfc	Eq. var. assumed	4.328	.051	2.425	19	**.025**	1.418	.585	.194	2.642
	Eq. var. not assumed			2.498	15.116	.025	1.418	.568	.209	2.628

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
User_Stsfc	IPD	10	13.70	137.00
	Non-IPD	11	8.55	94.00
	Total	21		

Test Statistics[a]

	User_Stsfc
Mann-Whitney U	28.000
Wilcoxon W	94.000
Z	-2.141
Asymp. Sig. (2-tailed)	.032
Exact Sig. [2*(1-tailed Sig.)]	.061[b]
Exact Sig. (2-tailed)	**.049**
Exact Sig. (1-tailed)	.027
Point Probability	.021

Owner Satisfaction

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Ownr_Stsfc	IPD	10	7.80	1.033	.327
	Non-IPD	11	6.45	1.572	.474

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
Ownr_Stsfc	Eq. var. assumed	2.223	.152	2.291	19	**.034**	1.345	.587	.116	2.575
	Eq. var. not assumed			2.337	17.391	.032	1.345	.576	.133	2.558

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
Ownr_Stsfc	IPD	10	13.70	137.00
	Non-IPD	11	8.55	94.00
	Total	21		

Test Statistics[a]

	Ownr_Stsfc
Mann-Whitney U	28.000
Wilcoxon W	94.000
Z	-2.054
Asymp. Sig. (2-tailed)	.040
Exact Sig. [2*(1-tailed Sig.)]	.061[b]
Exact Sig. (2-tailed)	**.067**
Exact Sig. (1-tailed)	.035
Point Probability	.009

Overall Satisfaction

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Satisfaction	IPD	10	4.600	.3944	.1247
	Non-IPD	11	3.909	.7355	.2218

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
Satisfaction	Eq. var. assumed	2.823	.109	2.641	19	**.016**	.691	.262	.143	1.238
	Eq. var. not assumed			2.716	15.594	.016	.691	.254	.150	1.231

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
Satisfaction	IPD	10	14.10	141.00
	Non-IPD	11	8.18	90.00
	Total	21		

Test Statistics[a]

	Satisfaction
Mann-Whitney U	24.000
Wilcoxon W	90.000
Z	-2.253
Asymp. Sig. (2-tailed)	.024
Exact Sig. [2*(1-tailed Sig.)]	.029[b]
Exact Sig. (2-tailed)	**.029**
Exact Sig. (1-tailed)	.017
Point Probability	.011

Safety

T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Safety	IPD	10	4.400	.8433	.2667
	Non-IPD	11	3.364	.6742	.2033

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
Safety	Eq. var. assumed	1.354	.259	3.125	19	**.006**	1.036	.332	.342	1.731
	Eq. var. not assumed			3.091	17.255	.007	1.036	.335	.329	1.743

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
Safety	IPD	10	14.40	144.00
	Non-IPD	11	7.91	87.00
	Total	21		

Test Statistics[a]

	Safety
Mann-Whitney U	21.000
Wilcoxon W	87.000
Z	-2.597
Asymp. Sig. (2-tailed)	.009
Exact Sig. [2*(1-tailed Sig.)]	.016[b]
Exact Sig. (2-tailed)	**.013**
Exact Sig. (1-tailed)	.007
Point Probability	.005

OPQR
T-test

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
ZOPQR	IPD	11	.5227759	.78080333	.23542106
	Non-IPD	9	-.8004697	1.21553084	.40517695

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
ZOPQR	Eq. var. assumed	2.500	.131	2.951	18	**.009**	1.323	.449	.381	2.265
	Eq. var. not assumed			2.824	13.117	.014	1.323	.469	.312	2.335

Mann Whitney Wilcoxon

Ranks

	Groups	N	Mean Rank	Sum of Ranks
ZOPQR	IPD	11	13.55	149.00
	Non-IPD	9	6.78	61.00
	Total	20		

Test Statistics[a]

	ZOPQR
Mann-Whitney U	16.000
Wilcoxon W	61.000
Z	-2.545
Asymp. Sig. (2-tailed)	.011
Exact Sig. [2*(1-tailed Sig.)]	.010[b]
Exact Sig. (2-tailed)	**.010**
Exact Sig. (1-tailed)	.005
Point Probability	.001

APPENDIX H – MULTIVARIATE ANALYSIS SPSS SELECTED OUTPUT

Multiple (Stepwise) Regression

```
REGRESSION
  /DESCRIPTIVES MEAN STDDEV CORR SIG N
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA COLLIN TOL CHANGE
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ZOPQR
  /METHOD=STEPWISE Const_Type Proj_Type ProjCmplx PDS CompLS CompCPlusP
CompCPlusF CompPrSh CompGMP ProjTeam TMSelec SH_Invl TE_Unt SH_Intrac Co_Loc
F_Transp TExp_PrjTyp RskRwd BIM Incntv Lean_T LastPlanner Succ_Strtgy IPD
Contrct_Lm Mangmt_Strctr
  /SCATTERPLOT=(*ZRESID ,*ZPRED)
  /RESIDUALS HISTOGRAM(ZRESID) NORMPROB(ZRESID).
```

Descriptive Statistics

	Mean	Std. Deviation	N
ZOPQR	.0000000	1.00000000	32
Const_Type	1.44	.759	32
Proj_Type	2.69	1.176	32
ProjCmplx	5.69	2.520	32
PDS	3.56	1.813	32
CompLS	1.16	1.221	32
CompCPlusP	.78	1.313	32
CompCPlusF	.47	.671	32
CompPrSh	.31	.998	32
CompGMP	1.00	.718	32
ProjTeam	3.75	1.047	32
TMSelec	1.9292	1.06306	32
SH_Invl	6.8927	4.43640	32
TE_Unt	.78	.870	32
SH_Intrac	6.3229	1.29372	32
Co_Loc	.56	.504	32
F_Transp	.84	.369	32
TExp_PrjTyp	6.2969	2.18037	32
RskRwd	.69	.471	32
BIM	1.16	1.322	32
Incntv	.38	.492	32
Lean_T	2.94	2.816	32
LastPlanner	.50	.508	32
Succ_Strtgy	.53	.507	32
IPD	.34	.483	32
Contrct_Lm	1.63	1.314	32
Mangmt_Strctr	6.8281	2.06589	32

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	F_Transp	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	Mangmt_Strctr	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	Lean_T	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: ZOPQR

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.698[a]	.488	.470	.72769371	.488	28.542	1	30[a]	.000
2	.801[b]	.642	.617	.61848329	.155	12.530	1	29[b]	.001
3	.832[c]	.692	.659	.58427502	.050	4.495	1	28[c]	.043

a. Predictors: (Constant), F_Transp

b. Predictors: (Constant), F_Transp, Mangmt_Strctr

c. Predictors: (Constant), F_Transp, Mangmt_Strctr, Lean_T

d. Dependent Variable: ZOPQR

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	15.114	1	15.114	28.542	.000[b]
	Residual	15.886	30	.530		
	Total	31.000	31			
2	Regression	19.907	2	9.953	26.021	.000[c]
	Residual	11.093	29	.383		
	Total	31.000	31			
3	Regression	21.441	3	7.147	20.936	.000[d]
	Residual	9.559	28	.341		
	Total	31.000	31			

a. Dependent Variable: ZOPQR

b. Predictors: (Constant), F_Transp

c. Predictors: (Constant), F_Transp, Mangmt_Strctr

d. Predictors: (Constant), F_Transp, Mangmt_Strctr, Lean_T

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-1.597	.325		-4.907	.000		1.000
	F_Transp	1.893	.354	.698	5.342	.000	1.000	
2	(Constant)	-2.629	.402		-6.542	.000		1.176
	F_Transp	1.446	.327	.533	4.427	.000	.850	1.176
	Mangmt_Strctr	.206	.058	.426	3.540	.001	.850	
3	(Constant)	-2.670	.380		-7.023	.000		1.177
	F_Transp	1.461	.309	.539	4.735	.000	.850	1.260
	Mangmt_Strctr	.175	.057	.362	3.072	.005	.794	1.079
	Lean_T	.082	.039	.231	2.120	.043	.927	1.000

a. Dependent Variable: ZOPQR

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	Const_Type	.085[b]	.576	.569	.106	.807	1.239	.807
	Proj_Type	-.074[b]	-.555	.583	-.103	.987	1.014	.987
	ProjCmplx	.084[b]	.617	.542	.114	.950	1.053	.950
	PDS	.185[b]	1.255	.219	.227	.776	1.289	.776
	CompLS	-.200[b]	-1.390	.175	-.250	.802	1.247	.802
	CompCPlusP	.059[b]	.431	.670	.080	.932	1.073	.932
	CompCPlusF	.099[b]	.749	.460	.138	.998	1.002	.998
	CompPrSh	.036[b]	.270	.789	.050	.981	1.019	.981
	CompGMP	-.139[b]	-1.064	.296	-.194	1.000	1.000	1.000
	ProjTeam	.234[b]	1.694	.101	.300	.843	1.187	.843
	TMSelec	.302[b]	2.267	.031	.388	.843	1.186	.843
	SH_Invl	.411[b]	3.060	.005	.494	.741	1.349	.741
	TE_Unt	.156[b]	1.200	.240	.217	.992	1.008	.992
	SH_Intrac	.344[b]	1.911	.066	.334	.485	2.061	.485
	Co_Loc	.049[b]	.352	.727	.065	.901	1.110	.901
	TExp_PrjTyp	.181[b]	1.275	.212	.230	.829	1.207	.829
	RskRwd	.206[b]	1.433	.163	.257	.795	1.258	.795
	BIM	.220[b]	1.677	.104	.297	.937	1.067	.937
	Incntv	.158[b]	1.143	.262	.208	.889	1.125	.889
	Lean_T	.318[b]	2.655	.013	.442	.993	1.007	.993
	LastPlanner	.119[b]	.902	.374	.165	.993	1.007	.993
	Succ_Strtgy	.208[b]	1.557	.130	.278	.918	1.089	.918
	IPD	.185[b]	1.363	.183	.245	.903	1.107	.903
	Contrct_Lm	.048[b]	.362	.720	.067	.984	1.016	.984

	Mangmt_Strctr	.426[b]	3.540	.001	.549	.850	1.176	.850
	Const_Type	.035[c]	.273	.787	.051	.796	1.256	.681
	Proj_Type	.079[c]	.651	.520	.122	.859	1.165	.740
	ProjCmplx	-.100[c]	-.793	.434	-.148	.788	1.268	.706
	PDS	.031[c]	.223	.825	.042	.679	1.473	.679
	CompLS	-.037[c]	-.275	.786	-.052	.685	1.461	.685
	CompCPlusP	-.092[c]	-.747	.461	-.140	.821	1.217	.749
	CompCPlusF	.071[c]	.629	.534	.118	.993	1.007	.846
	CompPrSh	.061[c]	.539	.594	.101	.977	1.023	.831
	CompGMP	-.076[c]	-.667	.510	-.125	.973	1.028	.827
	ProjTeam	.165[c]	1.361	.184	.249	.817	1.223	.764
	TMSelec	.135[c]	.989	.331	.184	.666	1.500	.666
	SH_Invl	.259[c]	1.874	.071	.334	.595	1.680	.595
2	TE_Unt	.131[c]	1.181	.247	.218	.987	1.013	.847
	SH_Intrac	.016[c]	.078	.938	.015	.316	3.166	.316
	Co_Loc	.150[c]	1.259	.219	.231	.856	1.168	.732
	TExp_PrjTyp	.069[c]	.539	.594	.101	.768	1.302	.768
	RskRwd	.097[c]	.750	.460	.140	.741	1.350	.741
	BIM	.137[c]	1.172	.251	.216	.892	1.121	.809
	Incntv	.055[c]	.442	.662	.083	.831	1.204	.795
	Lean_T	.231[c]	2.120	.043	.372	.927	1.079	.794
	LastPlanner	.065[c]	.570	.573	.107	.973	1.027	.834
	Succ_Strtgy	.013[c]	.094	.926	.018	.705	1.419	.653
	IPD	.175[c]	1.529	.138	.278	.902	1.108	.783
	Contrct_Lm	-.137[c]	-1.119	.273	-.207	.820	1.220	.708
	Const_Type	.045[d]	.380	.707	.073	.795	1.258	.680
	Proj_Type	.087[d]	.764	.451	.146	.858	1.166	.701
	ProjCmplx	-.146[d]	-1.228	.230	-.230	.766	1.305	.684
	PDS	-.057[d]	-.419	.679	-.080	.616	1.623	.616
	CompLS	.036[d]	.267	.791	.051	.637	1.569	.637
	CompCPlusP	-.053[d]	-.442	.662	-.085	.798	1.253	.682
	CompCPlusF	.057[d]	.530	.600	.102	.989	1.011	.791
	CompPrSh	.005[d]	.041	.968	.008	.915	1.093	.780
	CompGMP	-.075[d]	-.695	.493	-.133	.973	1.028	.774
	ProjTeam	.113[d]	.945	.353	.179	.772	1.295	.756
	TMSelec	.096[d]	.730	.471	.139	.651	1.535	.651
3	SH_Invl	.157[d]	1.012	.321	.191	.458	2.181	.458
	TE_Unt	.138[d]	1.327	.196	.247	.987	1.014	.790
	SH_Intrac	.036[d]	.188	.852	.036	.315	3.174	.315
	Co_Loc	.108[d]	.934	.358	.177	.825	1.211	.725
	TExp_PrjTyp	.032[d]	.261	.796	.050	.751	1.332	.751
	RskRwd	.066[d]	.526	.603	.101	.728	1.373	.728
	BIM	.056[d]	.462	.648	.089	.765	1.307	.765
	Incntv	.036[d]	.308	.761	.059	.826	1.211	.752
	LastPlanner	-.095[d]	-.728	.473	-.139	.655	1.527	.623
	Succ_Strtgy	-.008[d]	-.060	.952	-.012	.701	1.427	.628
	IPD	.045[d]	.308	.760	.059	.542	1.844	.542
	Contrct_Lm	-.195[d]	-1.703	.100	-.311	.785	1.273	.689

a. Dependent Variable: ZOPQR

b. Predictors in the Model: (Constant), F_Transp

c. Predictors in the Model: (Constant), F_Transp, Mangmt_Strctr

d. Predictors in the Model: (Constant), F_Transp, Mangmt_Strctr, Lean_T

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	F_Transp	Mangmt_Strctr	Lean_T
1	1	1.919	1.000	.04	.04		
	2	.081	4.854	.96	.96		
2	1	2.867	1.000	.01	.02	.01	
	2	.091	5.608	.16	.98	.10	
	3	.041	8.323	.83	.01	.89	
3	1	3.496	1.000	.01	.01	.01	.03
	2	.375	3.052	.01	.04	.01	.92
	3	.089	6.281	.20	.94	.09	.04
	4	.041	9.273	.78	.01	.90	.02

a. Dependent Variable: ZOPQR

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-1.8815569	1.2813954	.0000000	.83166052	32
Residual	-1.12118328	.98936963	.00000000	.55528442	32
Std. Predicted Value	-2.262	1.541	.000	1.000	32
Std. Residual	-1.919	1.693	.000	.950	32

a. Dependent Variable: ZOPQR

Factor Analysis

```
COMPUTE IPD_Attrib=Incntv+RskRwd+Co_Loc+F_Transp.
EXECUTE.
FACTOR
  /VARIABLES ProjCmplx CompLS CompPrSh CompGMP ProjTeam TMSelec SH_Invl
TE_Unt SH_Intrac TExp_PrjTyp BIM Lean_T Contrct_Lm Mangmt_Strctr IPD_Attrib
  /MISSING LISTWISE
  /ANALYSIS ProjCmplx CompLS CompPrSh CompGMP ProjTeam TMSelec SH_Invl TE_Unt
SH_Intrac TExp_PrjTyp BIM Lean_T Contrct_Lm Mangmt_Strctr IPD_Attrib
  /PRINT INITIAL CORRELATION KMO EXTRACTION ROTATION FSCORE
  /FORMAT SORT BLANK(.30)
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PAF
  /CRITERIA ITERATE(25) DELTA(0)
  /ROTATION OBLIMIN
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.683**
Bartlett's Test of Sphericity	Approx. Chi-Square	219.823
	Df	105
	Sig.	**.000**

Communalities

	Initial	Extraction
ProjCmplx	.633	.657
CompLS	.705	.742
CompPrSh	.538	.598
CompGMP	.528	.608
ProjTeam	.459	.335
TMSelec	.672	.596
SH_Invl	.657	.745
TE_Unt	.394	.732
SH_Intrac	.761	.695
TExp_PrjTyp	.683	.756
BIM	.577	.551
Lean_T	.464	.263
Contrct_Lm	.558	.975
Mangmt_Strctr	.680	.509
IPD_Attrib	.692	.628

Extraction Method: Principal Axis Factoring.

Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Required Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	5.428	36.189	36.189	5.055	33.699	33.699	4.101
2	1.909	12.723	48.912	1.549	10.330	44.029	1.752
3	1.313	8.755	57.667	1.140	7.600	51.630	1.549
4	1.238	8.253	65.920	.919	6.127	57.756	.958
5	1.088	7.251	73.171	.726	4.837	62.594	3.543
6	.935	6.233	79.404				
7	.630	4.197	83.601				
8	.593	3.951	87.552				
9	.448	2.984	90.536				
10	.360	2.398	92.934				
11	.308	2.051	94.986				
12	.285	1.902	96.888				
13	.198	1.319	98.207				
14	.166	1.103	99.310				
15	.104	.690	100.000				

Extraction Method: Principal Axis Factoring.

a. When factors are correlated, sums of squared loadings cannot be added to obtain a total variance.

Factor Matrix[a]

	Factor				
	1	2	3	4	5
CompLS	-.793				
SH_Invl	.780				
SH_Intrac	.777				
IPD_Attrib	.725				
Mangmt_Strctr	.696				
TMSelec	.634				
BIM	.624	-.353			
ProjCmplx	.623				
ProjTeam	.498				
Lean_T	.478				
CompPrSh		-.664			
TExp_PrjTyp	.543	.628			
CompGMP		.531			.495
Contrct_Lm	.340		.886		
TE_Unt				.817	

Extraction Method: Principal Axis Factoring.[a]

a. Attempted to extract 5 factors. More than 25 iterations required.

(Convergence=.009). Extraction was terminated.

Pattern Matrix[a]

	Factor				
	1	2	3	4	5
TMSelec	.805				
SH_Invl	.742				
BIM	.637				
IPD_Attrib	.580				
Lean_T	.401				
CompGMP		.809			
CompPrSh	.400	-.547			
Contrct_Lm			.973		
TE_Unt				.856	
TExp_PrjTyp					-.894
ProjCmplx			.335		-.608
SH_Intrac	.383				-.605
CompLS		.441			.556
Mangmt_Strctr	.384				-.425
ProjTeam					-.419

Extraction Method: Principal Axis Factoring.

Rotation Method: Oblimin with Kaiser Normalization.[a]

a. Rotation converged in 22 iterations.

Structure Matrix

	Factor				
	1	2	3	4	5
SH_Invl	**.784**				-.561
TMSelec	**.765**				
IPD_Attrib	**.718**	-.364			-.480
BIM	**.697**	-.379	.301		
Lean_T	**.472**				
CompGMP		**.763**			
CompPrSh	.431	**-.668**			
Contrct_Lm			**.974**		
TE_Unt				**.849**	
TExp_PrjTyp					**-.844**
SH_Intrac	.622				**-.746**
ProjCmplx	.380		.459		**-.669**
CompLS	-.611	.520			**.656**
Mangmt_Strctr	.576				**-.604**
ProjTeam	.342				**-.499**

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.

Factor Correlation Matrix

Factor	1	2	3	4	5
1	1.000	-.319	.187	.069	-.410
2	-.319	1.000	-.063	-.081	.004
3	.187	-.063	1.000	-.017	-.168
4	.069	-.081	-.017	1.000	-.078
5	-.410	.004	-.168	-.078	1.000

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.

Factor Score Coefficient Matrix

	Factor				
	1	2	3	4	5
ProjCmplx	-.037	-.013	.006	-.181	-.233
CompLS	-.075	.362	.043	.047	.130
CompPrSh	.162	-.307	.045	.072	.126
CompGMP	.072	.405	.044	-.018	.058
ProjTeam	.029	-.033	.008	.042	-.021
TMSelec	.213	.032	-.107	.032	-.026
SH_Invl	.344	.224	.056	-.072	-.058
TE_Unt	-.028	.022	-.104	.781	-.058
SH_Intrac	.073	.016	-.045	.159	-.285
TExp_PrjTyp	-.089	.167	.110	.114	-.451
BIM	.175	-.057	-.088	.035	.051
Lean_T	.033	-.012	.004	.047	-.020
Contrct_Lm	.032	-.029	1.039	.063	.029
Mangmt_Strctr	.087	.002	.033	-.075	-.011
IPD_Attrib	.180	-.120	.039	.004	.029

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
Factor Scores Method: Regression.

Factor Score Covariance Matrix

Factor	1	2	3	4	5
1	1.924	-1.071	2.193	.715	-1.680
2	-1.071	1.120	-.713	-.463	2.079
3	2.193	-.713	2.932	.492	.557
4	.715	-.463	.492	1.071	-1.114
5	-1.680	2.079	.557	-1.114	4.244

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
Factor Scores Method: Regression.

Multiple (Stepwise) Regression on Factors

```
REGRESSION
  /DESCRIPTIVES MEAN STDDEV CORR SIG N
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA COLLIN TOL CHANGE
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ZOPQR
  /METHOD=STEPWISE FAC1_1 FAC2_1 FAC3_1 FAC4_1 FAC5_1
  /SCATTERPLOT=(*ZRESID ,*ZPRED)
  /RESIDUALS HISTOGRAM(ZRESID) NORMPROB(ZRESID).
```

Descriptive Statistics

	Mean	Std. Deviation	N
ZOPQR	.0000000	1.00000000	32
FAC1_1	.0563957	.94012544	32
FAC2_1	-.0131814	.91507075	32
FAC3_1	-.0362517	.96418962	32
FAC4_1	-.0039646	.87316733	32
FAC5_1	-.0552999	.93846086	32

Correlations

		ZOPQR	FAC1_1	FAC2_1	FAC3_1	FAC4_1	FAC5_1
Pearson Correlation	ZOPQR	1.000	.680	-.147	-.068	.279	-.585
	FAC1_1	.680	1.000	-.380	.268	.077	-.452
	FAC2_1	-.147	-.380	1.000	-.102	-.101	.003
	FAC3_1	-.068	.268	-.102	1.000	-.076	-.178
	FAC4_1	.279	.077	-.101	-.076	1.000	-.078
	FAC5_1	-.585	-.452	.003	-.178	-.078	1.000
Sig. (1-tailed)	ZOPQR	.	.000	.211	.356	.061	.000
	FAC1_1	.000	.	.016	.069	.338	.005
	FAC2_1	.211	.016	.	.290	.290	.493
	FAC3_1	.356	.069	.290	.	.339	.165
	FAC4_1	.061	.338	.290	.339	.	.336
	FAC5_1	.000	.005	.493	.165	.336	.
N	ZOPQR	32	32	32	32	32	32
	FAC1_1	32	32	32	32	32	32
	FAC2_1	32	32	32	32	32	32
	FAC3_1	32	32	32	32	32	32
	FAC4_1	32	32	32	32	32	32
	FAC5_1	32	32	32	32	32	32

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	FAC1_1	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	FAC5_1	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	FAC3_1	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: ZOPQR

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.680[a]	.463	.445	.74517901	.463	25.827	1	30[a]	.000
2	.748[b]	.559	.529	.68660717	.096	6.337	1	29[b]	.018
3	.799[c]	.638	.599	.63318260	.079	6.100	1	28[c]	.020

a. Predictors: (Constant), FAC1_1

b. Predictors: (Constant), FAC1_1, FAC5_1

c. Predictors: (Constant), FAC1_1, FAC5_1, FAC3_1

d. Dependent Variable: ZOPQR

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14.341	1	14.341	25.827	.000[b]
	Residual	16.659	30	.555		
	Total	31.000	31			
2	Regression	17.329	2	8.664	18.379	.000[c]
	Residual	13.671	29	.471		
	Total	31.000	31			
3	Regression	19.774	3	6.591	16.441	.000[d]
	Residual	11.226	28	.401		
	Total	31.000	31			

a. Dependent Variable: ZOPQR

b. Predictors: (Constant), FAC1_1

c. Predictors: (Constant), FAC1_1, FAC5_1

d. Predictors: (Constant), FAC1_1, FAC5_1, FAC3_1

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-.041	.132		-.309	.759		
	FAC1_1	.723	.142	.680	5.082	.000	1.000	1.000
2	(Constant)	-.052	.122		-.426	.673		
	FAC1_1	.556	.147	.523	3.780	.001	.795	1.257
	FAC5_1	-.371	.147	-.348	-2.517	.018	.795	1.257
3	(Constant)	-.068	.112		-.607	.549		
	FAC1_1	.629	.139	.592	4.533	.000	.759	1.318
	FAC5_1	-.393	.136	-.369	-2.885	.007	.792	1.263
	FAC3_1	-.303	.123	-.292	-2.470	.020	.924	1.082

a. Dependent Variable: ZOPQR

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	FAC2_1	.131[b]	.902	.375	.165	.855	1.169	.855[b]
	FAC3_1	-.270[b]	-2.042	.050	-.355	.928	1.078	.928[b]
	FAC4_1	.228[b]	1.756	.090	.310	.994	1.006	.994[b]
	FAC5_1	-.348[b]	-2.517	.018	-.423	.795	1.257	.795[b]
2	FAC2_1	.065[c]	.471	.642	.089	.820	1.220	.652[c]
	FAC3_1	-.292[c]	-2.470	.020	-.423	.924	1.082	.759[c]
	FAC4_1	.213[c]	1.788	.085	.320	.992	1.008	.794[c]
3	FAC2_1	.061[d]	.478	.636	.092	.819	1.220	.628[d]
	FAC4_1	.186[d]	1.671	.106	.306	.981	1.019	.755[d]

a. Dependent Variable: ZOPQR

b. Predictors in the Model: (Constant), FAC1_1

c. Predictors in the Model: (Constant), FAC1_1, FAC5_1

d. Predictors in the Model: (Constant), FAC1_1, FAC5_1, FAC3_1

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	FAC1_1	FAC5_1	FAC3_1
1	1	1.061	1.000	.47	.47		
	2	.939	1.063	.53	.53		
2	1	1.470	1.000	.02	.26	.26	
	2	.985	1.222	.98	.01	.01	
	3	.546	1.641	.00	.73	.73	
3	1	1.619	1.000	.01	.20	.18	.11
	2	1.024	1.257	.82	.00	.01	.13
	3	.823	1.403	.18	.03	.19	.70
	4	.534	1.741	.00	.77	.62	.06

a. Dependent Variable: ZOPQR

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-1.8644634	1.1337446	.0000000	.79867297	32
Residual	-1.06172621	1.15781355	.00000000	.60176530	32
Std. Predicted Value	-2.334	1.420	.000	1.000	32
Std. Residual	-1.677	1.829	.000	.950	32

a. Dependent Variable: ZOPQR