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Integrated project delivery for industrial projects

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Integrated project delivery for industrial projects

by

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The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this dissertation. The Graduate College will ensure this dissertation is globally accessible and will not permit alterations after a degree is conferred.

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NOMENCLATURE

AIA	American Institute of Architects
CII	Construction Industry Institute
DBB	Design Bid Build
EPC	Engineering Procurement and Construction
IPD	Integrated Project Delivery
I2PD	Industrial Integrated Project Delivery
KPI	Key Performance Indicator

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ABSTRACT

Industrial capital projects are risky business ventures with increasing size, uncertainty, and complexity that frequently experience growth in cost and time to deliver, and oftentimes do not achieve their desired performance results. From Merrow (2011), "65% of all industrial projects fail to meet business objectives." The misuse of capital project funds and resources does not provide a stable foundation for sustainable business development in the industrial sector to stay competitive in the global market. The adversarial environment created from the risk shedding structure of current project delivery methods not only impedes the performance of industrial projects but can also stifle innovation and create inefficiencies in the industrial project development sector. Industrial capital project delivery has suffered from stunted growth in productivity and broad industry innovation while seeing an increase in claims and disputes for a number of years dating back to the 20th century. Integrated project delivery (IPD) in the healthcare industry in the United States and alliance contracting on public infrastructure projects in Australia and New Zealand have proven to effectively use enhanced collaboration and integration strategies and methods to bring value for money to the overall project. Using the principles of IPD and alliancing can be a way to deliver industrial projects with more active collaboration of participants and with higher levels of integration of project stakeholders to reduce the probability of failed projects and to create a better environment of innovation and efficiency leading to a more efficient use of the industry's available resources.

The dissertation aims to contribute to the body of knowledge by evaluating the use of increased integration and collaboration by applying the principles of IPD and alliancing in the industrial capital projects sector. The results of an industry-wide survey indicate industrial projects can benefit from implementing IPD and alliancing strategies with nearly all (98%)

survey participants responding that more collaboration and integration increases overall project value for money on industrial projects. Thus, the research seeks to test the hypothesis;

Increased integration and collaboration by implementing IPD and alliancing principles can lead to better project performance and increase the probability of successfully achieving its business case objectives on an industrial project.

The research findings provide evidence to suggest industrial project performance is improved by increased collaboration and integration, demonstrating that industrial projects are good candidates for an IPD delivery. The findings also provide guidance to effectively structure project delivery with the right balance of IPD and alliancing collaboration and integration principles to enhance industrial project performance and achieve important business objectives. Finally, the research will propose an IPD framework for industrial projects, defining the principles and methods, as well as their expected impact and it will also report on barriers to implementation of this delivery method on an industrial project.

CHAPTER 1 INTRODUCTION

Problem

Industrial projects have become increasingly long, complex and costly, and often do not achieve the desired results. Ernst & Young (2014) reported "64% of projects are facing cost overruns, and 73% are reporting schedule delays" in a review of 365 large scale industrial project. These failures are the result of misalignment of expectations, incomplete hand-offs between phases, and hierarchical team organization, as well as contentious project delays, change orders, and claims. The report identified "65% of project failures were due to softer aspects such as people, organization, and governance" (EY 2014). Commonly used project delivery arrangements do not work well for complex industrial projects due to the large scale of uncertainties, complexities, work processes, and interactions required from project participants. To combat these challenges industrial projects must endure a more dynamic system incorporating higher levels of active collaboration between team members and integration of work processes is required to improve project delivery functionality in this difficult environment.

The commercial construction sector, specifically the health care facilities sector, has seen successful implementation of the Integrated Project Delivery (IPD) approach over the past decade. IPD is considered a structured, but flexible project delivery arrangement that promotes and enhances team collaboration and work process integration. However, the industrial sector has been slow to implement IPD. Industrial projects are capital investments designed by engineers to furnish specific process capacities to achieve business objectives, centered on the development of production capability. The focus of industrial project development is on the process equipment, with the design requirements built around this production process. Industrial projects are oftentimes built in challenging and changing environments with high levels of

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complexity and uncertainty. In order to achieve pro forma financial objectives, industrial projects must maintain high quality process design capability to optimize production performance while balancing capital costs and risks associated with construction of the facility. The very nature of large, complex industrial projects makes them a good candidate to benefit from the emerging IPD project delivery methodology.

Integrated Project Delivery and Alliancing

The traditional approach to deliver projects using design-bid-build transactional contracting methods intentionally separates designers from construction contractors in order to maintain checks and balances (Franz et al 2016). In doing so, it limits opportunities for team collaboration and integration to bring the best value to the project and often creates adversarial environments leading to claims, disputes, and delays. Due to this, owners have turned to alternative delivery methods integrating design and construction, such as design-build, engineering procurement and construction (EPC), and CM-at-risk with the objective of reallocating risks among project stakeholders and increasing the collaboration among project teams. These alternative delivery methods also incorporate transactional contracts designed to transfer project risk from the owner to the contractor and from the contractor to the consultants and trade contractors. While these alternative delivery methods have been shown to improve project performance, it has become apparent that merely transferring risks in a different way does not guarantee project success. The CII RT210 study revealed that nearly 20 percent of the overall project cost resulted from contractors increasing their contingencies in response to inappropriate risk shifting by the owner (CII RR 210-11 2007). Another recent CII study (RT271) argued that current project delivery methods were insufficient to satisfy the needs and values of the owner and the contractor, and an ideal project delivery system must be able to a)

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align the interests of the parties, b) integrate organizationally, engaging downstream players in upstream work and vice-versa, and c) place management attention on enabling successful performance as opposed to strictly enforcing compliance to overly detailed requirements (CII RR 271-11 2012). The recent appearance of relational project delivery arrangements (IPD and Alliance Contracting) represent a paradigm shift as they entail risk sharing rather than risk transfer, taking project team collaboration and integration to a higher level. In its most complete form, IPD encourages active behavior that maximizes project performance by removing impediments to creativity and collaboration, aligning stakeholders' goals with project objectives, and incentivizing actions that add value to the project (Ashcraft 2012). This transition from risk transfer to risk sharing represents an evolution in project delivery philosophy, creating a high level of trust and open communication among project participants as the keys to project success.

Integrated Project Delivery is a project delivery approach that integrates people, systems, business structures, and practices into a collaborative process to optimize results and increase value of the project by maximizing efficiency through all phases of design, fabrication, and construction (AIA 2007). While IPD is still an evolving concept, it comprises a broad spectrum of project delivery strategies, methods and tools that fundamentally promote team collaboration and work process integration to achieve the best value for the project. Using research findings from Lahdenpera (2012), Kent and Becerik-Gerber (2010), and AIA et al. (2014), IPD characteristics may be categorized as six cardinal pillars; a) early involvement of key stakeholders, b) shared risk and reward, c) collaborative decision-making and control, d) jointly developed and validated targets, e) Liability waivers among key participants, and f) multi-party agreements. The characteristics in these six pillars are not mutually exclusive but rather highly interdependent.

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A significant number of commercial IPD (CIPD) projects have been completed in the past decade and early studies on IPD experience and its performance are highly positive (Cheng et al. 2018). El Asmar et al. (2013) used data gathered from 35 recent commercial projects and concluded that IPD provided higher quality facilities faster with no significant cost premium and achieved "statistically significant improvements in 14 metrics across six performance areas: quality, schedule, project changes, communication among stakeholders, environmental, and financial performance." Franz et al. (2016) surveyed more than 200 respondents and found that as team integration increased, project schedule growth was significantly reduced. It is also important to note that another highly integrated project delivery method called Alliance Contracting or more commonly Alliancing has been successfully employed internationally to deliver large infrastructure and industrial projects in Europe, Australia and New Zealand. In Australia, Alliancing has become a broadly accepted procurement and delivery method for risky and complex projects (DTF 2010). Philosophically and conceptually, Alliancing strives to achieve the same goals as IPD and both operate on a "best for project" basis where everybody wins or loses. Alliancing has performed with similar positive results as commercial IPD in a survey of 71 alliance infrastructure projects, 85% of projects met or came in under budget, and 94% of alliance projects were completed on time or ahead of schedule (Tamburro 2009).

Research Objectives

Current methods for the delivering of industrial capital projects have frequently failed to meet business objectives. Due to this failure in current industrial project delivery, the research is evaluating use of a more integrated and collaborative project delivery method. Thus the question is posed, can increased collaboration and integration though the use of Integrated Project Delivery (IPD) and alliancing improve overall project performance and

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provide a better business case on industrial projects? Therefore, research seeks to test the following hypothesis:

IPD theory and principles can significantly improve industrial projects' key project performance metrics including safety, early cost and schedule certainty, and quality.

Assuming that the hypothesis is confirmed to be true, the primary purpose of the research is to develop a framework for implementing IPD for industrial projects by identifying, evaluating, and adapting the major IPD principles and methods used in execution of industrial projects. The specific research objectives include:

1. The dissertation will develop a way to measure overall collaboration and integration on an industrial project and determine if there is a business case for a more integrated and collaborative project delivery method on industrial capital projects.
2. The study will compare collaborative and integrated delivery methods used in parallel sectors such as commercial IPD (CIPD) and civil infrastructure alliancing to define the collaboration and integration principles needed to create a structure to enhance performance on an industrial project.
3. This research will develop an industrial integrated project delivery (I2PD) framework to deliver an industrial project with higher levels of collaboration and integration. This thesis will define specific implementation methods and evaluate the impact of each method on overall project collaboration and integration within the I2PD framework. And finally, this study will report on any challenges and barriers to implementation of I2PD collaboration and integration principles on industrial projects.

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Methodology and Data Collection

The specific methodology used for each research study is detailed in each of the chapters. However, the data sources used in the findings of the chapters used information gathered through the use of research instruments to include content analysis of literature, questionnaire surveys, case study projects, and structured interviews. The primary source of data used in development of the results and findings of this dissertation was a web-based questionnaire survey. The web-based questionnaire survey was distributed to Construction Industry Institute (CII) member companies in different market sectors including industrial projects such as manufacturing, power and utilities, midstream and mining, downstream and chemical, and the commercial sector including healthcare and buildings. 85 complete responses across these market sectors were recorded with an average of 29 years of experience in the industry. The survey respondents included representatives from owner, contractor, and designer organizations with 51% representing owners, 33% representing contractors, and 16% representing designers. The survey included 34 total questions designed for the purpose of evaluating if a more collaborative and integrated project is correlated to better project performance. The survey was broken into two parts of data collection. Part 1 of the survey was developed to gather demographic information about the survey participant and their company they represent. Part 2 of the survey was for the respondent to identify a project they have experienced that demonstrated a great amount of collaboration and integration and evaluate the performance of the project. The responses varied between projects that were completed or in-progress, with the majority of projects selected as being completed. The survey respondents were each asked the same questions and the questions were designed in a way to measure the level of collaboration and integration used on a project and the corresponding performance of the project using specified metrics (Fowler 1993). The measured outcomes were rated outcomes by the survey respondents compared to a typical

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project and a Likert scale was used to measure each question. See appendix B for a copy of the web-based questionnaire survey.

The results obtained from the web-based survey were validated with the use of selected case study projects' actual data. A case study project was selected from each of the five industry sectors as defined by CII, a) Upstream, Midstream, and Mining, b) Downstream and Chemicals, c) Manufacturing, metals and Life Sciences, d) Power and Utilities, and e) Healthcare and Buildings. A case study is an empirical study and is the preferred strategy when "how" and "why" questions are being posed, when the investigator has little control over the events, and when the focus is within some real-life context (Yin 1994). The case study allows the investigation to retain the holistic and meaningful characteristics of real-life events. Another benefit of using a case study is the ability to cover contextual conditions when the researcher believes that they might be highly pertinent to the analysis. In this sense, the case study is neither a data collection protocol nor merely an experimental design feature, but a comprehensive research strategy. Case studies involving participant interviews allow the researcher to probe the rationale behind events that produced the project performance outcomes (Harris and Brown 2010), which in turn permits a context to be defined in a manner unlike more common analytical/statistical research instruments. Please refer to appendix C for a copy of the full case study protocol.

Industry workshops were conducted with subject matter experts with the purpose of delving further into the information with the use of structured interviews. Structured interview techniques create an environment that encourages dialog and allows both the interviewee and the interviewer to digress as required to reach a meeting of the minds. This approach requires the researcher to first ensure that the question being asked was fully understood by the interviewee

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and before recording the answer, the protocol requires the interviewer to read back the answer to the interviewee and make sure that no misunderstanding has taken place. The structured interview questionnaire was developed on lines similar to the methodology prescribed by the US Department of Education (DOE) (ERIC/AE 1997). The DOE methodology is prescribed for use when the researcher needs to "spend considerable time probing participant responses, encouraging them to provide detail and clarification" (Harris and Brown 2010). The structured interview is best used when "information must be obtained from program participants or members of a comparison group… or when essentially the same information must be obtained from numerous people for a multiple case-study evaluation" (GAO 1991). Since both of these conditions apply to the problem at hand, the instrument is the appropriate tool for this research. A total of 32 subject matter experts participated in the industry workshop and the structured interview protocol is included in appendix D.

The I2PD framework developed and described within this dissertation was validated by a panel of subject matter experts in the industrial capital project delivery sector representing owner companies, contractors, and designers.

The self-test form provided by the Institutional Research Board (IRB) at Iowa State University, (https://www.compliance.iastate.edu/sites/default/files/imported/irb/forms/docs/RIH-self-test%2010.3.2017.pdf), was completed and it was clear that this research did not require an IRB review. Based on this information, the project did not proceed for the IRB review process.

Content Organization

The dissertation is organized in a three-paper format, Figure 1-1 shows the key research objectives of each paper. Chapter 1 describes the study's problem statement purpose and the motivation.

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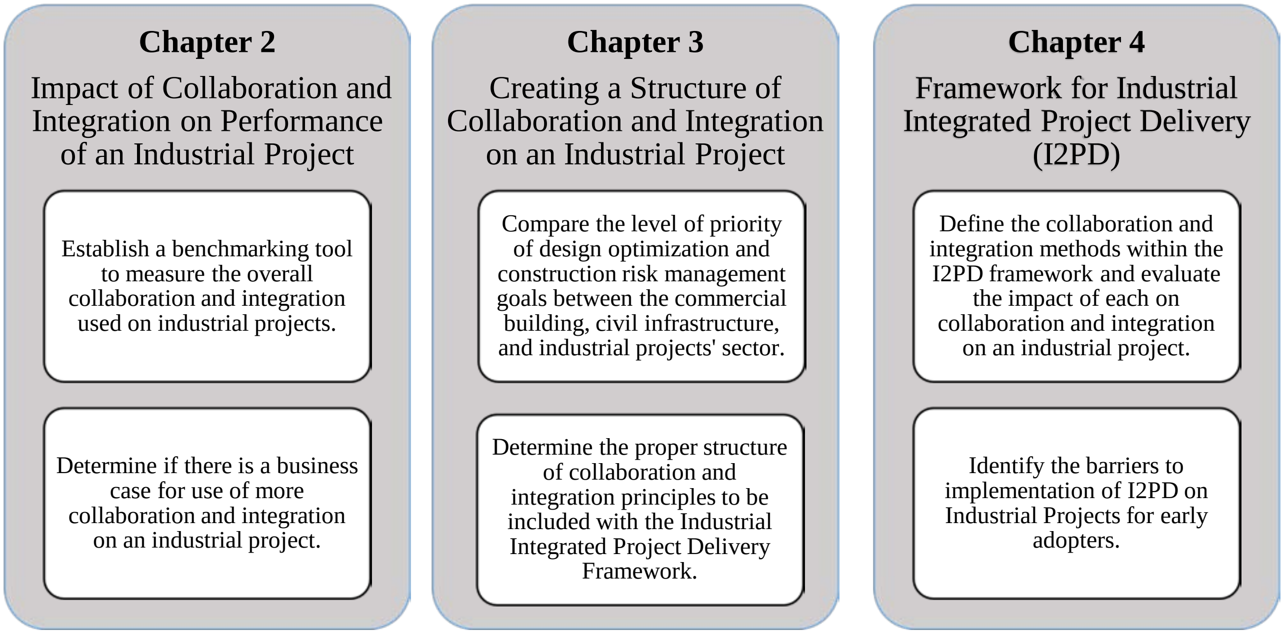

Figure 1-1. Research Objectives for each paper.

Chapter 2 reports the results of an industry survey and tests the hypothesis that increased collaboration and integration can significantly improve the overall performance on an industrial project. The findings of this paper lay the groundwork for Chapters 3 and 4.

Chapter 3 reports the results of a comparison of key performance objectives from a survey of industrial projects and a content analysis of the literature on commercial building projects and civil infrastructure projects to investigate if industrial projects performance was more closely related to commercial building or civil infrastructure projects. The paper also identifies a set of collaboration and integration principles found on commercial IPD and infrastructure alliance projects.

Chapter 4 proposes the industrial integrated project delivery (I2PD) framework, describing how to implement collaboration and integration on an industrial project. The paper defines each of the collaboration and integration methods included in the I2PD framework and

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charts the impact of each method on project collaboration and integration. The chapter also informs early adopter practitioners by reporting on barriers to implementation.

Chapter 5 presents the conclusions, limitations and future research, and contributions to body of knowledge.

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CHAPTER 2 IMPACT OF COLLABORATION AND INTEGRATION ON PERFORMANCE OF INDUSTRIAL PROJECTS

A paper to be submitted to the Journal of Construction Engineering and Management, published by the American Society of Civil Engineers (ASCE).

Barutha, P., Jeong, H.D., Gransberg D., Touran A.

Abstract

Large scale industrial projects are challenging undertakings due to high degrees of complexity, multiple stakeholders with differing business objectives, evolving technology, building in adverse environments, and other difficulties. Due to these multitude of challenges industrial projects experience, they can be seen as high risk business ventures. More collaborative project delivery strategies such as Integrated Project Delivery (IPD) and alliancing have been used to manage and mitigate risks associated with delivery of projects in other sectors such as commercial buildings in the United States. These project delivery methods use more collaboration and integration to increase the amount of certainty in the project life thus reducing the amount of risk experienced through project execution and increasing project performance. This study evaluates the performance of industrial projects when more collaboration and integration strategies and methods are used. The research is based on the results of a survey of highly experienced professionals for industrial projects. In total, 85 complete survey responses were used and an index to quantitatively measure the level of collaboration and integration of a project was developed. The findings from this study statistically support that as the degree of collaboration and integration increases, the project performance increases in direct correlation while significantly minimizing uncertainties about project outcomes. This paper presents evidence to suggest more collaborative and integrated project delivery methods lead to better project performance certainty on industrial projects, increasing the likelihood of meeting industrial stakeholder business objectives.

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Introduction

Industrial projects have a documented history of failure during project execution, "data from more than 300 global megaprojects shows 65 percent of industrial projects with budgets larger than $1 billion US dollars failed to meet business objectives" (Merrow 2011). Merrow goes on to state "most big mistakes are made by senior business managers…because they have control of the things that matter most: strategy, money, and people." The commercial building sector in the United States (US) has utilized a more collaborative and less autocratic project delivery method for execution of projects and the American Institute of Architects (AIA) has defined this project delivery method as Integrated Project Delivery (IPD). "IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction" (AIA 2014). "IPD seeks to improve project outcomes through a collaborative approach of aligning the incentives and goals of the project team through shared risk and reward, early involvement of all parties, and a multiparty agreement" (Kent 2010). "IPD collaboratively involves key participants very early in the project timeline, often before the design is started" (El Asmar et al. 2013). IPD shifts from the autocratic structure of traditional delivery described by Merrow where control resides solely with the business manager to putting "control in the hands of the project participants and makes them responsible for total project outcome, not just their individual performance" (Ashcraft 2012). The US commercial sector is not the only industry to utilize a more collaborative and integrated style of delivering a project. Alliance contracting is a multiparty contracting strategy used in Australia, New Zealand, and Europe (Gransberg et al. 2015) and is defined by the Australian Department of Infrastructure

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and Transport as “a delivery model where the owner(s), contractor(s), and consultant(s) work collaboratively as an integrated team and their commercial interests are aligned with actual project outcomes.” (ADIT 2011)

Studies have been conducted in the US commercial building sector evaluating the performance of projects utilizing this more collaborative integrated style of delivering a project. El Asmar et al. (2013) found that IPD projects achieved “statistically significant improvements in 14 metrics across six performance areas: quality, schedule, project changes, communication among stakeholders, environmental, and financial performance.” Cohen (AIA 2010) performed case studies on 6 commercial IPD projects and concluded that a key outcome of IPD “is its ability to manage and mitigate risk for the three principal parties: the owner, the architect/engineer” and goes on to state “increased certainty means lowered risk.” Franz et al. (2016) collected data on 204 completed projects and concluded “delivery methods that involved the builder and specialty trade contractors before schematic design achieved higher levels of integration and were more equipped to control project schedule growth.” Other more collaborative delivery methods have shared similar success as commercial IPD. “Alliancing has a strong track record of successfully delivering high risk, complex infrastructure projects in Australia, New Zealand and elsewhere” (Gransberg et al. 2016). In a study conducted by Tamburro et al. (2009) survey results found that “85% of alliances had an actual outturn cost that met or came below the target outturn cost and 94% of alliances were completed on time or ahead of schedule.”

Industrial projects have been slower in adopting this collaborative and integrated approach of delivering projects such as IPD. A typical way to deliver an industrial project in today’s market is a project delivery method termed engineering, procurement, and construction

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(EPC) and can be seen as a mechanism to transfer project risk from the owner directly to the contracting firm. "The EPC contract approach shifts all the risk of project completion cost and performance onto the contractor's shoulders, it tends to trigger an adversarial project team relationship" (Grynbaum 2004). Due to less adoption of IPD in the industrial sector, there have not been many studies performed to determine if industrial projects see the same performance improvement delivering projects more collaboratively and in an integrated manner. This study seeks to answer whether higher collaboration and integration result in better performance of industrial projects by statistically evaluating the survey results of project performance from highly experienced professionals in the industrial sector.

Background

65 percent of industrial megaprojects fail to meet business objectives, (Merrow 2011) megaprojects are rarely mediocre; they tend to be either very, very good, or they are horrid. The 35 percent of the projects that succeeded were genuinely excellent projects, with average underrun of budget at 2 percent, completed on time, and the average production was well ahead of average (Merrow 2011). By contrast, the failures are truly miserable projects, they average a 40 percent cost overrun, slipped schedule by an average of 28 percent, and only averaged 60 percent of planned production in the first year. Merrow (2011) goes on to state, very large projects are fragile, they do not tend to simply degrade toward poor outcomes, they tend to collapse instead. Most of these projects must be very tightly integrated to achieve economic success, if one of the parts fails, the whole effort fails (Merrow 2011). Figure 2-1 below shows the success and failure projects detailed in Merrow's study, with the blue data points representing "successful" extraction and production (E&P) projects as defined by the study, while the red data points represent "failed" E&P projects. The metric on the spider graph

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represents the percent overrun or failure in cost (index and growth), schedule (index and slip), and facility production.

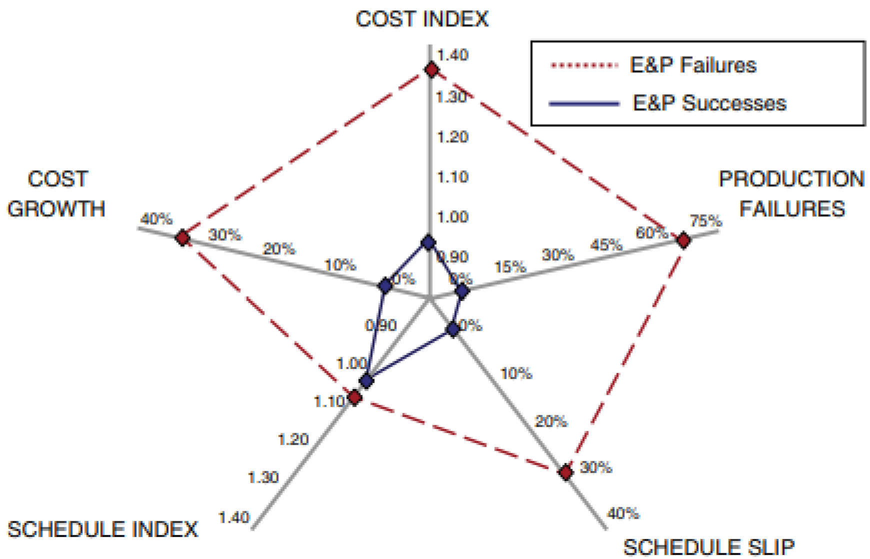

Figure 2-1 Industrial megaprojects successes and failures reprinted from Merrow (2012) with permission from Oil and Gas Facilities

In a similar study of capital project delivery, *Ernst & Young (2014)* identified 73 percent of megaprojects studied experienced schedule overruns, and 64 percent had cost overruns averaging 59 percent higher than original estimates, while Rui et al. (2016) analyzed approximately 200 public oil and gas projects, finding the average cost overrun of the projects is 18 percent, with a high variance of 29 percent standard deviation in this performance metric. And comparing the entire industry with the manufacturing industry, there is up to 57 percent of time, effort, and investment attributed to waste as compared with 26 percent in the manufacturing industry (CII RS 191 2005, Smith and Tardiff 2009). A study performed by *McKinsey&Company* has observed this overall industry trend while comparing labor productivity between the manufacturing industry and the construction industry Changali et al. (2015). The results show how manufacturing productivity has seen a steady increase since 1994

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while the construction industry has actually seen a slight decrease in productivity since 1994 with the productivity gap that is measured in value added per worker quantified by dollars per worker increasing to 1.7 times more productive for manufacturing workers compared with construction workers. Table 2-1 is a list of factors identified by the study leading to poor productivity and cost outcomes in the construction industry.

Table 2-1 Factors leading to poor productivity and cost outcomes in the construction industry (Changali et al. 2015)

Factors Leading to Poor Productivity and Cost Outcomes	
Poor organization	Decision-making and procurement processes do not have the speed and scale required.
Inadequate communication	Inconsistencies in reporting mean subcontractors, contractors, and owners do not have a common understanding of how the project is fairing at any given time.
Flawed performance management	The procurement team typically negotiates the contract, and this is almost always dense and complicated. When a problem comes up, project managers may not understand how to proceed.
Missed connections	There are different levels of planning, from high-end preparation to day-by-day programs. If the daily work is not finished, schedulers need to know – but often don't – so that they can update the priorities real time.
Poor short-term planning	Companies are generally good at understanding what needs to happen in the next two to three months, but not nearly so much at grasping the next week or two. The result is that necessary equipment may not be in place.
Insufficient risk management	Long-term risks get considerable consideration; the kinds that crop up on the job not nearly as much.
Limited talent management	Companies defer to familiar people and teams rather than asking where they can find the best people for each job.

Al Subaih (2015) observed similar findings, with analysis of available literature on industrial project delay factors, it was noticed communication, design, and planning represent the highest percentage in delay factors, accounting for a total of 44% of overall project delays.

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EPC is one of the popular project delivery methods in construction contracts of industrial projects (Baram 2005 and Loots et al. 2007) and is a single-point contract which includes the entire supply of materials and equipment, all design, engineering, procurement, construction and installation works as well as commissioning, start-up, training, acceptance and testing activities (Schramm et al. 2010). Schramm et al. (2010) goes on to state, industrial projects are characterized by increasing project complexity, different sizes and intensified international involvement leading to difficulties in meeting the project objectives and challenges in terms of timely completion, costs, quality and revenue. The complex nature of major projects together with their risks require detailed and carefully written contracts that define the legal, financial and technical aspects of the results and behavior desired by the contracting parties (von Branconi et al. 2003). Contracts shape the behavior of the parties involved and thus have a major impact on project success, contracts are, in essence, tools for allocation of tasks, responsibilities and risks (Schramm et al. 2010). It is the principle of contracting that the party who controls risk should carry the risk, however, a contractor will often carry a risk whether it is controlled by them or not – but at a price. EPC agreements are designed to transfer project risk from the owner to the EPC contractor and from the EPC contractor to designers and trade contractors. Contracts and subcontracts are used to assign and compartmentalize project risks, define rigid information process flows, and project objectives are defined through scope and performance specifications with an agreed to fixed cost and schedule. This structure built on rigid contract terms can impede efficient flow of information, optimized risk management, and achieving project focused objectives. The CII RT210 study revealed that nearly 20 percent of the overall project cost resulted from contractors increasing their contingencies in response to inappropriate risk shifting by the owner (CII 2007). Figure 2-2 depicts a typical EPC organizational arrangement.

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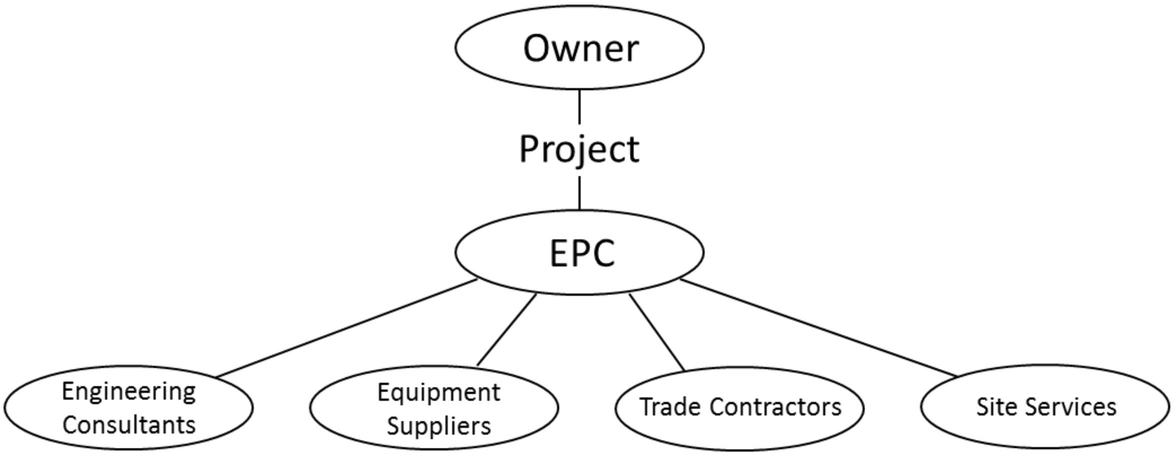

Figure 2-2 EPC project delivery organization chart adapted from Loots and Henchie (2007).

"Maximizing value and minimizing waste at the project level is difficult when the contractual structure inhibits coordination, stifles cooperation and innovation, and rewards individual contractors for both reserving good ideas and optimizing their performance at the expense of others" (Matthews 2005). Matthews (2005) goes on to state, there are two types of contracts, transactional and relational, with the latter being defined by the project team of the case study as Integrated Project Delivery (IPD). Ashcraft (2012) describes a commercial IPD project to have the following attributes;

- Remove impediments to communication, collaboration and creativity;
- Align participants to well understood and agreed objectives; and
- Encourage and reward behavior that increases project value.

Ashcraft (2012) explains further, these attributes must be built into the fabric of the IPD agreement, meaning, that no element of the contract should be inconsistent with the drivers of IPD, and that all elements should be consistent with IPD's values. Ashcraft lists the following as major structural elements of IPD;

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Table 2-2 List of major structural elements of IPD from Ashcraft (2012)

Major Structural Elements of Commercial IPD	
Early involvement of key participants	Reduced liability exposure
Joint project control	Jointly developed and validated targets
Shared risk and reward based on project outcome	

The American Institute of Architects (2014) describes IPD as having a multi-party agreement between owner, designer, and contractor.

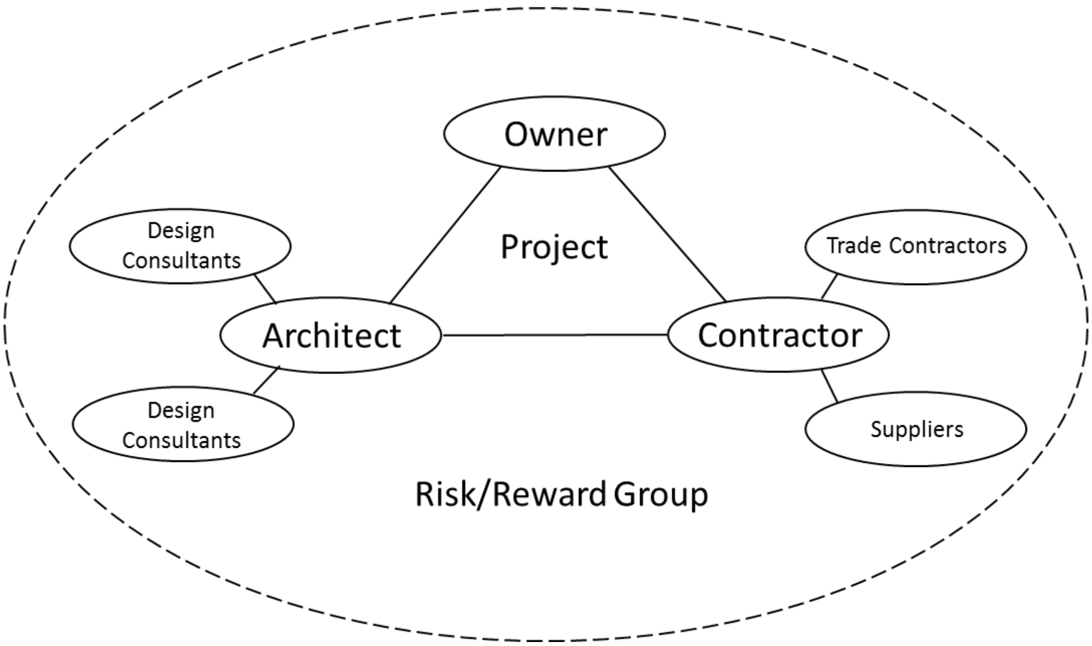

Figure 2-3 IPD relationship between project participants adapted from Ashcraft (2012)

Alliance contracting has been extensively used to stimulate collaborative relations between supply chain members as well as to address the need to improve the performance of projects (Davis et al. 2011). After the Canterbury earthquake in New Zealand (NZ), a massive reconstruction program commenced, with the total damage to commercial and infrastructure assets being estimated at approximately NZ$20 billion (Scheepbouwer et al. 2014). The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) is a ‘pure’ alliance commercial model that aligns commercial drivers with high performance objectives to deliver mutually agreed outcomes. Alliance contracting is defined by the Australian Government as delivering

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major capital assets where the owner works collaboratively with non-owner participants and all participants are required to work together as an integrated, collaborative team in good faith, acting with integrity and making unanimous best-for-project decisions on all key project delivery issues (ADIRD 2015). The value of projects undertaken in Australia using alliance contracting in the road, rail and water sectors over the period 2004 to 2009 was Aus$32 billion (Wood and Duffield 2009). "All major capital works projects involve inherent risks, e.g. political or economic change, climate, technology, ground conditions, engineering uncertainties, errors, industrial disputes, land issues, environmental issues and many more…In order to achieve optimal outcomes the project owner must select the most appropriate strategy for managing these risks" (Ross 2003). Ross (2003) continues to state that from an owner's perspective the traditional "risk transfer" approach still can be a good method for many projects – especially ones where the scope is clear and the circumstances and risks are reasonably predictable. However, more and more projects are being required to be delivered in an environment of uncertainty – driven by diverse stakeholder interests, shifting business or political imperatives and rapid technological change (Ross 2003).

A project alliance can be characterized as a commercial/legal framework for delivering one or more capital works projects with the following characteristics (Department of Treasury and Finance of Victoria 2006);

- Collective sharing of all project risks;
- No fault, no blame and no dispute between the alliance participants;
- 100 percent open book basis;
- A fee to cover corporate overheads and normal profit;

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- Gainshare/painshare regime where the rewards of outstanding performance and the pain of poor performance are shared equitably among all alliance participants;
- Unanimous principle-based decision-making on all key project issues; and
- An integrated project team selected on the basis of best person for each position (Department of Treasury and Finance of Victoria 2006).

Motivations for alliancing have a sustainability focus; sustainability in human capital, organization knowledge, risk and uncertainty management (Walker et al. 2015). Walker et al. (2015) performed a study on performance data from three surveys of construction alliance projects in Australia and New Zealand undertaken in 2008, 2010 and 2012. The findings suggest evidence of a significant industry improvement in large-scale engineering infrastructure project delivery. In comparing the actual final cost to the budgeted target cost of the 61 results the average cost underrun between actual cost and target was 4.07 percent under budget. Cost and time results were closely related in this study. Also of note is how the projects faired with overall project value including all other key performance indicators. This was defined by the study as project value statement (PVS) which represents the summary of the Value for Money (VfM) proposition of the project that justified the client investing in the project. Alliance projects outperformed their counterparts with higher ratings of PVS client satisfaction.

Methodology and Data Collection

A web-based questionnaire survey was distributed to Construction Industry Institute (CII) member companies in different market sectors including industrial projects such as manufacturing, power and utilities, midstream and mining, downstream and chemical, and the commercial sector including healthcare and buildings. 85 complete responses across these market sectors were recorded with an average of 29 years of experience in the industry. The

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survey included 34 total questions designed for the purpose of evaluating if a more collaborative and integrated project is correlated to better project performance. The survey was broken into two parts of data collection. Part 1 of the survey was developed to gather demographic information about the survey participant and their company they represent. Part 2 of the survey was for the respondent to identify a project they have experienced that demonstrated a great amount of collaboration and integration and evaluate the performance of the project. The survey respondents were each asked the same questions and the questions were designed in a way to measure the level of collaboration and integration used on a project and the corresponding performance of the project using specified metrics (Fowler 1993). A Likert scale was used to measure each question.

The survey was designed in a manner to collect data that could later be used to create an index to quantitatively measure the degree of collaboration and integration used in the project (Assaf et al. 2005). Specific principles and methods used to create and facilitate collaboration and integration were identified through literature review of project delivery methods such as commercial IPD in the US and Alliance contracting overseas. The survey respondents were asked to identify if each listed method and tool was used on their chosen project and if so what the relative frequency and intensity were.

Data Analysis and Results

Mesa et al. (2016) performed a study to determine what drivers were the most influential to project delivery performance. Their study found the most influential drivers to project success to be communication, alignment of interest and objectives, team working, trust, and gain/pain sharing. Lofgren et al. (2009) studied the effect of collaboration methods on project performance and found project performance is enhanced by collaboration. There is a suite of defined

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collaboration and integration principles and methods available that both create a structure of collaboration and integration as well as facilitate coordination of horizontally aligned work tasks within the integrated team. Many of these principles and methods are used in IPD projects in the US commercial building sector and in projects delivered as an Alliance overseas. The principles are developed to align the interest and objectives of project stakeholders and to better share the gain/pain, while the methods help to enhance communication and teamwork among the project team members. Table 2-3 represents the list of collaboration and integration (C.I.) principles and Table 2-4 represents the list of C.I. methods evaluated with this study.

Table 2-3 List of collaboration and integration principles measured on survey.

Collaboration and Integration Principles	
Early Involvement of Stakeholders	Shared Cost and Reward
Continuous Team Building	Negotiated Risk Distribution
Jointly Developed and Validated Targets	Non-traditional Contracting
Collaborative and Equitable Decision Making	

Table 2-4 List of collaboration and integration methods measured on survey.

Collaboration and Integration Methods	
Alternative Scheduling Method	Partnering Sessions
Co-location	Pre-assembly
Constructability Planning in Design	Quality Improvement Process Techniques
Contract Incentives	Rapid Process Improvement Workshops
Design to Cost Approach	Standardized Design Techniques
Front End Planning	Strategic Partnerships
Joint Risk Assessment Tool	Team Building
Value Stream Mapping	Use of Technology as an Integration Tool
Multi-party Agreements	Value Engineering Planning in Design
No Dispute Charter	Waste Minimization Techniques

A C.I. Index was created for each project identified on the survey. This measured the number of collaboration and integration principles and methods used on the project along with the intensity of each principle and methods used. The C.I. index (equation 2-1) is based on a metric from 0-100 and combines the Principles Index (number of principles used x intensity of principles used) and the Methods Index (number of methods used x intensity of methods used).

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$$C.I.Index = \frac{Principles\ Index\ x\ Methods\ Index}{100} \qquad \text{(Equation 2-1)}$$

Where,

$$Principles\ Index = \left[\frac{Number\ of\ Principles\ used}{Total\ Number\ of\ Principles} x\ 100\right] x \left[\frac{Average\ impact\ rating\ of\ Principles\ used}{5} x\ 100\right],$$

$$Methods\ Index = \left[\frac{Number\ of\ Methods\ used}{Total\ Number\ of\ Methods} x\ 100\right] x \left[\frac{Average\ impact\ rating\ of\ Methods\ used}{5} x\ 100\right],$$

Each survey participant identified how each project performed relative to the specific performance metrics tracked on each project. The top five performance metrics used were safety, quality, client satisfaction, schedule certainty, and profit (return on investment). An average project performance was calculated for each project on a scale of 1-5 with 5 being the best and 3 being as compared to a typical project. Figure 2-4 shows the graph of average project performance plotted on the y-axis and the C.I. Index on the x-axis.

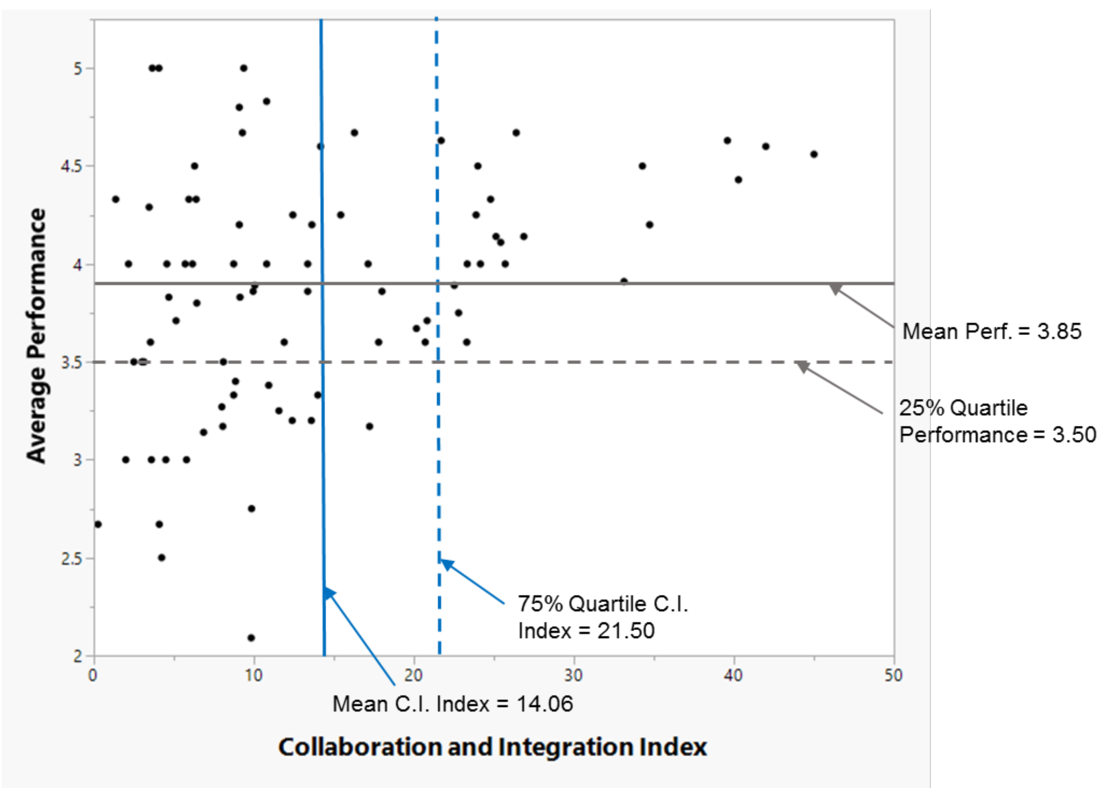

Figure 2-4 C.I. Index (x-axis) x Average Project Performance (y-axis)

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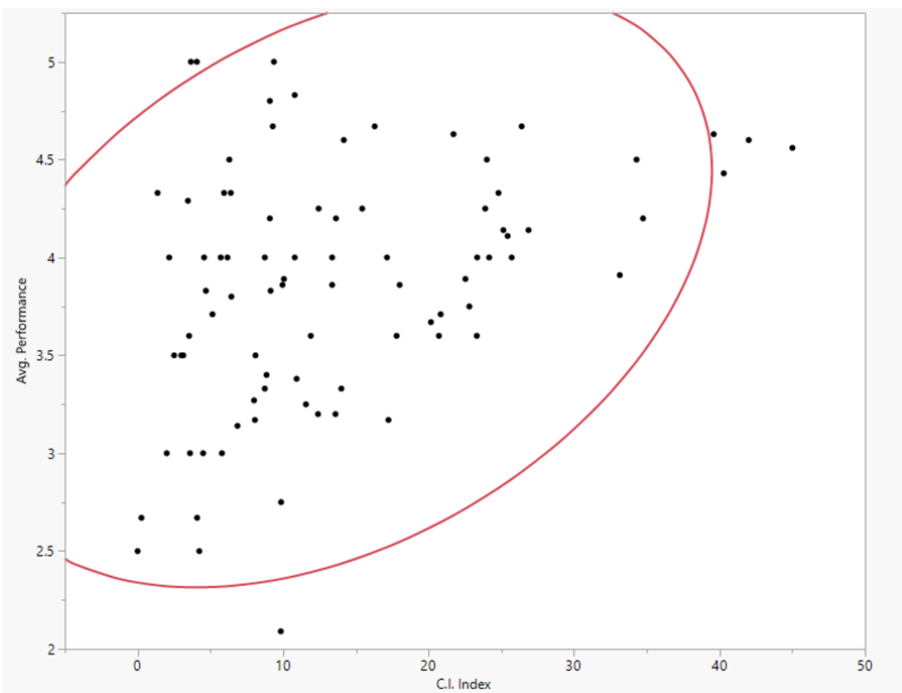
The graph illustrates a pattern that shows how collaboration and integration affect project performance. It is clearly evident that as the C.I. Index increases, little to no low performing projects exist on the plot. There is a high degree of variability in project performance when fewer C.I. principles and methods are used, but this performance variability significantly decreases as more C.I. principles and methods are used. A correlation test was performed to analyze if in fact more use of collaboration and integration is correlated to better project performance, thus testing the study's hypothesis. Figure 2-5 shows there is a statistically significant positive correlation as the C.I. Index increases, the average project performance increases.



Correlation Test – Normal Ellipse P = 0.95

Variable	Mean	Std Dev	Correlation	P-Value	Number
C.I. Index	14.06	10.45	**0.38599**	0.0003	85
Avg. Performance	3.85	0.62			

Figure 2-5 Correlation test results of C.I. Index correlated to better project performance.

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For further analysis, the projects were divided into bins of 5 to statistically measure the degree of correlation and the performance variability. The 85 projects were separated into a total of 17 bins of 5 ranked from the highest C.I. Index to the lowest C.I. Index. A simple linear regression was used identifying the average C.I. Index of each bin as the independent variable and the average project performance of each bin as the response variable. Figure 2-6 shows the graph of the average C.I. Index of each bin on the x-axis and the average project performance of each bin on the y-axis.

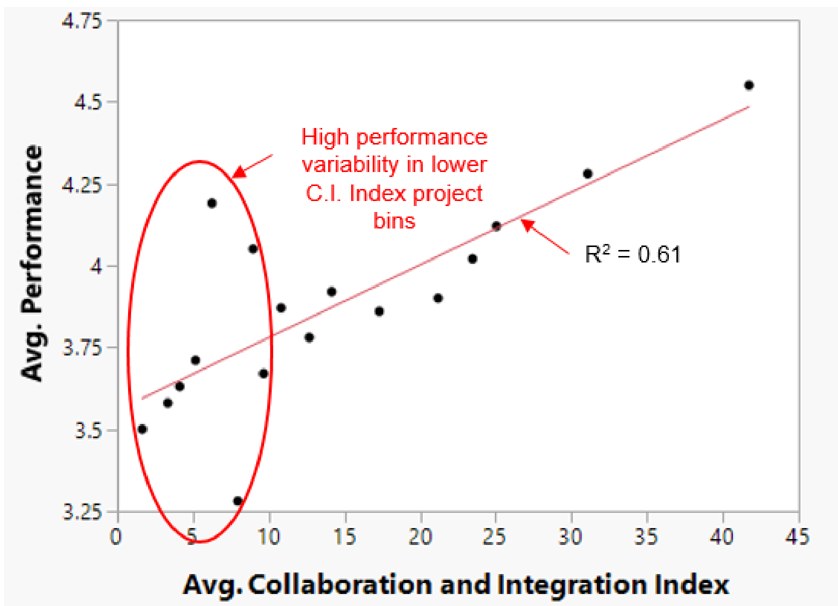

Figure 2-6 17 bins ranked by C.I. Index vs Average Performance

This graph illustrates a higher degree of variability of the average project performance with bins of projects of lower C.I. Indexes, while the top 8 ranked bins (40 projects) in use of C.I. principles and methods, demonstrate that the variability is dramatically reduced. The difference in project performance variability can be measured using the standard deviation. The average standard deviation of the top 8 bins is 0.36, and the average standard deviation of the

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bottom 8 bins is 0.63. The difference in this statistic indicates the risk of a low performing project is significantly reduced as more collaboration and integration is used on a project.

To evaluate the statistical difference of performance of the two groups, high use of C.I. (C.I. Index > 10) versus low use of C.I. (C.I. Index < 10), a two sample non-parametric t-test was performed using the Wilcoxon method due to the non-normal distribution of the high C.I. projects' group (Sawilowsky 1990). The p-value of the z-statistic from the chi-square distribution is P = 0.0245, meaning the two groups are statistically significantly different with respect to performance. A simple linear regression was plotted showing the correlation of the high C.I. group (C.I. > 10) to project performance, using the average C.I. Index of each bin as the independent variable and the average project performance as the response variable. Figure 2-7 illustrates the correlation in the top 8 ranked bins C.I. Index (x-axis) and the average project performance (y-axis). The regression analysis using a simple linear regression plot shows a very high coefficient of determination (R^2), indicating a very good fit in correlation between the amount of collaboration and integration principles and methods used (x-axis) and the average project performance of the project (y-axis).

This result means that when the project has reached a certain level of collaboration and integration, there is a direct correlation between the level of collaboration and integration and project performance. Below the certain level of collaboration and integration needed, the average performance of the project is highly variable and unpredictable. There are some high performing projects with lower collaboration and integration, but there are also many projects performing at a much lower rate. When the amount of collaboration and integration is increased, the likelihood of a poor performing project is extremely low.

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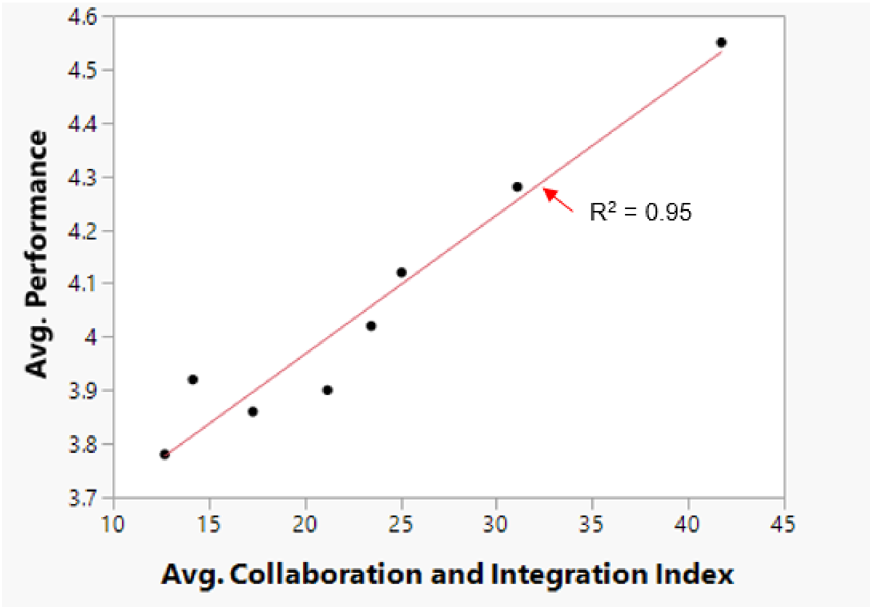

Figure 2-7 Regression plot of Top 8 bins

Value of Project Certainty

In the project world, significant cost and schedule overruns are the norm and are rarely predictable despite the application of seemingly sophisticated risk analysis methods (Hollman 2016). Many company's project system is not capable of managing such a complex project effectively even if the scope is well-defined. Project strategy, processes, practices, organization, and stakeholder interaction are a system, and if this is weak, this is the risk that matters most. To treat systemic risks and improve project outcomes, the project system must be improved (Hollman 2016). Risks emerge and evolve over time, risks in consideration during the initial phases of the project are usually very different from the ones at the completion phase of the project and require changes in project execution plans (Kardes et al. 2013). IPD provides a project delivery method that uses collaboration and integration to enable a project to be more adaptable to the changing environment and more resilient to internal and external risks. The use of collaboration and integration provides a system to allow efficient flow of information,

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optimized risk distribution and management, and decisions focused on achieving project centered objectives. The results of this study show a strong correlation as collaboration and integration increases beyond a certain threshold, project performance reaches levels close to 97 percent certainty. Figure 2-8 shows how the use of collaboration and integration can increase project predictability and significantly reduce the risk of a poor performing industrial project.

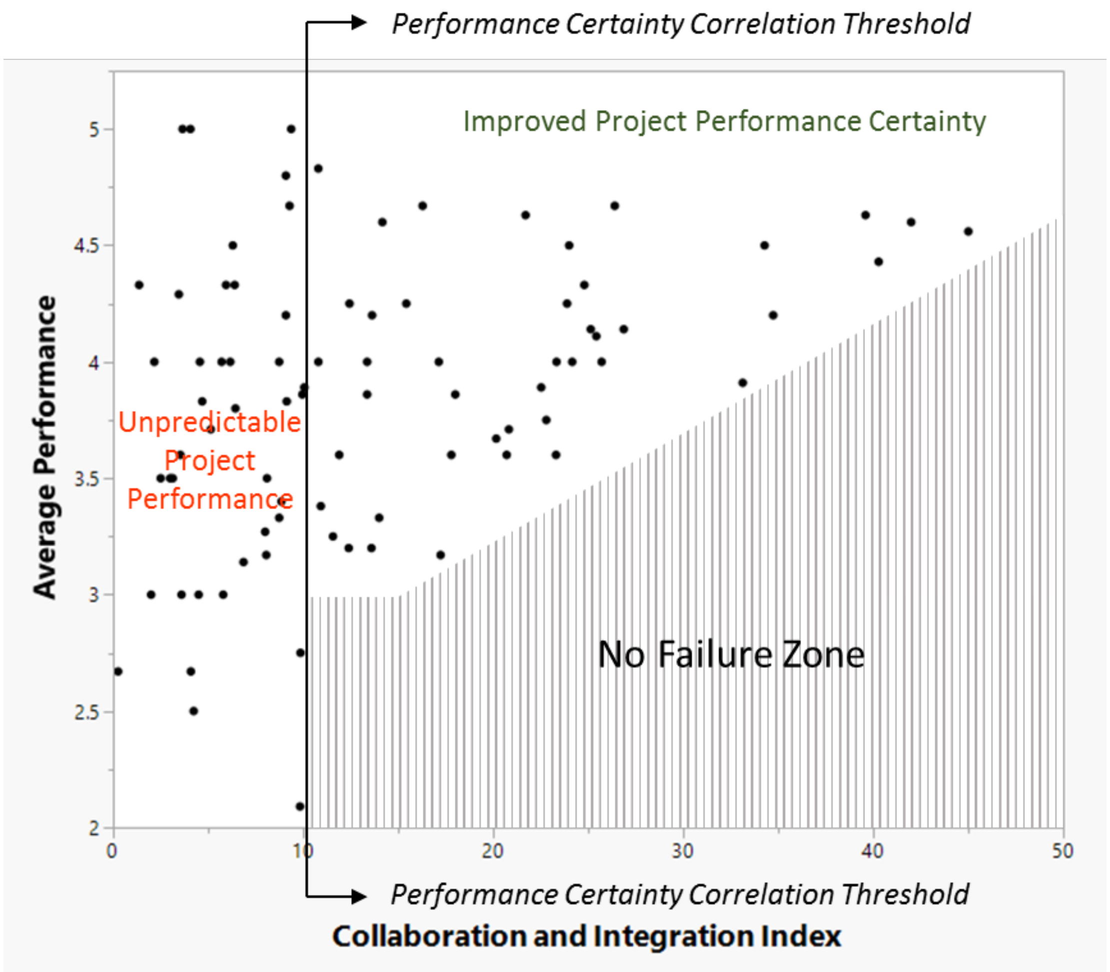

Figure 2-8 As collaboration and integration increase, project performance certainty increases.

Conclusion and Discussion

IPD is a project delivery method that creates a culture of best for project decisions through collaboration and alignment of commercial interests through integration among the

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major stakeholders of a project including the owner, designer, and contractor. Over 98% of survey participants responded that more collaboration and integration increases overall project value for money on industrial projects. This study's results are consistent with the industry professionals' perception about the value of project collaboration and integration. Statistical analysis on 85 complete survey responses in this study has revealed that project performance increased as the number and intensity of collaboration and integration principles and methods used increase. The study also concluded that the variability of project performance decreases as collaboration and integration increases, meaning there is less probability of a poor performing project if more collaboration and integration principles and methods are used on the project and higher certainty of overall project performance. The findings of this research are consistent with previous studies conducted evaluating project performance on commercial IPD projects (El Asmar et al 2013) and alliance contracting overseas (Tamburro et al. 2009) which showed more collaborative delivery strategies outperformed traditional project delivery. The C.I. index developed in this study could be used as an effective benchmarking tool for project managers. The findings of this research can also be used as proven evidence for the industrial sector to accelerate the use of more collaborative and integrated project delivery methods such as IPD.

Limitations

This paper studied the effects of collaboration and integration on industrial project performance and the results are limited to member companies of the Construction Industry Institute (CII) which was the population of the survey distribution. The findings from this research may not be applicable to all capital projects and their sponsors.

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CHAPTER 3 CREATING A STRUCTURE OF COLLABORATION AND INTEGRATION ON AN INDUSTRIAL PROJECT

A paper to be submitted to the Journal of Management in Engineering, published by American Society of Civil Engineers (ASCE).

Barutha, P., Jeong, H.D., Gransberg, D., Kang, Y.

Abstract

There is evidence to suggest the use of collaboration and integration principles and methods improve overall project performance on industrial projects. Commercial IPD and Civil Infrastructure Alliance Contracting have specific collaboration and integration principles that define each as a unique delivery method. This paper investigates how commercial building, industrial capital projects, and civil infrastructure industry sectors each define project success, essentially, what are the important key performance indicators for each type of project, using data from an industry survey comprising 85 complete responses from subject matter experts in the industrial project delivery sector. The study also compares the use of specific collaboration and integration principles in the commercial and civil infrastructure sectors showing how some principles are used more predominantly in collaborative commercial IPD and where others are used more in integrated civil infrastructure alliancing project delivery. This study serves as a guide to properly identify collaboration and integration principles that will allow better enhanced performance of industrial integrated project delivery.

Introduction

From chapter 2, an industry-wide survey with 85 project responses show that increased collaboration and integration is correlated to industrial project performance. Figure 3-1 graphs the 85 projects with the amount of collaboration and integration used (C.I. Index) on the x-axis and average project performance on the y-axis. The C.I. Index is a metric

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created to measure the amount and intensity of collaboration and integration principles and methods used on the project. The responses are divided into 3 groups of projects; high C.I./high performance (A), low C.I./high performance (B), and low C.I./low performance (C). It was found the high C.I./high performance group (A), better performance was strongly correlated to the amount of C.I. used on the project. The low C.I./low performance group (C) showed no correlation to C.I. used but there was a moderate correlation to leadership, specifically poor leadership was correlated to poorer performing projects. The low C.I./high performance group (B) showed no performance correlation to any of the project attributes such as leadership, project team, C.I. used, delivery method, and project complexity. This group statistically outperformed the low C.I./low performance group, but the increased performance was found to be random success.

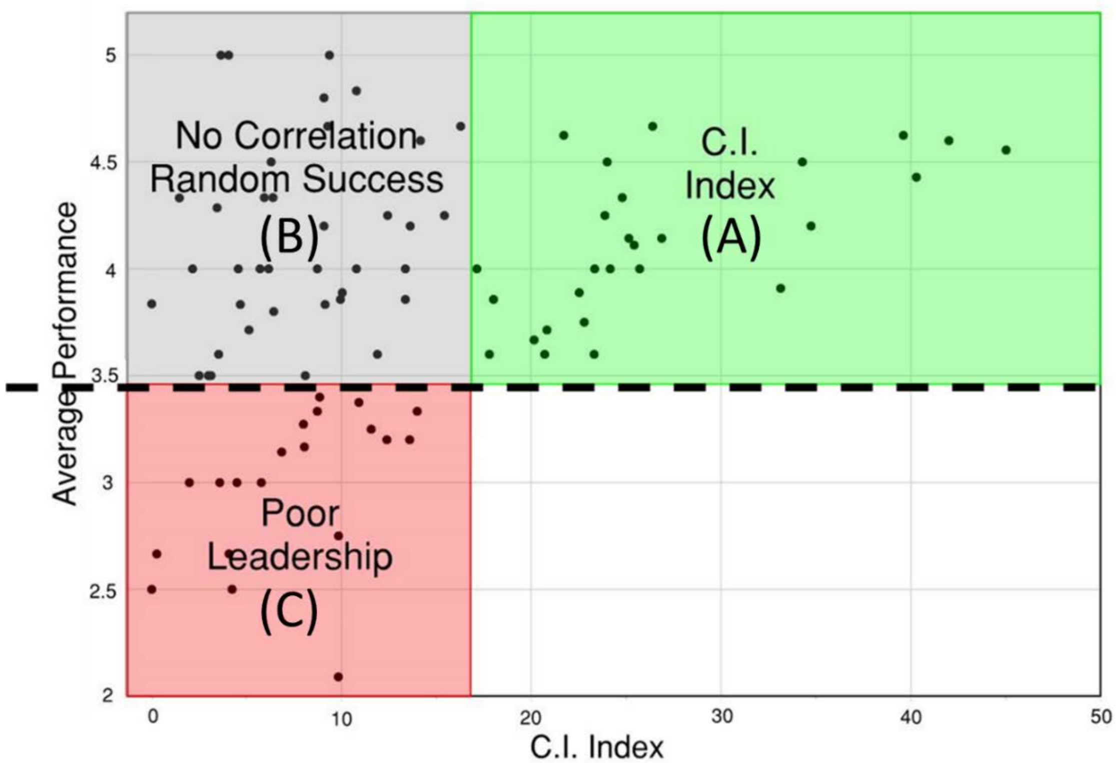

Figure 3-1 Correlation of average project performance grouped by amount of C.I. used on 85 industrial projects.

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These findings suggest a change in the project organizational structure from a model more reliant on strong top down leadership to a model more reliant on collaboration and integration amongst the project team. The results of this analysis indicate strong leaders are able to keep the project team focused on achievement of project performance objectives but when top down leadership has below average capability, the project team loses its project centered focus and meeting performance objectives becomes less achievable for the project. Whereas, an environment of collaboration and integration amongst key project participants creates a project structure centered on achievement of key performance objectives of a project. Figure 3-2 is adapted from Ashcraft and Reed (2017) illustrating how each of the two high performance groups (Group A and Group B) were able to achieve project performance goals, the group on the left through the effort of strong top down leadership and the group on the right using collaboration and integration to create a structure of project centered focus.

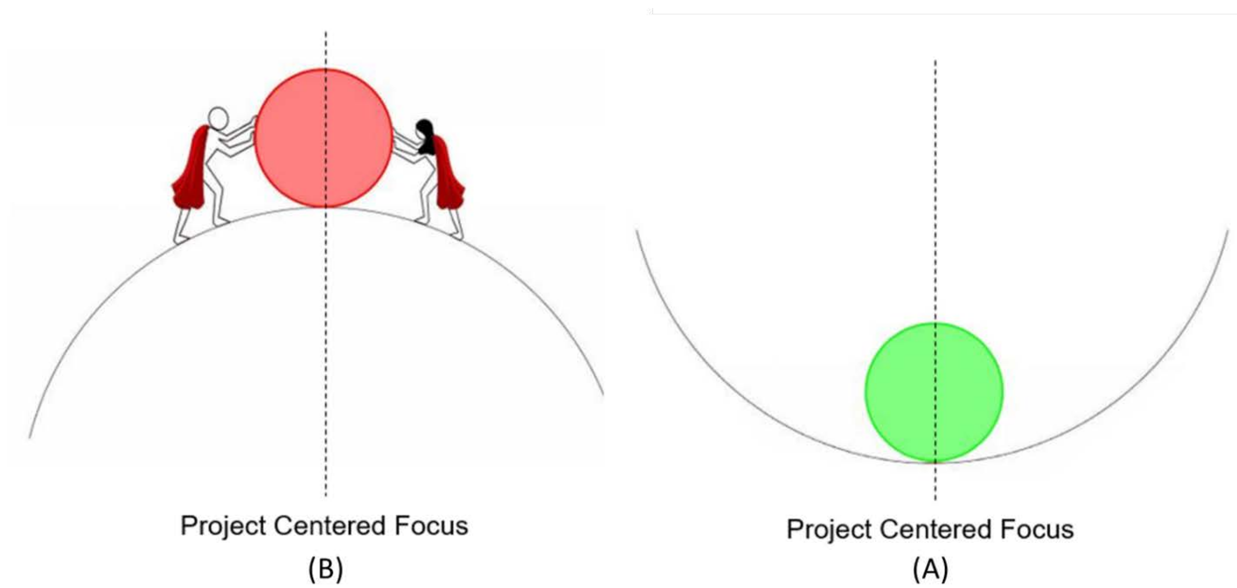

Figure 3-2 Diagram illustrating how project delivery structure impacts project center focus, adapted from Ashcraft and Reed (2017).

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This paper examines how industrial projects can structure the use of collaboration and integration to create an environment shaped to enhance the achievement of key performance objectives on these projects. Integrated Project Delivery (IPD) is used in the commercial sector to build an environment of collaboration structured in a way to achieve the important performance objectives of a commercial building project. Alliance contracting is a delivery method used in Australia and New Zealand on development of civil infrastructure projects that relies on integration of key project stakeholders aligned to specified business objectives to achieve project success. Both of these delivery methods rely on the use of specific collaboration and integration principles to create an environment of joint “best for project” decision-making and alignment of commercial interests among key project stakeholders. Commercial IPD and infrastructure alliancing have varied application in use of the collaboration and integration principles on their respective projects. There is no highly collaborative integrated delivery method comparable to commercial IPD or infrastructure alliancing in the industrial sector so the principles defining industrial integrated project delivery do not exist. Hence the answer to the following research question is evaluated:

Can the collaborative principles found in commercial IPD and the principles of integration used in infrastructure alliancing be combined to enhance the performance of industrial projects?

The research objectives of this paper are:

1. IPD and alliancing are outcome focused delivery methods, the first objective of this study is to evaluate how commercial building projects define success compared with civil infrastructure projects, essentially, to determine what the important outcomes or

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key performance indicators each sector values for overall project performance and compare importance of outcomes between sectors. Is there a higher priority on project design optimization outcomes or construction risk management outcomes in commercial buildings as compared with civil infrastructure projects?

2. Secondly, the study will evaluate how industrial project performance outcomes compare with commercial building and civil infrastructure projects. Do key performance indicators of industrial projects compare more favorably to commercial buildings, or civil infrastructure projects, or a combination?
3. Finally, the paper will assess if there is a heavier emphasis on use of specific key collaboration and integration principles used on commercial IPD projects and civil infrastructure alliancing projects to discover if there is a trend on principles used in relation to the key performance objectives of each industry sector. IPD and alliancing project delivery methods are based on achieving outcomes, and a collaborative and integrated project delivery method customized for industrial projects will need to be structured in a way to achieve the important performance outcomes of the industrial project sector.

Background

IPD and Alliancing Principles

The American Institute of Architects (AIA) provided a definition for commercial IPD; however, in practice, there is no consistent model accepted by the industry as a whole. “Different definitions and widely varying approaches and sophistication levels mean that the term “IPD” is used to describe significantly different contract arrangements and team processes.” (Kent 2010). Kent goes on to

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further state, “however there are some common principles to define IPD: 1) multi-party agreements, 2) early involvement of all parties; and 3) shared risk and reward.” In a review of five publications describing commercial IPD’s contract arrangements and team processes, the following six defining characteristics are found:

- Early involvement of key participants,
- Shared risk and reward,
- Collaborative decision-making and control,
- Jointly developed and validated targets,
- Liability waivers among key participants, and
- Multi-party agreements.

Table 3-1 represents the frequency of each characteristic observed in review of each publication defining the delivery method.

Table 3-1 Literature review of commercial IPD characteristics observed in each publication.

	Kent 2010	Aschcraft 2012	NASFA 2010	Lahpendera 2012	Cohen 2010
Early Involvement of Key Participants	X	X	X	X	X
Shared Risk and Reward	X	X	X	X	X
Collaborative Decision Making and Control		X	X	X	X
Jointly Developed and Validated Targets		X	X	X	X
Liability Waivers among Key Participants		X	X	X	X
Multi-party Agreements	X			X	X

The form of alliance contracting used in Australia and New Zealand relies on high levels of integration among alliance members that is thought to also produce enhanced cooperation between the individuals each member assigns to the project. A review of public policy documents on alliancing in Australia found the following six main principles:

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- Early involvement of key participants,
- Risk and opportunity sharing,
- Commitment to ‘No Disputes’, ‘no fault-no blame’ culture,
- ‘Best for Project’ unanimous decision-making processes,
- Transparency expressed as open book documentation and reporting, and
- Collective sharing of project risks.

The four most populous Australian states have institutionalized all of these principles in their policy documents, as shown in Table 3-2.

Table 3-2 Alliance contracting principles observed in each state institution guidelines.

	Queensland 2008	New South Wales 2005	Victoria 2010	Western Australia 2010
Early Involvement of Key Participants	X	X	X	X
Risk and Opportunity Sharing, gain share/pain share	X	X	X	X
Commitment to ‘No Blame’ culture, no disputes	X	X	X	X
‘Best for Project’ unanimous decision-making process	X	X	X	X
Transparency expressed as open book documentation and reporting	X	X	X	X
Collective Sharing of (nearly) all Project Risks	X	X	X	X

Commercial IPD and Alliancing Principles used on Selected Case Study Projects

Commercial IPD and alliancing share many of the same principles; “early involvement of key parties, transparent financials, shared risk and reward, joint decision making, and a collaborative multi-party agreement” (Lahdenpera 2012). The continent of Australia has institutionalized many of these principles in government policy documents as

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seen in Table -3-2 above where IPD's principles have been used primarily in the private sector in the US and literature has identified many of the principles through various studies. A content analysis was conducted of selected case study projects performed using commercial IPD in the US and alliancing in Australia or New Zealand to determine the frequency of use of these principles on actual projects. The commercial IPD case studies were building projects, with most of them being hospitals, documented in an AIA and University of Minnesota study published in 2012. The alliancing case studies were civil infrastructure projects upon which a content analysis was performed to identify the principles documented in the request for proposal (RFP), project alliancing agreement (PAA), or contract templates. The alliancing projects were selected at random. The content analysis focused on the commercial IPD collaboration principles and alliancing integration principles used in each respective case study project. Table 3-3 depicts the percentage of each principle used on 12 commercial IPD projects, and table 3-4 illustrates the percentage of each principle used on 10 alliancing projects.

Table 3-3 Commercial IPD Case Study Projects use of IPD principles (AIA 2012).

IPD Principles	Cathedral Hill	Mercy Master Plan	Lawrence & Schiller	Spawglass Austin	Edith Green Wendell	Autodesk	Sutter Health	Cardinal Glennon Childrens Hospital	St. Clare Health	Encircle Health	Walter Cronkite School of Journalism	UCFS Mission Bay	**Total Frequency**
Collaborative Decision-making and control	X	X	X	X	X	X	X	X	X	X	X	X	**100%**
Early Involvement of Key Participants	X	X	X	X	X	X	X		X	X	X	X	**92%**
Jointly Developed and Validated Targets	X	X	X	X		X	X			X	X	X	**75%**
Multi-party Agreements	X	X	X	X		X	X	X	X	X			**75%**
Shared Risk and Reward		X		X	X	X	X			X			**50%**
Liability waivers among key participants	X			X		X							**25%**

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Table 3-4 Civil Infrastructure Alliancing Case Study Projects us of Alliance principles.

Alliance Principles	Robinson Road	Southland Alliance	Jialan Yard Upgrade	Northern Missing Link	Transit NZ	Waikato Roads	Whanganui Road	Australian Government	SCIRT Alliance	NCTIR Alliance	**Total Frequency**
'Best for Project' Unanimous Decision Making	X	X	X	X	X	X	X	X	X	X	**100%**
Transparency expressed as open book documentation	X	X	X	X	X	X	X	X	X	X	**100%**
Early Involvement of Key Participants	X	X	X	X	X	X	X		X	X	**90%**
Gain Share/Pain Share, Commercial Risk and Opportunity Sharing	X		X	X	X	X	X	X	X	X	**90%**
Commitment to 'No Blame' Culture, 'No Disputes'	X	X	X	X	X		X	X	X	X	**90%**
Collective Sharing of (Nearly) all Project Risks	X		X	X	X		X	X	X	X	**80%**

The content analysis of the selected case studies shows the alliancing projects in Australia and New Zealand use a higher percentage of their defined principles than that of their commercial IPD counterparts in the US.

Methodology

A content analysis of literature (Weber 1985) was used in this study and a frequency index was created on a scale from 0-100 (Gunduz 2018) of the literature's content to compare relative importance. Due to little to no literature performed on industrial integrated project delivery, the use of an industry survey sent to the industrial construction sector, Construction Industry Institute (CII) member companies, was employed to compare the results of the content analysis of literature in the commercial and civil infrastructure projects difference in relative importance of project key performance indicators using the frequency index as a baseline metric. The survey participants were senior project managers and executives with an average of 29 years of experience in delivering industrial capital projects,

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with industrial sectors to include but not limited to; energy, manufacturing, and mining. A total of 85 survey responses were collected and applied to this comparison study.

Results

Comparing Key Performance Indicators of Commercial Building, Civil Infrastructure, and General Construction Projects

Both commercial IPD and civil infrastructure alliancing are performance outcome focused delivery methods (Lahdenpera 2012), meaning the structure and incentives of IPD and alliancing should match the intended outcome of the project. While the two project sectors of commercial building and civil infrastructure share many common attributes, this study looks to better understand if these different construction industry sectors have the same level of importance on specific performance objectives of completing projects such as safety, quality, cost, and schedule. And if the relative importance of these performance objectives differ, is the industrial project sector more closely related to the performance objectives of commercial building or civil infrastructure? Industrial capital projects share similarities to the commercial building sector and the civil infrastructure project sector but is unique to both in certain characteristics. A content analysis of literature was used to evaluate the level of relative importance of specific project performance objectives in the different construction industry sectors. A comprehensive literature review was performed and every article including construction project performance outcomes was included. Only articles incorporating multiple key performance indicators were included in the final content analysis. Each literature article was sorted into one of three groups; commercial building projects, civil infrastructure projects, and general construction projects. The list of articles selected for this study can be found in Table 3-5.

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Table 3-5 Literature review of key performance indicators grouped by project type; commercial, infrastructure, and general construction.

#	Author	Title	Year	Country	Project Sector Type
1	Franz et al.	Impact of team integration and group cohesion on project delivery performance	2016	USA	Commercial Buildings
2	WBDG	Determine Project Performance Requirements	2016	USA	Commercial Buildings
3	El Asmar et al.	Quantifying performance for the integrated project delivery system as compared to established delivery systems	2013	USA	Hospital Buildings
4	Roberts and Latorre	KPIs in the UK's Construction Industry: Using System Dynamics to Understand Underachievement	2009	UK	Commercial Buildings
5	Ballard, Glenn	The Lean Project Delivery System: An Update	2005	USA	Hospital Buildings
6	Beach et al.	An evaluation of partnership development in the construction industry	2005	USA and UK	Hospital Buildings
7	Chan et al.	Key performance indicators for measuring construction success	2004	Australia	Hospital Buildings
8	Wong	Contractor performance prediction model for the United Kingdom construction contractor: Study of logistic regression approach	2004	UK	Commercial Buildings
9	Chan et al.	Construction process reengineering: a case study	1999	Hong Kong	Hospital Building
10	Sanvido et al.	Critical Success Factors for Construction Projects	1992	USA	Commercial Buildings
11	Amiril et al.	Transportation Infrastructure Project Sustainability Factors and Performance	2014	International	Transportation Infrastructure
12	Molenaar and Navarro	Key Performance Indicators in Highway Design and Construction	2011	USA	Transportation Infrastructure
13	Zhou and Lacouture	Key Performance Indicators for Infrastructure Sustainability - A Comparative Study between China and the United States	2011	USA and China	Civil Infrastructure
14	Shen et al.	Key assessment indicators for the sustainability of infrastructure projects	2010	China	Civil Infrastructure
15	Toor and Ogunlana	Beyond the 'iron triangle': Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects	2010	Thailand	Large Public Infrastructure
16	Tamburro	In Pursuit of Additional Value	2009	Australia	Civil Infrastructure
17	Rankin et al.	Initial metrics and pilot program results for measuring the performance of the Canadian construction industry	2008	Canada	Civil Infrastructure
18	Ugwu and Haupt	Key performance indicators and assessment methods for infrastructure sustainability—a South African construction industry perspective	2007	South Africa	Civil Infrastructure
19	Grajek et al.	Partnered project performance in Texas Department of Transportation	2000	USA	Transportation Infrastructure
20	Gransberg et al.	Quantitative Analysis of Partnered Project Performance	1999	USA	Transportation Infrastructure
21	Radujković et al.	Application of key performance indicators in South-Eastern European construction	2010	Eastern Europe	General Construction

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Table 3-5 Continued

22	Hapanova and Al-Jibouri	Influence of process performance during the construction stage on achieving end-project goals	2010	Netherlands	General Construction
23	Skiebnowski and Ghosh	Determination of key performance indicators with enterprise resource planning systems in engineering construction firms	2009	USA	General Construction
24	Forgues and Koskela	The influence of a collaborative procurement approach using integrated design in construction on project team performance	2009	UK and Canada	Manufacturing General Construction
25	Kim et al.	Improving project management performance of large contractors using benchmarking approach	2008	Vietnam	General Construction
26	Yeung et al.	Establishing Quantitative Indicators for Measuring the Partnering Performance of Construction Projects in Hong Kong	2007	Hong Kong	General Construction
27	Menches and Hanna	Quantitative Measurement of Successful Performance from the Project Manager's Perspective	2006	USA	General Construction
28	Choi et al.	Forecasting Potential Risks through Leading Indicators to Project Outcome	2006	USA	General Construction
29	Lim and Mohamed	Criteria of project success: an exploratory re-examination	1999	UK	General Construction
30	Shenhar et al.	Mapping the Dimensions of Project Success	1997	USA	General Construction

Design Optimization and Construction Risk Management Project Performance Objectives

A total of 14 project key performance indicators (KPI's) were identified through literature review of these articles. The 14 KPI's shaping definition of success on construction projects have been observed to be cost and schedule savings, cost and schedule certainty, quality, safety, energy/water efficiency, operational functionality, material optimization, adaptability, minimize claims, minimize environmental impacts, and minimize public disruption. The final list of KPI's included in this study were determined by the regularity of appearance in literature, only KPI's with a frequency higher than three appearances were included. An objective of the study was to determine if commercial buildings have a higher priority on design optimization goals as compared with construction risk management goals and is the ratio of priority similar to the civil infrastructure project sector. Thus, these 14 KPI's were divided into two main categories; project performance

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objectives closely related to design optimization and project performance objectives closely related to construction risk management. Review of literature on design optimization and construction risk management were performed to identify the recurring performance goals of each.

The aerospace industry and NASA have been using collaborative design optimization strategies for multiple decades and often times refer to this process as multidisciplinary design optimization, or MDO (Braun et al. 1995, Sobieszcsanski-Sobieski et al. 1997, Kroo 2000). The goal of this collaborative optimization exercise is to maximize or minimize specific design objectives. In the architecture, engineering, and construction (AEC) industry, MDO has been stated to be used "to improve product quality and reduce time to market" (Fischer 2017). Some cited benefits of MDO are "22 percent *cost savings* on average…20 percent *less time*" (Flager 2014), "maximize *energy efficiency*" (Best 2015), and "reducing *total project construction cost* by 7 percent" (Fischer 2017), "in a multidisciplinary design environment, use of the collaborative architecture provides additional *operational* advantages" (Braun 1996), and "collaborative design is an emerging promising field…*optimizing the use of materials and energy* can be effectively achieved using these new technologies" (Chryssolouris et al. 2008). The following KPI's have been identified as project performance objectives achieved through good design optimization;

- Cost savings,
- Schedule savings,
- Energy/water efficiency,
- Operational functionality,
- Adaptability, and
- Material optimization (Reduced waste).

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Risk is defined by the US Project Management Institute (PMI) as, "an uncertain event or condition, if it occurs, has a positive or negative effect on a project objective" (PMI 2017). Project uncertainty is the probably that the objective will not reach its planned target value (Jaafari 2001). Construction projects face much uncertainty due to many factors, thus increasing the risk of not achieving the target value, or project performance goals and objectives. "Risk is inherently present in all construction projects…quite often, construction projects fail to achieve their *time, quality, and budget goals*" (Al-Bahar 1990). Other studies have identified similar uncertainty to achieving project performance objectives, with risks observed causing defective physical works (difficulty in *quality* control), *schedule delays*, and *cost overruns* (Zhi 1995) and Zou et al. (2007) identified five main impacts to project success caused by risk; *cost overrun, time delay, quality, safety, and environmental* risks. Legal claims and disputes have also been identified by scholars as a risk present with construction projects, "construction industry professionals have increasingly sought legal assistance to help identify, allocate, control, minimize risk in the design and construction process…in spite of these efforts at controlling risk, the industry has witnessed an alarming rise in *claims and disputes*." (Hanna 2007) "The construction industry has long been considered to have high injury and fatality rates" Cheng et al. goes on to state (2012), "*safety* management information and committees are significantly related to *project performance*." Social impacts of construction projects, such as public disruption, have also hampered overall achievement of project goals. Documented in a study performed by Waitt (2003) of the Olympic Games development work performed in Sydney, Australia, "Personal *disruptions* impacted more heavily than any benefits. One respondent expressed displeasure with the Olympics in terms of personal *disruptions* to daily activities as follows, 'It's been bloody

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chaos, mate. It's all bad. Nothing but [a] *disruption* to my life.'" The following KPI's have been identified as project performance objectives achieved through good construction risk management;

- Cost certainty (meet budget),
- Schedule certainty (meet schedule),
- Safety,
- Quality,
- Minimize claims,
- Minimize environmental impacts, and
- Minimize public disruption.

Client satisfaction has been observed in literature to be both related to good design optimization and good construction risk management and therefore categorized as both. There are a total of six KPI's categorized as design optimization, seven KPI's categorized as construction risk management, and one categorized as both. The frequency index (0-100) of these total 14 KPI's categorized as design optimization and/or construction risk management represents the frequency of literature articles observed identifying each of these specific KPI's grouped as commercial buildings, civil infrastructure, and general construction projects and is summarized in Table 3-6. The frequency index was calculated using the following equation;

$$\text{Frequency Index (\%)} = \sum (n/N) * 100 \qquad \text{Eq X.3-1}$$

Where n is the frequency of appearances of each KPI in literature, and N is the total number of articles in each group.

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Using the average frequency of all sectors including general construction as the baseline frequency index, the results of the frequency analysis summarized in Table 3-6 indicate commercial building projects are higher in importance of KPI's more closely associated with design optimization, having an average frequency index rating of 62 for all design optimization KPI's as compared to an average frequency index rating of 43 for all sectors' design optimization KPI's. Cost savings and operational functionality were the two highest ranked KPI's for commercial building projects. While civil infrastructure projects are higher in importance of KPI's more closely associated with construction risk management, having an average frequency index rating of 71 for all construction risk management KPI's as compared to an average frequency index rating of 54 for all sectors' construction risk management KPI's. Cost and schedule certainty, and quality were the three highest ranked KPI's for civil infrastructure projects. The results indicate project performance is more closely linked to design optimization for commercial projects, while civil infrastructure project performance relies more heavily on construction risk management.

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Table 3-6 Literature review of design optimization and construction risk management key performance objectives grouped by project type.

	Design Optimization KPI's							Construction Risk Management KPI's								
	Cost Savings	**Schedule Savings**	**Energy/Water Efficiency**	**Operational Functionality**	**Adaptability/Reliability**	**Material Optimization**	**Average of All Design Optimization KPI's**	**Cost Certainty**	**Schedule Certainty**	**Safety**	**Quality**	**Minimize Claims**	**Minimize Environmental Impacts**	**Minimize Public Disruption**	**Average of all Construction Risk KPI's**	**Client Satisfaction**
Commerical Building																
1 – Franz	X	X	X	X				X	X		X					X
2 – WBDG	X		X	X	X					X						
3 – El Asmar	X	X		X		X		X	X	X	X	X				X
4 – Roberts	X	X		X				X	X	X	X		X			X
5 – Ballard	X		X	X		X		X								
6 – Beach	X	X		X		X		X		X		X				
7 – Chan	X	X		X		X		X	X	X	X		X			X
8 – Wong	X	X						X	X	X	X					
9 – Chan	X	X		X		X				X						
10 - Sanvido	X			X	X	X		X	X	X	X	X				X
Frequency**Building**	**100**	**70**	**30**	**90**	**20**	**60**	**62**	**80**	**60**	**80**	**60**	**30**	**20**	**0**	**47**	**50**
Infrastructure																
11 – Amiril	X		X	X	X	X		X	X	X	X	X	X	X		X
12 – Molenaar				X				X	X	X	X			X		X
13 – Zhou	X			X		X					X		X	X		
14 – Shen	X		X	X		X		X		X	X	X	X	X		
15 – Toor						X		X	X	X	X	X				X
16 – Tamburro				X				X	X	X	X	X	X	X		
17 – Rankin								X	X	X	X		X			
18 – Ugwu	X	X				X		X	X	X	X		X	X		
19 – Grajek	X							X	X			X				
20 – Gransberg	X							X	X			X				
Frequency Infrastructure	**60**	**10**	**20**	**50**	**10**	**50**	**33**	**90**	**80**	**70**	**80**	**60**	**60**	**60**	**71**	**30**
General Construction																
21 – Radujkovic	X	X						X	X		X	X				X
22 – Hapanova				X				X	X	X	X					X
23 – Skiebnowski	X	X		X				X	X	X	X					X
24 – Forgues		X	X			X										X
25 – Kim						X		X	X	X	X					X
26 – Yeung	X	X						X	X		X					X
27 – Menches	X	X						X	X							
28 – Choi	X	X						X	X	X	X					X
29 – Lim				X				X	X	X	X		X			X
30 – Shenhar		X		X	X			X	X		X					X
Frequency All Sectors	**70**	**50**	**20**	**60**	**13**	**43**	**43**	**87**	**77**	**67**	**73**	**33**	**30**	**20**	**54**	**57**

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Comparing Commercial and Civil Infrastructure to Industrial Project Performance Objectives

Industrial projects "satisfy the world's demand for energy, metals, chemicals, and other products" (Merrow 2011). Merrow goes on to state, "as the projects have increased in size and complexity, they have become more difficult to manage…cost overruns, serious slips in completion schedules, and operability problems have all become more common." Merrow evaluated five industrial project performance outcomes and are as follows; cost overruns, cost competitiveness, slip in execution schedules, schedule competitiveness, and production versus plan. These five performance outcomes could be seen as cost certainty, cost savings, schedule certainty, schedule savings, and operational functionality if included in Table 3-6 above. To better understand the perception of performance objectives important to successful completion of an industrial project, a survey was distributed to industry professionals with an average of 29 years of experience delivering industrial capital projects. 85 total responses were used in development of this frequency index ranking relative importance of industrial project KPI's. KPI's listed on the survey include:

- Safety,
- Quality,
- Cost certainty,
- Schedule certainty,
- Client satisfaction,
- Profit,
- Facility production (Operational functionality),
- Speed to market (Ease of startup),
- Minimize environmental impacts, and
- Adaptability.

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The column labeled "industrial projects" in Table 3-7 below, represents the frequency index of each KPI obtained from the results of the industry survey. Table 3-7 compares all sectors' KPI's; commercial building, civil infrastructure, general construction, and industrial projects and each KPI is ranked by level of importance as measured by the frequency index (F.I.). Each KPI is designated as a design optimization KPI (D), construction risk management KPI (C), or both (D/C).

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Table 3-7 KPI comparison of commercial, infrastructure, general construction, and industrial project type.

Literature Review									Industry Survey		
Commercial Building Projects			Civil Infrastructure Projects			General Construction			Industrial Projects		
KPI	**F.I.**	**D/C**	**KPI**	**F.I.**	**D/C**	**KPI**	**F.I.**	**D/C**	**KPI**	**F.I.**	**D/C**
Cost Savings	100	D	Cost Certainty	90	C	Cost Certainty	87	C	Safety	96	C
Operational Functionality	90	D	Schedule Certainty	80	C	Schedule Certainty	77	C	Quality	90	C
Safety	80	C	Quality	80	C	Quality	73	C	Client Satisfaction	67	D/C
Cost Certainty	80	C	Safety	70	C	Cost Savings	70	D	Schedule Certainty	56	C
Schedule Savings	70	D	Minimize Claims	60	C	Safety	67	C	Cost Certainty	44	C
Material Optimization	60	D	Minimize Environmental Impacts	60	C	Operational Functionality	60	D	Cost Savings / Profit	44	D
Quality	60	C	Minimize Public Disruption	60	C	Client Satisfaction	57	D/C	Operational Functionality / Facility Production	30	D
Schedule Certainty	60	C	Cost Savings	60	D	Schedule Savings	50	D	Schedule Savings / Start-up	29	D
Client Satisfaction	50	D/C	Operational Functionality	50	D	Material Optimization	43	D	Minimize Environmental Impacts	27	C
Minimize Claims	30	C	Material Optimization	50	D	Minimize Claims	33	C	Adaptability	25	D
Energy / Water Efficiency	30	D	Client Satisfaction	30	D/C	Minimize Environmental Impact	30	C			
Minimize Environmental Impacts	20	C	Energy / Water Efficiency	20	D	Minimize Public Disruption	20	C			
Adaptability	20	D	Schedule Savings	10	D	Energy / Water Efficiency	20	D			
Minimize Public Disruption	0	C	Adaptability	10	D	Adaptability	13	D			

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Results of Frequency Analysis: Industrial Projects Most Closely Resemble General Construction in Project Performance Definition

Industrial projects and general construction share the same top seven KPIs' level of importance used to measure project success. Cost and schedule certainty, quality, cost savings, safety, operational functionality (facility production), and client satisfaction are all listed as the top seven KPI's used to determine success. They are a balance of categorized design optimization and construction risk management KPI's. It can be reasonably inferred by the results summarized in this comparison table, commercial building projects have more of an emphasis on design optimization, civil infrastructure projects emphasize more construction risk management, and industrial projects are a balance of design optimization and construction risk management similar to general construction.

Collaboration and Integration Principles Within the Industrial IPD Framework

Collaboration can be defined as "a community of people working together to achieve a common goal…in a project, the community is mostly defined by the immediate participants: designers, contractors, trades, vendors, and the owner" (Fischer et al. 2017). Fischer goes on to state, "working together implies an engagement among participants who are not only attempting to execute their work well, but are also supporting the success of others." Integration in the context of integrated project delivery can be seen as "integration of versatile expertise, systems and business practices for the best of the project are at the core of IPD" (Lahdenpera 2012). Industrial integrated project delivery (I2PD) has used these core principles of collaboration and integration found in commercial IPD and civil infrastructure alliance contracting to create a project delivery framework based on collaboration of people and integration of business practices (CII RT-341).

The collaboration principles have been defined within this framework to be principles used to promote project collaboration of people to create a culture of evaluating and making decisions

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centered around 'best for project' intended to optimize design and construction project performance. The integration principles have been defined in this framework as principles used to promote the integration of business practices to create an environment where project stakeholders agree to jointly pursue mutually agreed commercial objectives and implement those goals by sharing business systems, performance metrics, and project controls intended to create a system more resilient to higher degrees of project uncertainty. The existing principles of commercial IPD and civil infrastructure alliancing were combined to form the foundational principles required to create an environment of collaboration and integration on industrial projects; early involvement of key stakeholders, collaborative decision making, jointly developed targets, commercial shared risk and reward, relational multi-party agreements, financial transparency, and collective sharing of project risk such as mutual liability waivers. In addition to these seven principles identified with IPD and alliancing, further research was performed to investigate the possible inclusion of additional principles contributing to better collaboration and integration within the I2PD framework.

Building information modeling, or BIM, has been used predominantly in the commercial sector over the last decade as an integration tool intended to optimize the design and construction of buildings. "Building information modeling (BIM) represent[s] all the disciplines in a single model and is a good example of integrated information" (Fischer et al. 2017). Access to this shared information has been included as a collaboration principle within the industrial IPD framework due to the high regularity of use of this collaboration method, and is defined as 'Access to Shared Information Systems.' This includes shared 3D modelling, project information databases, and other project documents amongst key project participants. Fischer et al. (2017) describe the importance of this information system within a project framework, "an integrated

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information system supports decision making with a holistic view across relevant factors and the right information available in making these decisions. ‘Continuous communication and issue resolution process’ has also been identified in literature as an effective collaboration method used extensively in “partnering” processes (AASHTO 2018) and has been indicated on an industry survey as having a high degree of impact to overall collaboration and integration on industrial projects (CII RT-341 2018). A framework of collaboration and integration principles was created including these nine principles, five collaboration principles and four integration principles, combining elements of commercial IPD and civil infrastructure alliancing and are as follows;

Collaboration Principles:

- Continuous communication and issue resolution process,
- Jointly developed and validated targets,
- Access to shared information systems,
- Early involvement of stakeholders, and
- Collaborative and equitable decision making.

Integration Principles:

- Financial transparency among key participants,
- Commercial shared risk and reward (gain share/pain share),
- Relational contracting (Multi-party agreement, ‘No Blame’ culture), and
- Negotiated risk distribution (Mutual liability waivers, Collective sharing of risks).

Table 3-8 summarizes the commercial IPD and civil infrastructure alliance case study projects included previously in this study and identifies the frequency of each of the nine principles used in delivery of each case study project categorized by collaboration or integration principles.

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Table 3-8 Frequency analysis of collaboration and integration principles used on case study commercial IPD and civil alliancing projects.

	Collaboration Principles					*Integration Principles*			
	Continuous Communication and Issue Resolution Process	**Jointly Developed and Validated Targets**	**Access to Shared Information Systems**	**Early Involvement of Stakeholders**	**Collaborative and Equitable Decision Making**	**Financial Transparency among Key Participants**	**Commercial Shared Risk and Reward** (Gain Share/Pain Share)	**Relational Contracting** (Multi-party Agreement, No Blame culture)	**Negotiated Risk Distribution** (Mutual Liability Waiver, Collective Sharing of Risks)
Commercial IPD									
Cathedral Hill	X	X	X	X	X	X	X	X	X
Mercy Master Plan	X	X	X	X	X	X	X	X	
Lawrence & Schiller	X	X		X	X			X	
Spawglass Austin	X	X	X	X	X	X		X	X
Edith Green Wendell	X		X	X	X	X		X	X
Autodesk	X	X	X	X	X	X	X	X	X
Sutter Health	X	X	X	X	X	X		X	
Cardinal Glennon Childrens Hospital	X				X	X	X	X	
St. Clare Health	X		X	X	X	X		X	
Encircle Health	X	X	X	X	X	X	X	X	
Walter Cronkite School of Journalism	X	X		X	X	X			
UCFS Mission Bay	X	X	X	X	X	X	X		
Frequency	**100**	**75**	**75**	**92**	**100**	**92**	**50**	**75**	**25**
Average F.I. of C.I. Principles	*88*					*60*			
Civil Infrastructure Alliancing									
Robinson Road	X			X	X	X	X	X	X
Southland Alliance	X			X	X	X		X	
Jialan Yard Upgrade	X	X		X	X	X	X	X	X
Northern Missing Link	X	X		X	X	X	X	X	X
Transit NZ	X	X		X	X	X	X	X	X
Waikato Roads	X	X		X	X	X	X		
Whanganui Road	X	X		X	X	X	X	X	X
Australian Government	X				X	X	X	X	X
SCIRT Alliance	X	X	X	X	X	X	X	X	X
NCTIR Alliance	X	X	X	X	X	X	X	X	X
Frequency	**100**	**70**	**20**	**90**	**100**	**100**	**90**	**90**	**80**
Average F.I. of C.I. Principles	*76*					*90*			

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Connecting Key Performance Objectives to Collaboration and Integration Principles

This analysis has identified a different emphasis on the frequency of collaboration and integration principles used on commercial IPD projects compared with civil infrastructure alliance projects. Commercial IPD has a stronger emphasis on the use of collaboration principles, where infrastructure alliancing has a stronger emphasis on the use of integration principles. This study previously discovered commercial buildings has a higher level of importance on the achievement of design optimization performance objectives, where civil infrastructure has a higher level of importance on the achievement of construction risk management performance objectives. It can be interpreted, commercial buildings put a higher emphasis on design optimization, thus having a higher emphasis of use of collaboration principles helping to achieve these objectives closer linked with design optimization. While civil infrastructure projects put a higher emphasis on construction risk management, thus having a higher emphasis on the use of integration principles to achieve the objectives closer linked with construction risk management. It can be reasonably inferred, the collaboration principles have a greater impact to design optimization, while the integration principles have a greater impact to construction risk management. Industrial projects have been observed to be similar to general construction in importance of project performance objectives, with a more balanced importance of design optimization and construction risk management, thus the need for industrial projects to maintain the balanced use of collaboration and integration principles in delivery of industrial capital projects.

Conclusion

Industrial IPD is different from commercial IPD. It combines the collaboration principles of commercial IPD with the integration principles of alliance contracting, and creates its own customized set of principles to fit the key business objectives of an industrial project. Thus,

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industrial IPD provides a structure of both collaboration and integration to enhance performance of an industrial project.

This study found that there is a discernable difference between commercial, industrial and civil infrastructure projects regarding the relative importance of key performance indicators. Commercial project KPIs are more focused on design optimization; whereas civil infrastructure project KPIs promote construction risk management. Thus, it can be inferred that commercial projects are inherently “design-centric” where critical project success factors revolve around the design solution. On the other hand, civil infrastructure projects are much larger in scale and typically impact a greater population making achieving cost and schedule certainty through “construction-centric” risk management key for project success. Industrial projects are generally driven by the need to bring the relevant industrial or manufacturing process online in a timely manner to meet the constraints of the project’s financial proforma requiring both an optimized design that generates early cost and schedule certainty. Industrial projects share many of the construction risk management performance objectives as civil infrastructure projects such as the need for early cost and schedule certainty and minimizing environmental impacts. Industrial projects share some design optimization performance objectives such as operational functionality and waste reduction. Thus, industrial IPD must demonstrate a greater robustness than the other two options and deliver a design solution achieved via high levels of collaboration that aligns all parties’ business objectives through high levels of integration.

Limitations

This paper reflects the perception of industrial project performance objectives limited to member companies of the Construction Industry Institute (CII) which was the population of the survey and workshop samples.

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CHAPTER 4 IMPLEMENTING COLLABORATION AND INTEGRATION ON AN INDUSTRIAL PROJECT: A FRAMEWORK FOR INDUSTRIAL INTEGRATED PROJECT DELIVERY

A paper to be submitted to the Journal of Transactions on Engineering Management, published by the Institute of Electrical and Electronic Engineers (IEEE).

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Abstract

Combining collaboration and integration principles with implementation methods has been proven to both enhance performance and increase certainty on industrial projects. This paper investigates how to deliver an industrial project with use of more collaboration and integration implementation methods. The paper relies on information provided through workshops and surveys of over 80 experienced professionals in the industrial capital project delivery sector to provide a guide on how to implement the use of the different collaboration and integration methods. The research investigates how the use of different combinations of implementation methods contribute to overall collaboration and integration on an industrial project. The study will also report potential challenges and barriers to implementation to increasing industrial project collaboration and integration. The findings provide an overall framework for effective delivery of an industrial project using increased collaboration and integration. The framework is defined as industrial integrated project delivery (I2PD).

Introduction

Chapter 2 has quantitatively proved that the relationship between collaboration and integration and project performance as measured by increased cost and schedule certainty on industrial projects directly correlated. "Collaborative construction project arrangements have been the subject of many development efforts owing to the frustration felt toward the opportunism

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inherent in traditional contracting" (Lahdenpera 2012). Commercial IPD (CIPD) and civil infrastructure alliancing are project delivery methods incorporating high degrees of collaboration and integration on their respective construction sector projects. However, there is not a highly collaborative and integrated project delivery strategy well established in the industrial capital projects sector. Merrow (2012), in a study of 318 industrial megaprojects, observed a lack of a more functionally integrated project delivery methodology, "approaches have not evolved with the degree of separation between functions that is so prevalent in the petroleum industry. [In other] industries, the functions are better integrated at the outset." Industrial integrated project delivery (I2PD) (CII RT-341 2018) combines principles from commercial IPD (CIPD) and infrastructure alliancing to create a balanced structure of collaboration and integration on an industrial project (Chapter 3).

Industrial capital projects are risky, highly complex projects (Rui et al. 2016) reliant on long term facility production outcomes to meet overall business objectives to sponsor organizations, and thus have been deemed as being "creators and destroyers of capital" (Merrow 2011). These projects endure many external risks such as regulatory delay and policy uncertainty, geopolitical challenges such as commodity constraints, global economic downturn, and diplomatic issues, inadequate infrastructure, civil and workforce disruption, and transformation in the industry (EY 2014). However, EY (2014) goes on to state, "non-technical issues are responsible for the majority of cost overruns; [citing Credit Suisse 2013] 65% of project failures were due to softer aspects such as people, organization, and governance and only 14% of the failures [are] due to external factors such as government intervention and environment-related mandates." Alliancing has proven to show higher degrees of resiliency to project uncertainty to include risks such as cost and schedule certainty, safety, environmental, and quality, while CIPD demonstrates an ability to

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provide better design optimization for projects to achieve important design performance objectives such as operational functionality, waste reduction, and cost and time savings (Chapter 3). I2PD is a project delivery method combining the design optimization principles of CIPD to achieve important facility design goals such as facility production and project cost and time savings, with the construction risk management principles of infrastructure alliancing to achieve important construction management objectives such as cost and schedule certainty, safety, quality, and minimizing environmental impacts and public disruption (Chapter 3). Industrial capital projects require this balance to deliver highly functional facilities while minimizing the project risk in environments with high levels of complexity and uncertainty (Ite 2016) to maintain important business objectives keeping the capital investment commercially viable. “Stakeholders increasingly demand improved return on investment and capital discipline, along with reduced risk and exposure” (EY 2014).

The collaboration principles defined within the I2PD framework are used to promote project collaboration of people, creating a culture of joint ‘best for project’ decision-making intended to optimize design and construction project performance. Whereas, the framework defines integration principles as those used to promote the integration of business practices creating an environment where project stakeholders agree to jointly pursue mutually agreed commercial objectives and implement those goals by sharing business systems, performance metrics, and project controls (CII RT-341 2018). Delivering an I2PD project requires collaboration and integration methods to create a system to function in this structure. CIPD and infrastructure alliancing have been well documented in the last decade, however, the characteristics of delivering a highly collaborative and integrated industrial project are not well understood. Thus this research seeks to answer,

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Within the I2PD framework, what are the collaboration and integration (C.I.) methods used to implement I2PD, and how do each impact overall collaboration and integration on an industrial capital project?

The research objectives within this chapter are:

1. The paper will define the methods used to implement I2PD on an industrial project using literature of current collaboration and integration methods used in project delivery.
2. The study investigates how each implementation method impacts overall collaboration and integration on an industrial project by use of an importance index with data collected through an industry workshop and targeted survey.
3. The research reports on the different barriers to implementing I2PD by identifying and reporting on frequently cited challenges to applying each collaboration and integration principle on an industrial project collected from a workshop with subject matter experts.

I2PD Framework

I2PD is a project delivery method using higher degrees of collaboration and integration to structure and execute an industrial capital project. I2PD combines five collaboration principles centered on 'best for project' decisions with four integration principles to align commercial interests of key project participants around project business objectives (Chapter 3). The principles create a structure of collaboration and integration for the project team, however the findings from Chapter 2 suggest, to properly implement I2PD on an industrial project, collaborative and integrated methods must be coupled with these overarching principles to create a system to deliver the project within this structure. When referring to capital projects, Hollman (2016) defines the project system as "the project strategy, processes, practices, organization, and stakeholder interaction are a system" and states this system is the risk that matters the most while delivering

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capital projects. Figure 4-1 illustrates the I2PD as a structure founded in collaboration and integration supported by the nine principles as pillars and the implementation methods providing the means, or the system, to execute the industrial project.

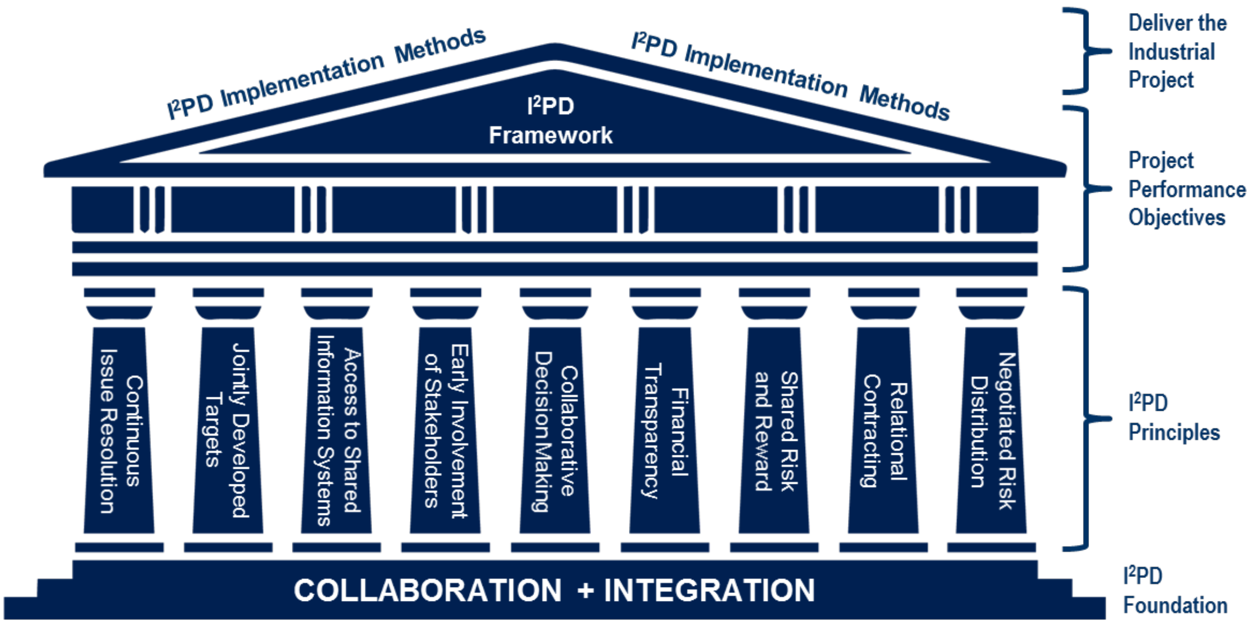

Figure 4-1 I2PD Framework

Collaboration and Integration Methods

"Project delivery systems are used in the construction industry for organizing the performance of construction work and assigning the roles and responsibilities to project parties" (Ballard et al. 2012). CIPD is seen as a relational contracting approach, bringing in all parties involved in the delivery of the project, such as owners, designers, contractors, subcontractors, suppliers, as an integrated team and one that coincides with the expanded use of Lean construction methods (Ballard et al. 2012). "Lean applications in design and construction are continually evolving, the most successful applications have been observed with forms of contract that reward cooperation and collaboration between parties that are actively involved in delivering design and construction" (Forbes and Ahmed 2010). Forbes et al. (2010) goes on to state, "the Integrated Form of Agreement (IFOA) is one form of contract that has been successfully applied to lean

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construction." An IFOA is the contract incorporating the key collaboration principles of CIPD used in the building sector. There has been a synergistic relationship with lean and CIPD in the building sector as a way to encourage collaboration among parties of a project and align stakeholders with project objectives (Ballard et al. 2012). The Lean Construction Institute (LCI) has developed many collaboration methods and tools to be used in various design and construction applications (Ballard 2008). The Construction Industry Institute (CII) has also realized the benefit of "team alignment to incorporate a uniform set of project objectives that meet the business needs of the facility" (CII RR-113-1 1997) and has created many integration methods and tools used in development and delivery of capital projects.

LCI and Dodge Data & Analytics performed a study that found the use of lean methods was doubled on projects categorized as "best" projects as opposed to projects categorized as "typical" projects (Mace 2016) with the collaborative methods of co-location (44 percent) and target value design (40 percent) having the largest increased use from "best" to "typical" projects. LCI has a suite of documented collaboration methods contained in much of its literature with examples of these methods as applied to commercial building projects. CII created a database of "best practices" to be utilized on construction projects and has observed, "best practices improve performance not only in terms of cost, schedule, and safety, but they also increase consistency and predictability of project performance" (CII Best Practices Handbook 2017). Table 4-1 reflects a list of 20 methods found in review of collaborative and integrated project systems, many of which are reflected in literature of LCI lean methods and CII best practices. The list of 20 methods was validated through workshops consisting of 32 industry professionals in the industrial capital projects' sector to confirm each method can be used in an industrial project application.

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Table 4-1 List of the 20 collaboration and integration methods included in the I2PD Framework.

Collaboration and Integration Methods	
Alternate Scheduling Method (Pull-planning)	No Dispute Charter
Co-location (Big Room)	Formal Partnering and/or Team Building
Constructability Planning in the Design Phase	Pre-assembly or Modular Construction
Contract Incentives to include shared risk and reward	Quality Improvement Process (Six Sigma)
Design to Cost Approach (Target Value Design)	Rapid Process Improvement Workshops
Front End Planning (PDRI tool)	Standardized Design Techniques
Joint Risk Assessment Tool	Strategic Partnerships
Multi-party Agreements (IFOA, Alliancing)	Use of Technology as an Integration Tool
Multi-party Project Management Team	Value Engineering in Design Phase
Mutual Liability Waivers	Value Stream Mapping

Collaboration and Integration Method Definitions

Alternate Scheduling Method: This method can also be referred to as pull-planning, which is a plan for executing a specific phase of a project using a pull technique to determine hand-offs. It is prepared by the team actually responsible for doing the work through conversation. Work is planned at the "request" of a downstream "customer" (LCI *Glossary* 2017). Other alternate scheduling methods, such as Last Planner, are described by LCI as a "production planning system designed to produce predictable work flow and rapid learning in programming, design, construction, and commissioning of projects" (Lemke 2014).

Co-Location: An organizational placement strategy where the project team members are physically located close to one another to improve communication, working relationships, and productivity (PMI 2013). LCI commonly refers to this method as the "Big Room" (UHS 2017) and can be defined as a space where stakeholders in the IPD team can come together and work, as opposed to individuals working in silos in their own offices, this allows for open communication and dialogue.

Constructability Planning in the Design Phase: the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve

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overall project objectives by improving the means and methods and enhancing the design intent (O'Connor 2006).

Contract Incentives to include Shared Risk and Reward: Incentives written in the contract that combine risks and rewards of all team members and incentive the achievement of common project goals. The goals may vary but are typically associated with cost, schedule, and quality metrics commonly used to measure project success (Kent and Becerik-Gerber 2010).

Design to Cost Approach: Often referred to as Target Value Design, is an approach used to increase the value delivered to the owner by collaboratively designing to a detailed estimate based on a given cost or the owner's allowable cost (Macomber 2007). Ultimately, the design follows the allowable cost.

Front End Planning: the process of developing sufficient strategic information with which owners can address risk and make decisions to commit resources to maximize the potential for a successful project (CII RR 113-1). Front end planning (FEP) is often perceived as synonymous with front end engineering design (FEED), front end loading (FEL), pre-project planning (PPP), feasibility analysis, programming and conceptual planning.

Joint Risk Assessment Tool: used by the owner, contractor, and designer to collaboratively identify, evaluate, and estimate the levels of risks involved on a project and determine an acceptable level of risk (CII RR 210-11). Hanna et al. (CII RR-210-11) state, for the risk to be distributed appropriately, and ensure all parties are comfortable, key participants should be included in the risk allocation process.

Multi-party Agreements: one contract for the entire project. The contract is often entered by the owner, designer, general contractor, and any other party who may have a primary role in the project (Kent and Becerik-Gerber 2010). By including all key participants in the contract,

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agreeing to the same terms and conditions, enables participants to understand other roles, responsibilities, and risk (Saunders and Mosey 2005).

Multi-party Project Management Team: represents the key-decision making body for the project. They are responsible for providing leadership and governance to the project and ensuring that the obligations of the participants are fulfilled, and the owner's objectives are achieved (Australian Government 2015).

Mutual Liability Waivers: a contracting mechanism with the intent of reducing liability exposure for key project stakeholders. Can include simple waivers of consequential damages to prevent the owner, contractor, or designer from seeking damages for delay, or can include a more comprehensive approach to include project performance, builder's risk and third party claims and in some circumstances it can waive claims such as cost and schedule (Ashcraft 2012).

No Dispute Charter: an agreement there should be no litigation or arbitration between key participants and a failure does not entitle to reimbursement (Australian Government 2015).

Partnering Sessions and/or Team Building: project focused process that builds and develops shared goals, interdependence, trust, commitment, accountability, and improve team members' problem-solving skills (Albanese 1993). Partnering can be further defined as a structured sequence of the principles initiated at the starting point of the project that is based on mutual objectives and applies specific tools and techniques such as conflict resolution techniques in order to achieve the agreed performance metrics of the project (AASHTO 2018).

Pre-assembly or Modular Construction: Refers to the use of offsite construction and includes all substantial construction and assembly components and areas of the finished project (CII RT 171-11).

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Rapid Process Improvement Workshops: a lean tool commonly referred to as Kaizen during construction and design charrette in design. It involves line workers in decision processes for improvements and focuses on making quick, feasible changes (Ikuma 2011).

Quality Improvement Process: Oftentimes referred to as Six Sigma and is a quality process that utilizes the elimination of process variation techniques defined as a statistical measure used to measure the performance of processes or products against customer requirements (Pheng 2004).

Standardized Design Techniques: The attempt to design elements of a facility in a consistent manner in such a way to promote repetition, increase productivity, and reduce field errors (O'Connor 2006).

Strategic Partnerships: a long-term commitment between two or more organizations also referred to as a strategic alliance. It typically involves multiple stakeholders partnered to deliver multiple projects within a program or portfolio. The purpose of a strategic partnership is to achieve specific business objectives by maximizing the effectiveness of each participant's resources (CII RT 102-11).

Use of Technology as an Integration Tool: can combine the design, fabrication information, erection instructions, and project management logistics in one database and provides a platform for collaboration throughout the project's design and construction (AIA 2007). Building Information Modeling (BIM) is an example of technology used to integrate project information, which is defined by LCI as the process of generating and managing building data during the life cycle of a building (LCI Glossary 2017). BIM allows teams to fully understand the implications of the design early on by detecting clashes and to sequence work (UHS 2017).

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Value Engineering in Design Phase: an organized effort directed at analyzing designed building features, systems, equipment, and material selections for the purpose of achieving essential functions at the lowest life cycle cost consistent with required performance, quality, reliability, and safety (GSA 2017).

Value Stream Mapping: mapping of all steps in the project delivery including material and information flow used to improve the production process with the identification of unnecessary steps and an improved understanding of the process (CII RT 234).

Methodology

Workshops were conducted with 32 participants of experienced industry professionals from four different industrial project delivery companies to identify what methods are linked to collaboration and integration principles on an industrial project. A structured interview protocol was developed and followed for all workshop participants to ensure consistent responses from the subject matter experts (ERIC 1997). The workshop participants were also asked to identify challenges and barriers to implementing more collaboration and integration methods on industrial projects.

A targeted survey distributed to the top quartile of experienced industry professionals in use of collaboration and integration methods on industrial projects were identified from an overall industry wide survey receiving a total of 85 respondents. Respondents included senior project managers and executives with an average 29 years of experience working on industrial projects. The criteria for selecting the sample of respondents for the targeted survey was defined as having a high frequency of use of collaboration and integration methods on an industrial project. A frequency index was created to measure the amount of C.I. methods used by each participant on a project, and the top 25% ranked participants were identified and selected as the sample for the

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targeted survey to evaluate the impact of the methods on overall project collaboration and integration. The frequency index number threshold for the top quartile participants was an index rating of 40 and above. The targeted survey received responses from 22 subject matter experts and identified the impact to overall collaboration and integration on an industrial project of each implementation method, using a Likert scale (Fowler 1993).

A relative importance index was created combining the *frequency* data from the workshops with the perceptional *impact* from the targeted survey. The objective of the index is to create a measure to evaluate the overall impact to project collaboration and integration. The relative importance index followed the methodology described by Assaf et al. (2005) with creation of a scale from 0-100, with, *frequency x impact = relative importance*. The equations are as follows,

$$\text{Frequency Index (\%)} = \sum (n/N) * 100 \qquad \text{Eq X.4-1}$$

Where n is the frequency of responses identified as methods related to collaboration or integration principles in the workshop, and N is the total number of workshop participant responses, in this case 32.

$$\text{Impact Index (\%)} = \sum a(n/N) * 100/4 \qquad \text{Eq X.4-2}$$

Where a is the weight given to the response (1 – No impact, 2 – Little impact, 3 – Medium Impact, 4 – High Impact), n is the frequency of the responses, and N is the total number of survey participant responses, 22.

$$\text{Importance Index (\%)} = [\text{Frequency Index (\%)} * \text{Impact Index (\%)}]/100 \qquad \text{Eq X.4-3}$$

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Findings

As described in Chapter 3, I2PD principles can be separated by principles leading to better collaboration and principles leading to more integration on an industrial project. In addition to these nine principles, the I2PD framework consists of 20 collaboration and integration methods that aid in implementing collaboration and integration on an industrial project helping to achieve the goals of the principles. The industry workshop was used to identify which method was related to each of the nine I2PD principles. The workshop participants were asked to "identify which methods can be used to accomplish the goal of each principle." A frequency index from 0-100 was created for each method based on the results of the 32 workshop participants as it relates to collaboration principles and as it relates to integration principles. The overall frequency of each method accomplishing collaboration and integration goals on industrial projects can be seen in Table 4-2.

The targeted survey defined collaboration as "the collaboration of people for best for project decision making as a collaborative culture of evaluating and making decisions centered around what's 'best for the project' as opposed to what is 'best for me', the individual stakeholder." The survey asked each participant to identify each method as it impacts overall project collaboration as defined above and clarified further as, "the methods can help facilitate a system for the project to work with higher degrees of collaboration allowing the project to find more optimal design and construction solutions quicker and oftentimes with better outcomes. The survey defined integration as, "integration of business practices to align commercial interests as an integrated environment where stakeholders agree to jointly pursue mutually agreed commercial objectives and implement those goals by sharing business systems, performance metrics, and project controls, creating a dynamic system that is more resilient to high degrees of project

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uncertainty." The participant was asked to identify each method as it impacts overall project integration as defined with further clarification as, "The implementation methods can be mechanisms used to facilitate a more integrated structure of shared management or appropriate allocation of project risk amongst stakeholders." The 22 participants of the targeted survey indicated each method's overall impact to collaboration and integration on an industrial project and the overall impact index can be seen in Table 4-2.

Table 4-2 Workshop Frequency and Survey Impact Indices Results

	Industry Workshop		**Targeted Survey**	
Implementation Method	**Collaboration Frequency**	**Integration Frequency**	**Collaboration Impact**	**Integration Impact**
Alternate Scheduling Method	48	30	77	53
Co-Location	68	35	82	48
Constructability Planning in Design Phase	64	35	84	56
Contract Incentives to include shared risk/reward	40	60	60	84
Design to Cost Approach	48	40	60	70
Front End Planning (PDRI)	56	35	85	72
Joint Risk Assessment Tool	48	60	73	73
Multi-party Agreements	28	50	47	67
Multi-party Project Management Team	68	45	55	58
Mutual Liability Waivers	32	50	35	58
No Dispute Charter	40	55	42	56
Formal Partnering and/or Team Building	68	50	78	58
Pre-assembly or Modular Construction	20	15	65	47
Quality Improvement Process	44	15	41	31
Rapid Process Improvement Workshops	48	30	61	35
Standardized Design Techniques	24	15	68	53
Strategic Partnerships	60	65	62	77
Use of Technology as an Integration Tool	60	25	84	54
Value Engineering in Design Phase	44	45	68	55
Value Stream Mapping	40	10	58	47

An importance index (0-100) was created evaluating the overall importance of each method as it impacts overall collaboration and integration on an industrial project. The index combines the results of the workshop, frequency of methods linked with collaboration and integration principles, with the results of the targeted survey measuring the impact of each method to collaboration and integration are depicted in the chart below with the x-axis as overall impact to collaboration and

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the y-axis as overall impact to integration (0-100). The median importance of each method was calculated for collaboration, 30, and for integration, 25, and is plotted on the chart below. Quadrants were created using the medians of all methods' collaboration and integration importance index as the half-axes; high impact to both collaboration and integration (A), high impact to integration and low impact to collaboration (B), high impact to collaboration and low impact to integration (C), and low impact to both collaboration and integration (D). The chart in Figure 4-2 illustrates the results of each method's impact to overall collaboration and integration on an industrial project.

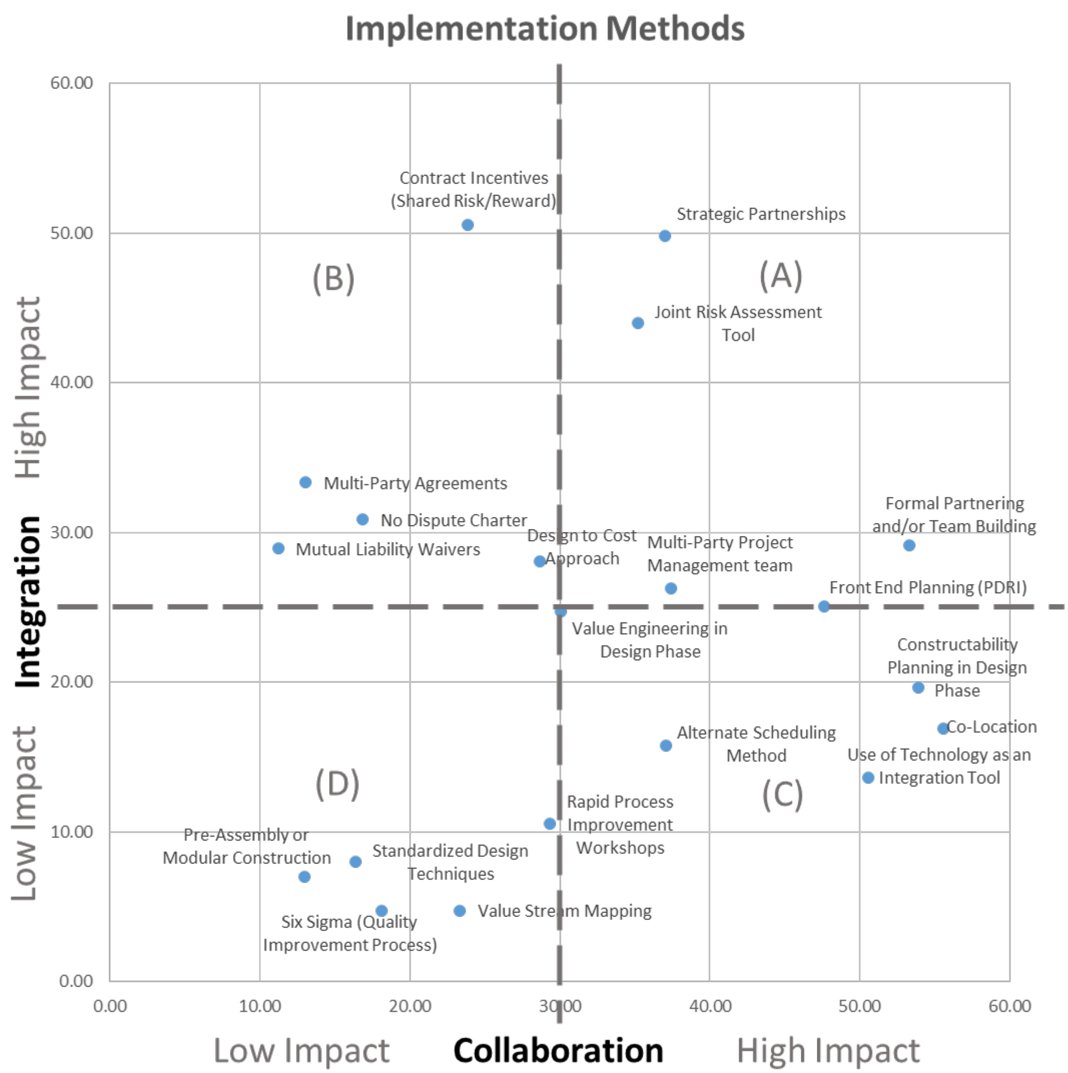

Figure 4-2 Overall impact of each method as it relates to Collaboration and Integration.

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Chapter 3 describes how collaboration and integration are strategies used to improve information speed and accuracy to enhance better more timely decisions, incentivize achieving of best-for-project business objectives, and properly distribute risk amongst project stakeholders. Figure 4-2, shows how each of the 20 methods uniquely contribute to achievement of both of the strategies and how the contribution of each method has varying degrees of impact to overall collaboration and integration on an industrial project. Some methods contribute to higher degrees of collaboration of people such as co-location while others have more of an impact to integration of business practices such as shared risk and reward contract incentives. Others have a high impact to achievement of both collaboration and integration such as strategic partnerships and joint risk assessment tool. There are five methods distributed in each of the four impact quadrants; high integration/high collaboration (A), high integration/low collaboration (B), low integration/high collaboration (C), and low integration/low collaboration (D). This impact chart will allow practitioners a guide to implement projects with desired levels of collaboration and integration to create a balanced system to achieve important project performance objectives on an industrial project. Figure 4-3 illustrates the grouping of the methods into each of the four impact quadrants.

	Low Collaboration	**High Collaboration**
High Integration	Contract Incentives (Shared risk/reward) Multi-party Agreements No Dispute Charter Mutual Liability Waiver Design to Cost Approach	Strategic Partnerships Joint Risk Assessment Tool Formal Partnering and/or Team Building Multi-party Project Management Team Front End Planning (PDRI)
Low Integration	Rapid Process Improvement Workshops Value Stream Mapping Standardized Design Techniques Quality Improvement Process (Six sigma) Pre-assembly or Modular Construction	Co-location Constructability Planning in Design Phase Use of Technology as an Integration Tool Alternate Schedule Method (Pull-plan) Value Engineering in Design Phase

Figure 4-3 Each I2PD method separated into quadrants of impact to collaboration and integration.

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Comparing DBB, EPC, and I2PD Delivery Methods on Industrial Projects

Design-Bid-Build (DBB) is a traditional delivery method used in all construction sectors including commercial buildings, civil infrastructure, and industrial projects (Konchar and Sanvido 1998). DBB is a transactional contracting approach that intentionally separates the owner, designer, and contractor to maintain checks and balances while delivering a project (Franz et al. 2016). Engineering Procurement and Construction (EPC) is another form of a transactional contract integrating design and equipment procurement with construction. From chapter 2, EPC is one of the popular project delivery methods in construction contracts of industrial projects (Baram 2005 and Loots et al. 2007) and is a single-point contract which includes the entire supply of materials and equipment, all design, engineering, procurement, construction and installation works as well as commissioning, start-up, training, acceptance and testing activities (Schramm et al. 2010). EPC agreements are designed to transfer project risk from the owner to the EPC contractor and from the EPC contractor to designers and trade contractors. In both EPC and DBB, contracts and subcontracts are used to assign and compartmentalize project risks, define rigid information process flows, and project objectives are defined through scope and performance specifications with an agreed to fixed cost and schedule. This structure built on rigid contract terms can impede efficient flow of information, optimized risk management, and achieving project focused objectives. Figures 4-4, DBB, and 4-5, EPC, show the risk transfer transactional contracting relationship between Owner, Contractor, Design Engineer, and Equipment Supplier on an industrial project.

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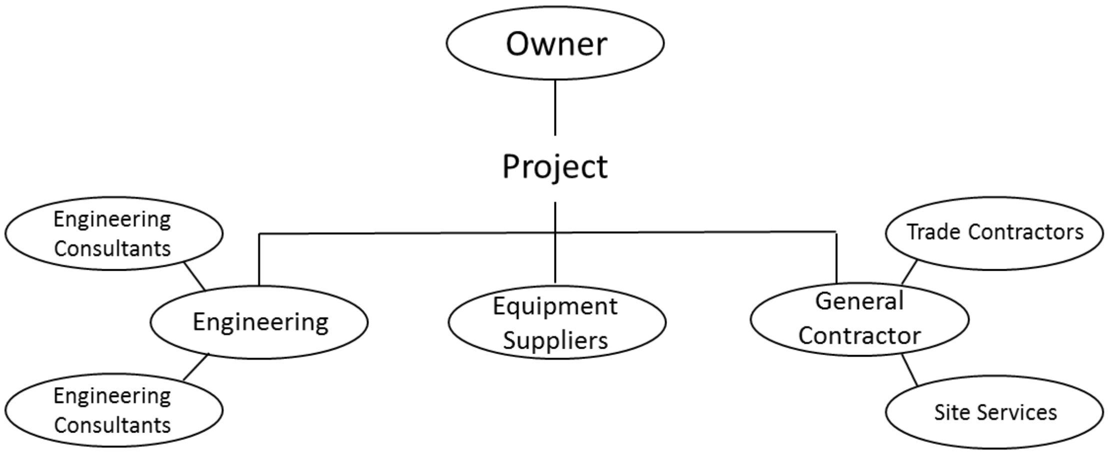

Figure 4-4 DBB contracting organizational relationship.

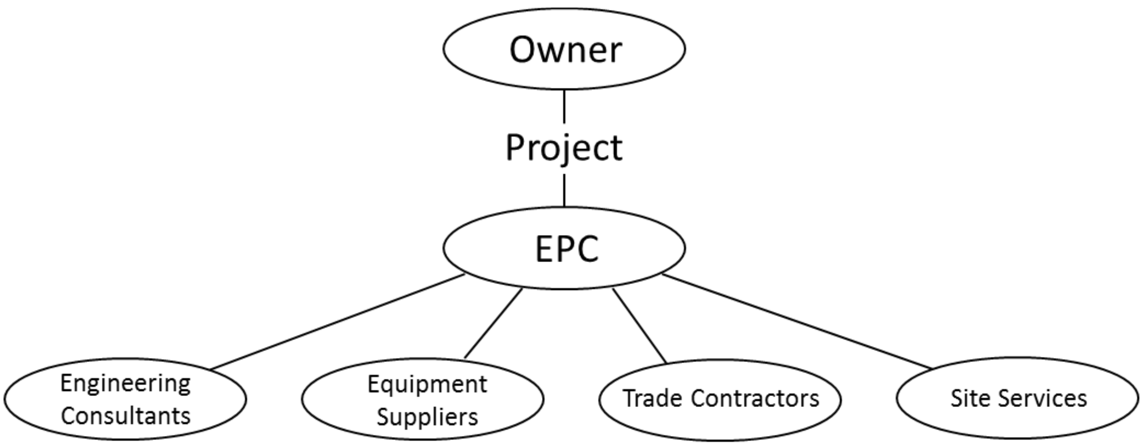

Figure 4-5 EPC contracting organizational relationship (adapted from Loots et al. 2007).

Industrial projects are characterized by increasing project complexity, different sizes and intensified international involvement leading to difficulties in meeting the project objectives and challenges in terms of timely completion, costs, quality and revenue (Schramm 2010). The complex nature of major projects together with their risks require detailed and carefully written contracts that define the legal, financial and technical aspects of the results and behavior desired by the contracting parties (von Branconi et al. 2003). In the transactional contracting approach including both DBB and EPC, contracts shape the behavior of the parties involved and thus have a major impact on project success, contracts are, in essence, tools for allocation of tasks, responsibilities and risks (Schramm et al. 2010). It is the principle of contracting that the party

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who controls risk should carry the risk, however, a contractor will often carry a risk whether it is controlled by them or not – but at a price. From chapter 2, Ross (2003) gleans some insight for owner practitioners in selection of delivery methods and contracting approaches, "All major capital works projects involve inherent risks, e.g. political or economic change, climate, technology, ground conditions, engineering uncertainties, errors, industrial disputes, land issues, environmental issues and many more…In order to achieve optimal outcomes the project owner must select the most appropriate strategy for managing these risks" Ross (2003) continues to state that from an owner's perspective the traditional "risk transfer" approach still can be a good method for many projects – especially ones where the scope is clear and the circumstances and risks are reasonably predictable. However, more and more projects are being required to be delivered in an environment of uncertainty – driven by diverse stakeholder interests, shifting business or political imperatives and rapid technological change (Ross 2003). I2PD provides a shared risk structure to deliver an industrial project in an environment of high uncertainty and rapid technological change by using collaboration and integration strategies to create a project system to allow for improved adaptability to change, better more timely decisions, and more resiliency to internal and external risks. Figure 4-6 shows the shared risk contracting relationship of the Owner, Contractor, Design Engineer, and Equipment Supplier in the I2PD delivery structure that creates a dynamic project system bound by integration and centered on collaboration to keep all stakeholders focused on the project.

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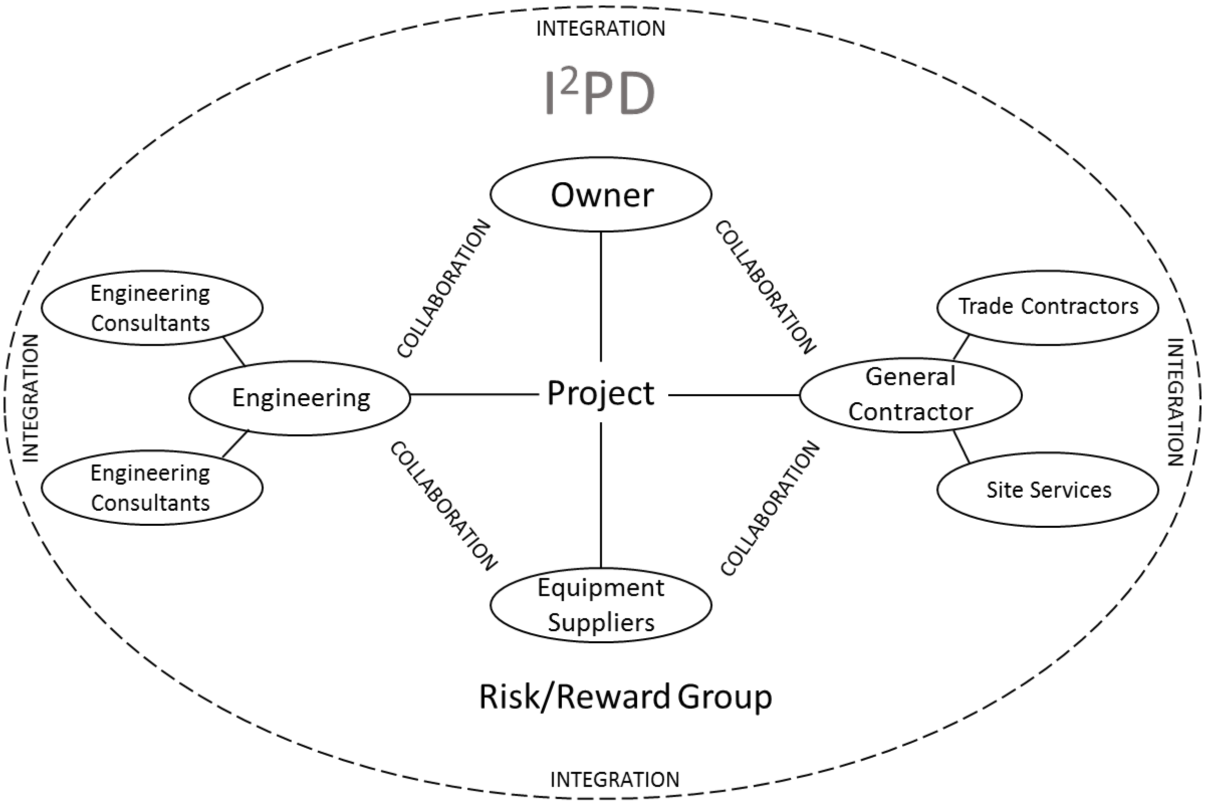

Figure 4-6 I2PD project system bound by integration and centered on collaboration to keep all participants focused on the project.

Challenges and Barriers to Implementation of I2PD

Changing business practices presents challenges (DeMarie and Keats 1995) and the practice of delivering industrial projects with more collaboration and integration will encounter barriers to implementation. The 32 participants of the industry workshop provided insight into the potential challenges and barriers to implementing I2PD on industrial projects. In an attempt to provide some exploratory analysis on the difficulty to implement each of the principles relative to each other, each participant was asked to rank which "principles are easier or more difficult to implement on an industrial project and why". A preliminary trend in ease of implementation was discovered, the five collaboration principles are easier to implement on an industrial project while the four integration principles are more difficult to implement. The workshop participants

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individually identified major barriers to implementation of each principle and the most frequent response of all participants for each principle's barrier is detailed in Table 4-3.

Table 4-3 Barriers to implementation of I2PD principles on an industrial project.

	Principle ranked in order of most challenging principle to implement on an industrial project from least to most	**Most Frequent Response to Barrier to Implementation of I2PD for each Principle**
Collaboration Principles	Continuous Communication and Issue Resolution	Poor system for good project communication among various stakeholders. The causes of a poor project communication system could be unclear roles/responsibilities, changing of personnel, no central information system, reliance on email, and lack of ownership of overall project communication system.
	Jointly Developed and Validated Targets	Lack of timely definition of project scope for all project stakeholders to properly develop and validate project targets.
	Access to Shared Information Systems	Misalignment of technology and how it is used amongst all project participants including different software, different levels of personnel competence, and different levels of use of technology. Other frequently cited barrier identified was data security and IT processes.
	Early Involvement of Stakeholders	Having the right people involved at the right time early on the project and maintaining consistency with this personnel throughout the duration of the project. Challenges identified in early involvement included not having the right personnel available at the time needed, they are busy or assigned to another project.
	Collaborative and Equitable Decision Making	There were two major barriers identified for this principle. The first, differing goals of project stakeholders cause misalignment of best for project decision making amongst project participants. And, reluctance by some project stakeholders to make decisions and be accountable for decisions made whether caused by risk aversion or the wrong people making decisions.
Integration Principles	Financial Transparency Among Key Participants	Unwilling to share cost information due to competitors seeing cost records, not being comfortable with the estimate, contractors' profit may become a target for cost reduction, and owners not willing to pay for contractor inefficiencies.
	Shared Risk and Reward	Existing cultural mindset by each stakeholder and their role on the project, Owner - "it's all my money" mindset and the Contractor - not willing to accept the shared risk and accountability for project performance.
	Relational Contracting (Multi-party agreement)	Lack of willingness from the legal and procurement departments within organizations to allow this contracting approach.
	Negotiated Risk Distribution	The culture of stakeholders not wanting to take responsibility for project risk, wanting to "push off" as much risk as possible to another stakeholder.

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These responses from the subject matter expert participants provide practitioners specific company and industry cultural barriers to performing a project I2PD. Table 4-3 identifies challenges specific to the organization business practices including legal, procurement, and contracting procedures that may need to be revised and what project delivery and information systems may need to be adapted in order to achieve the goals of each principle. Challenges identified by the subject matter experts included both organizational barriers, such as data security and IT processes as well as overall industry cultural barriers, such as the risk shedding mindset predominant in delivery of industrial projects. By informing practitioners of potential barriers to implementation of I2PD within their organization and the overall industry, managers and executives will have a point of departure in investigation of application of collaboration and integration principles in delivery of industrial projects. Many of the higher impact principles and methods require more effort to implement on industrial projects at present and the combined information of the impact chart of Figure 4-2 and the barriers to implementation list in Table 4-3 provides early adopter practitioners a guide to appropriate initial application of principles and implementation methods on industrial projects to enhance performance within the current environment of organizational constraints and industry cultural resistance.

Conclusion

Collaboration of people and integration of business practices are strategies that can be used to deliver improved project performance certainty on industrial projects. The use of collaboration and integration provides a dynamic system to allow efficient flow of information, optimized risk distribution and management, and decisions focused on achieving project centered objectives. The industrial integrated project delivery (I2PD) framework provides a structure and implementation strategy to execute industrial projects within this collaborative and integrated project system

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enabling improved adaptability to change, better more timely decisions, and more resiliency to internal and external risks. This study defines the implementation methods to be deployed in execution of an I2PD project and their impact on overall team collaboration and integration processes. Industrial capital projects are unique and may need different levels of collaboration and integration to achieve important project performance goals. Each C.I. method has been identified to have different impacts to overall team collaboration and integration of business practices with each helping to deliver important design optimization or construction risk management goals at varying levels of impact. The results of this paper will allow practitioners a guide to determine the best ways to implement each of the methods on an I2PD project to attain the necessary levels of collaboration and integration to achieve key performance objectives in delivery of each unique project.

Limitations

The results from this study are limited to the perceptions of subject matter experts using each of the methods on industrial projects without full implementation of all defined principles and methods included in the overall I2PD framework. Further research will need to be performed to evaluate the impact of each method on overall collaboration and integration on industrial projects using the full suite of principles and methods defined in the I2PD project framework.

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CHAPTER 5 CONCLUSIONS, CONTRIBUTION, AND LIMITATIONS

Conclusions

Industrial integrated project delivery (I2PD) is a project delivery method that enhances team member collaboration and integration of business practices through the use of defined principles. The primary outcome of this dissertation shows the theory of IPD and alliancing, with the use of more collaboration and integration, can be applied to industrial projects and significantly improves performance of key objectives, thus reducing the risk of the project in failing to meet important business objectives on an industrial project. The key performance indicators defining success on an industrial capital project is a balance of performance objectives of commercial building projects and civil infrastructure projects thus requiring a balanced use of collaboration principles achieving important design optimization goals of building projects with the use of integration principles achieving important construction risk management goals of civil infrastructure projects. This balanced set of collaboration and integration principles, included in the I2PD framework, provides a structure to enhance performance on an industrial project. Collaboration and integration methods can be applied to the delivery of an industrial project creating a system to implement more collaboration and integration on projects. Finally, changing the business culture of industrial capital project delivery may experience challenges and barriers to implementation of higher levels of collaboration and integration, thus, this study uses information provided by subject matter experts to report on potential barriers to implementation of each principle on an industrial project. Figure 5-1 is a summary of the key research objectives included in each of the research study papers of this dissertation.

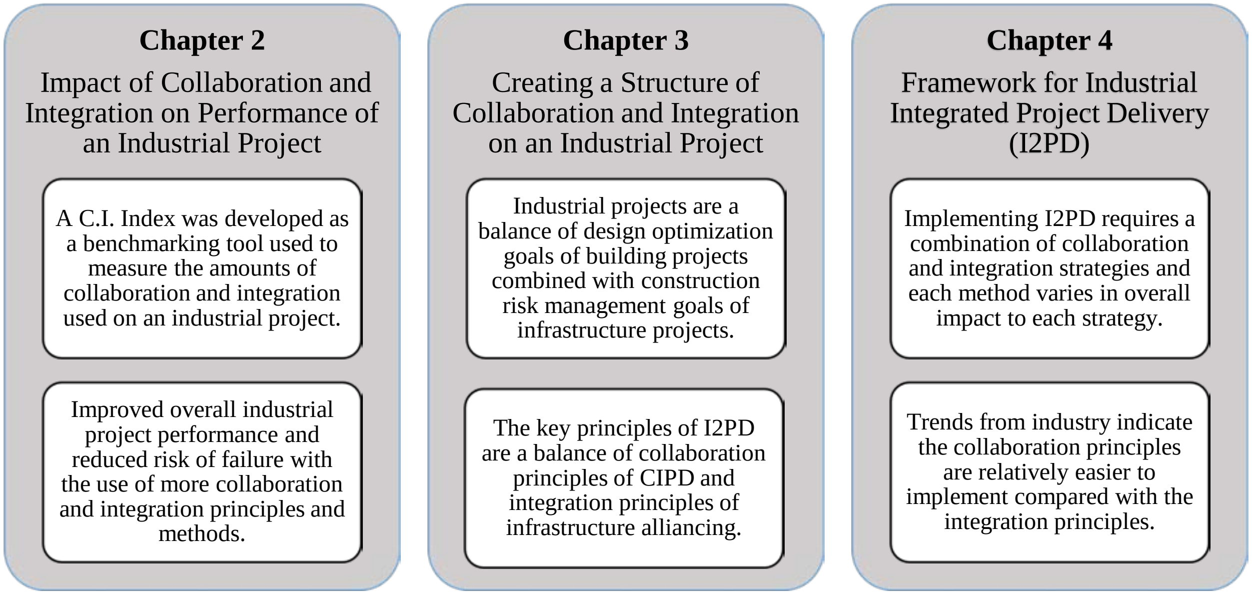

Figure 5-1 Summary of key research findings of each chapter.

Contribution to Theory

This study demonstrates that higher levels of collaboration and integration through the use of IPD and alliancing principles can not only be applied to industrial projects with a positive correlation to project performance and but also significantly reduce the risk of a failed project. This study advances the body of knowledge by providing evidence that IPD and alliancing theory can be applied to industrial projects and provide benefits to overall project performance significantly increasing the probability of successfully achieving important business objectives of an industrial capital project.

Contribution to Practice

The study further expands the community of practice knowledge base in delivery of industrial capital projects in the following applications.

1. Provides a business case to the industrial capital project development sector to accelerate the use of more collaboration and integration in delivery of industrial projects. As described in chapter 1, integrated project delivery is a paradigm shift in project delivery of industrial projects. The findings of this study provide supporting evidence for executives and senior managers of industrial project development companies to better inform decisions on incorporation of more collaboration and integration principles in delivery of industrial projects.

2. Provides a project delivery method (I2PD) framework to deliver an industrial project with more collaboration and integration with a defined set of principles and implementation methods. The I2PD framework provides a way for practitioners to structure industrial projects with more collaboration and integration on industrial projects to create a dynamic system to enhance project results, increase the value to the project, and maximize efficiency through all phases of design, procurement, fabrication, and construction.

3. Provides a suite of methods used to implement I2PD on industrial projects and provide the impact of each to overall project collaboration and integration for enhanced application of these methods on industrial projects. Provide practitioners with a metric to measure overall collaboration and integration on an industrial project through the use of the C.I. Index as a benchmarking tool. Provide insight for practitioners in implementation of I2PD by identification of potential barriers to implementation of collaboration and integration principles on an industrial project.

Limitations and Anticipated Future Research

The findings of this study are subject to several limitations, ultimately define opportunities for future work to advance I2PD theory and practice.

A. The study applies to industrial capital projects and the population of study is limited to member companies of the Construction Industry Institute (CII). With that being said, CII's database of member companies is very extensive with over 150 companies delivering industrial capital projects representing owner, designer, contractor, and supplier organizations. It can be reasonably inferred this group of member companies is representative of the larger group of all industrial capital projects population. However, further testing using the methodology of this study can be performed on industrial projects outside the CII member company population for validation to ensure proper representation.

B. Few industrial projects have been delivered using all the I2PD principles and methods. Thus, the ability to comprehensively evaluate the statistical performance of IPD on industrial projects is impossible at this writing. This study has proved that increased collaboration and integration improved the overall performance of an industrial project, leading one to infer that full use of IPD's collaboration and integration principles and methods may lead to better performing industrial projects. However, the data is not presently available to prove this statistically. Future research incorporating the full suite of collaboration and integration principles and methods on industrial projects will need to be performed to evaluate the full impact of I2PD on industrial projects.

C. The data from this study cannot provide a numerical value of specific increased project performance. For example, it cannot determine if the use of IPD on an industrial project would provide 10% improvement in cost savings or a 50% improvement in the project's safety record. Further research using test pilot projects to measure specific performance improvement in each of the key performance indicators will need to be performed in the future.

APPENDIX A GLOSSARY

Key Terms and Definitions

Industrial Projects: Capital asset projects including manufacturing, pharmaceutical and biotechnology, consumer products, upstream oil and gas, refining and petrochemical, chemicals, mining and metals, pulp and paper, power generation, and gas processing. (CII Knowledge Base 2018)

Integrated Project Delivery*:* AIA (2007) defines Integrated Project Delivery as "a project delivery approach that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all project participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction."

Alliance Contracting: The Australian Government defines alliance contracting as delivering capital assets where "all participants are required to work together in good faith, acting with integrity and making best-for-project decisions. Working as an integrated, collaborative team, they make unanimous decisions on all key project delivery issues. The structure capitalizes on the relationships between the participants, removes organizational barriers, and encourages effective integration with the Owner." (ADIRD 2015)

Design Bid Build (DBB): In a DBB project the owner initially enters into a contract with the designer for design services. The designer works with the owner to develop the owner's project requirements, from which point the designer develops a design. That design is then put out for bid, allowing the owner to select a constructor for the project. Upon the owner's selection of a contractor based on the bids received, the project proceeds to construction. The project is designed with little, if any, input from the parties actually constructing the project. (AIA 2007)

Engineering Procurement and Construction (EPC): a single-point contract which includes the entire supply of materials and equipment, all design, engineering, procurement, construction and installation works as well as commissioning, start-up, training, acceptance and testing activities (Schramm et al. 2010). A popular project delivery method in construction of industrial projects (Baram 2005 and Loots et al. 2007).

Industrial Integrated Project Delivery (I2PD): A project delivery method promoting enhanced collaboration of team members and integration of business practices through the use of defined principles. This structure removes organizational barriers and encourages effective collaboration and integration with all project participants to create a dynamic system to enhance project results, increase the value to the project, and maximize efficiency through all phases of design, procurement, fabrication, and construction (CII RT-341 2018).

Collaboration: the collaboration of people for best for project decision making as a collaborative culture of evaluating and making decisions centered around what's 'best for the project' as opposed to what is 'best for me', the individual stakeholder (CII RT-341 2018).

Integration: the integration of business practices to align commercial interests as an integrated environment where stakeholders agree to jointly pursue mutually agreed commercial objectives and implement those goals by sharing business systems, performance metrics, and project controls (CII RT-341 2018).

Principle: An important function in achieving a desired strategy. In the context of I2PD, the underlying principles create a plan in achieving the overall strategy of collaboration and that of integration on an industrial project (CII RT-341 2018).

Method: a systematic procedure or process for achieving a desired objective (CII RT-341 2018).

I2PD Principles:

- Continuous communication and issue resolution process,
- Jointly developed and validated targets,
- Access to shared information systems,
- Early involvement of key participants,
- Collaborative and equitable decision making,
- Financial Transparency among key participants,
- Shared cost and reward,
- Relational contracting, and
- Negotiated risk distribution.

APPENDIX B WEB-BASED QUESTIONNAIRE SURVEY

Questionnaire Survey

Purpose: The Construction Industry Institute (CII) is conducting a survey to investigate the role and impact of collaborative and integrated project delivery processes and culture on project performance. Please support this effort by completing this questionnaire for any project that you completed recently that had a high degree of collaboration of people and integration of work processes. This survey will take about 20 minutes to complete.

Confidentiality: The information you provided will be treated as strictly confidential. Only the research investigators will have access to the information. Your name and your project information will be treated anonymously during the survey analysis.

Benefits of Participation: Your participation is voluntary. If you complete the questionnaire and provide your email address, you will receive an electronic copy of the final report.

If you have any questions about the study, please contact:

H. David Jeong, PhD, Iowa State University, djeong@iastate.edu

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Respondent Personal Background

Q1. How many years of experience do you have? Enter the number of years in numbers (i.e., 10, 15, 25...).
_______ Years

Q2. Check your industry sector experience. (Check all that apply)
- ❑ Upstream, Midstream, & Mining (UMMC
- ❑ Power, Utilities, and Infrastructure (PUIC)
- ❑ Downstream, & Chemicals (DCC)
- ❑ Healthcare and Buildings (HBC)
- ❑ Manufacturing, Metals, & Life Sciences (MMLS)

Company/Organization Demographics Information

Q3. What type of projects does your company do?
- ❑ Power, Utilities, and Infrastructure (PUIC)
- ❑ Upstream, Midstream, & Mining (UMMC)
- ❑ Downstream, & Chemicals (DCC)
- ❑ Healthcare and Buildings (HBC)
- ❑ Manufacturing, Metals, & Life Sciences (MMLS)

Q4. Approximately how many projects does your company perform annually?
- ❑ Greater than $100M -- Please insert number of projects ____________________
- ❑ $25M to $100M -- Please insert number of projects ____________________
- ❑ Less than $25M ____________________

Q5. What is your company's annual total capital spend? (Total value of projects working on)
- ❍ Over $4B
- ❍ $1B to $4B
- ❍ $500M to $1B
- ❍ $100M to $500M
- ❍ Less than $100M

For the next Q6 to Q26 questions, pick the most collaborative and integrated project you have experienced recently as compared to your most typical projects you have experienced (normal project operating procedure).Collaboration: Collaboration of People Integration: Integration of Processes

Project characteristics of the most collaborative and integrated project

Q6. Project Characteristics of the project picked
Project name ___________________________
Location ______________________________
Size in dollar value ______________________
Overall duration (in months) _______________

Q7. What was the project type?
- ❍ Power, Utilities, and Infrastructure (PUIC)
- ❍ Upstream, Midstream, & Mining (UMMC)
- ❍ Downstream, & Chemicals (DCC)
- ❍ Healthcare and Buildings (HBC)
- ❍ Manufacturing, Metals, & Life Sciences (MMLS)

Q8. What was your company's role in the project?
- ❍ Owner
- ❍ Designer/engineer
- ❍ Contractor
- ❍ Other (Please specify) ____________________

Q9. What was the project delivery type? (Select the best matching one)
- ❍ Design/Bid/Build (Owner contracts with A/E separate from contractor)
- ❍ Engineering Procurement and Construction (EPC) / Design Build (Owner has a single agreement with designer and contractor)
- ❍ IPD (Single, Multi party agreement, IFOA)
- ❍ Construction Management at Risk, EPCM
- ❍ Alliancing (Alliance contract)
- ❍ Other (Please specify) ____________________

Q10. What was the site type?
- ❍ Greenfield (Undeveloped site)
- ❍ Brownfield (Existing facility)

Q11. Rate on a scale of 1-5 how complex each characteristic of the project was compared to a typical project. Refer **Appendix A** for more description.

	Significantly less complex 1	Less Complex 2	About the same 3	More complex 4	Significantly more complex 5
Number of stakeholders	❍	❍	❍	❍	❍
Number of interfaces	❍	❍	❍	❍	❍
Challenges of project location	❍	❍	❍	❍	❍
Adequacy of supply of resources	❍	❍	❍	❍	❍
Technology used	❍	❍	❍	❍	❍
Regulatory constraints	❍	❍	❍	❍	❍
Extent infrastructure requirements	❍	❍	❍	❍	❍
Geographically dispersed teams	❍	❍	❍	❍	❍
Political, economic, or social influence	❍	❍	❍	❍	❍
Environmental influence	❍	❍	❍	❍	❍
Challenges in scope definition	❍	❍	❍	❍	❍
Project governance (e.g. joint ventures, owner partnerships, executive oversight entities)	❍	❍	❍	❍	❍
Project Financing	❍	❍	❍	❍	❍
Others	❍	❍	❍	❍	❍

Q12. Select the project procurement method.

- ❍ Competitive low bid
- ❍ Competitive negotiated bid
- ❍ Single source negotiation

Q13. Select the predominant contract type used on the project.

- ❍ Fixed price - Lump Sum
- ❍ Fixed Price - Unit Price
- ❍ Cost plus - Fixed Fee
- ❍ Cost Plus - % Fee
- ❍ Guaranteed maximum price (GMP)

Q14. At What level was your estimate developed going into the project at full funding? (+/- %)

- ❍ < 10%
- ❍ 10% to 20%
- ❍ 20% to 30%
- ❍ 30% to 40%
- ❍ Greater than 40%

Q15. Rate the project team (1 star worst and 5 stars best) compared with the project teams on a typical project.

______ Project Team ☆ ☆ ☆ ☆ ☆
______ Leadership ☆ ☆ ☆ ☆ ☆

Q16. What was the owner's relationship with the project team?

- ❍ First Time
- ❍ Repeat

Answer this question only if option 'Repeat' is selected in Q16. If not just skip this question.
Q17. Rate the project team's previous experience as a unit?

	Significantly less positive 1	Less positive 2	About the same 3	More positive 4	Significantly more positive 5
Previous experience	❍	❍	❍	❍	❍

Q18. What success factors does your company use to measure project success? (Check all that apply)
Part 1: Rate the level of importance of each success factor to overall project success.
Part 2: Rate the level of project performance for each success factor on the most collaborative & integrated project you previously identified as compared to a typical project.

		Level of importance					Project Performance				
Check if used in project		Very little 1	2	3	4	Very high 5	Much worse 1	Somewhat worse 2	About the same 3	Somewhat better 4	Much better 5
☐	Safety	❍	❍	❍	❍	❍ `	❍	❍	❍	❍	❍
☐	Quality	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Early cost certainty	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Early schedule certainty	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Overall client satisfaction	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Profitability (contractor) / ROI (owner)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Speed to market (owner)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Lowest initial cost (owner)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Lowest life cycle cost	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Flexibility/adaptability of the facility	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Productivity	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Environmental	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Ease of startup	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Other please specify	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Other please specify	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Other please specify	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q19. On this most collaborative and integrated project, which of the following strategies were used (Check all that apply).

Rate on a scale of 1-5 the intensity level (how much) each strategy was used on the project compared to a typical project.

Check if used in project		Significantly Less 1	Somewhat Less 2	About the Same 3	Somewhat More 4	Significantly More 5
□	Early involvement of key participants	❍	❍	❍	❍	❍
□	Shared cost and shared reward (Pain Share Gain Share)	❍	❍	❍	❍	❍
□	Collaborative and equitable decision making	❍	❍	❍	❍	❍
□	Jointly developed and validated targets	❍	❍	❍	❍	❍
□	Negotiated risk distribution (e.g. Mutual Liability Waivers)	❍	❍	❍	❍	❍
□	Non-traditional Owner Engineer Contractor Relational Contracting (e.g. multi-party agreement, alliance)	❍	❍	❍	❍	❍
□	Continuous team building and conflict resolution	❍	❍	❍	❍	❍
□	Other please specify	❍	❍	❍	❍	❍
□	Other please specify	❍	❍	❍	❍	❍
□	Other please specify	❍	❍	❍	❍	❍

Q20. How did communication and reporting differ from typical projects?

	Significantly Less	Somewhat Less	About the Same	Somewhat More	Significantly More
Formality of documentation	❍	❍	❍	❍	❍
Amount of time allocated for each stakeholder's project task	❍	❍	❍	❍	❍
Level of detail of performance metrics	❍	❍	❍	❍	❍
Formality and frequency of defined production/performance expectations	❍	❍	❍	❍	❍
Frequency and formality of meetings	❍	❍	❍	❍	❍
Access to shared information (transparency)	❍	❍	❍	❍	❍
Amount of time taken for issue resolution	❍	❍	❍	❍	❍

Q21. Did this communication and reporting system enable your team to make more timely decisions compared to a typical project?

	Significantly Less	Somewhat Less	About the Same	Somewhat More	Significantly More
	❍	❍	❍	❍	❍

Q22. Select which collaboration and integration methods and tools used for this project. (Check all that apply). Refer **Appendix A** for definitions.

Part 1: Please evaluate how much collaboration of people was enhanced when each method or tool was used on a scale of 1-5 compared to a typical project.

Part 2: Please evaluate how much integration of processes was enhanced when each method or tool was used on a scale of 1-5 compared to a typical project.

1 - Significantly Less 4 - Somewhat More
2 - Somewhat Less 5 - Significantly More
3 - About the Same

Check if used in the project		1	2	3	4	5	1	2	3	4	5
		Collaboration of people					**Integration of processes**				
□	Alternate scheduling method (Last planner, pull planning)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	Co-location	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	Constructability planning in design phase	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	Contract incentives that may include shared cost and reward	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	Design to cost approach (e.g. target value design)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	Front end planning (project definition rating index [PDRI])	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	Joint risk assessment tool	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	Mapping of all steps in the project delivery including material and information flow	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	Multi-party agreements	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	No dispute charter	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	Partnering sessions	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	Pre-assembly or modular construction	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
□	Quality improvement process through elimination of process variation techniques	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

☐	Rapid process improvement workshops	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Standardized design techniques	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Strategic partnerships	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Team building	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Use of technology as an integration tool (3D Modeling, BIM)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Value engineering planning in design phase	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Waste minimization techniques throughout design and construction phase	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Other please specify	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Other please specify	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
☐	Other please specify	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q23. From Q22, rank the top 5 methods or tools that were selected which provided the most improvement in cost and schedule.

1. ____
2. ____
3. ____
4. ____
5. ____

Q24. Did the use of the methods and tools you selected in previous questions lead to improvements during each of the following phases compared to a typical project?

	Significantly Less 1	Somewhat Less 2	About the Same 3	Somewhat More 4	Significantly More 5
Scope Definition	❍	❍	❍	❍	❍
Detailed Design	❍	❍	❍	❍	❍
Construction	❍	❍	❍	❍	❍
Startup & Commissioning, Project Turnover	❍	❍	❍	❍	❍
Operations	❍	❍	❍	❍	❍

Q25. What was your experience in working relationship differences compared to a typical project?

	Much less	Somewhat less	About the same	Somewhat more	Much more
Respect & Trust	❍	❍	❍	❍	❍
Open and honest communication	❍	❍	❍	❍	❍
Commitment to collaboration	❍	❍	❍	❍	❍
Ability to react to change	❍	❍	❍	❍	❍

Q26. Based on your experience, Rate the primary barriers to implementing more collaborative and integrated project delivery strategies, methods and tools.

	Very Low impact	Low impact	Medium Impact	High Impact	Very High Impact
Legal barriers	❍	❍	❍	❍	❍
Regulatory Barriers	❍	❍	❍	❍	❍
Contractual barriers	❍	❍	❍	❍	❍
Business culture preventing more collaboration of people and higher integration of work processes	❍	❍	❍	❍	❍
Any costs associated with more collaborative and integrated project Management Systems	❍	❍	❍	❍	❍
Any costs associated with the integration of differing work processes	❍	❍	❍	❍	❍
Any costs associated with the integration of differing technology between project stakeholders	❍	❍	❍	❍	❍
Logistics	❍	❍	❍	❍	❍
Scale of Project	❍	❍	❍	❍	❍
Project development duration	❍	❍	❍	❍	❍
Availability of funding	❍	❍	❍	❍	❍
Contracting Strategies (e.g. project delivery method)	❍	❍	❍	❍	❍
Change Aversion (risk of doing something new)	❍	❍	❍	❍	❍
Other Barriers	❍	❍	❍	❍	❍

For questions Q27 and Q28, step away from the one most collaborative and integrated project you were a part of, and answer the questions through the lens of your overall company or organization you work for.
Q27. What factors does your organization consider in value for money on an industrial project? (Check all that apply). Refer **Appendix A** for definition of Value for Money.
Also, rate the importance on overall project value for money for each factor.

Check if used in project		Very Low Importance 1	Low 2	Medium Importance 3	High 4	Very High Importance 5
☐	Design Build Costs (overall costs and cost certainty)	❍	❍	❍	❍	❍
☐	Design Build Schedule (overall schedule and schedule certainty)	❍	❍	❍	❍	❍
☐	Planned Maintenance Costs (facility design maintenance requirements)	❍	❍	❍	❍	❍
☐	Operations Costs	❍	❍	❍	❍	❍
☐	Design Build Risks (risks causing higher construction costs than planned)	❍	❍	❍	❍	❍
☐	Operations and Maintenance Risks (e.g., costs associated with environmental events, unplanned maintenance work)	❍	❍	❍	❍	❍
☐	Commissioning and Start-up (Days) (ease of startup)	❍	❍	❍	❍	❍
☐	Facility Production (Revenue Generation)	❍	❍	❍	❍	❍

Q28. Does project integration and collaboration enhance value for money?
❍ Yes
❍ No

We may need to contact you to obtain further information about your project experience and possibly for case studies. Please provide your name and contact information. Your contact information will be treated as strictly confidential during the data analysis.

Q29. Can we contact you in the future?
❍ Yes
❍ No

If 'Yes' Is Selected
Q30. Please provide your contact information
Name ________________________________
Company Name ________________________________
E-mail ________________________________
Telephone ________________________________

Appendix A

Q12:

Number of stakeholders: Number of organizations, entities, and groups affiliated with the project.
Number of interfaces: Peak number of participants on the project management team during the engineering/design, procurement, and construction phase of the project.
Challenges of project location: Impact of the project location on the project execution plan.
Adequacy of supply resources: This pertains to direct field labor, project management, and other staff required for project execution. This also includes material and equipment supply.
Technology used: Difficulty in system design and integration. The company's degree of familiarity with the technologies involved in the design, procurement, and construction phase.
Regulatory constraints: Number of total permits to be required, the level of difficulty in obtaining the permits, and the difficulty in obtaining design approvals.
Extent of infrastructure requirements: Level of infrastructure existing at the site to support the project.
Geographically dispersed teams: Members of the project team geographically located in different locations.
Political, economic, or social influence: Were there any political, economic, or social considerations impacting the execution of the project.
Environmental influence: Were there environmental considerations impacting the execution of the project.
Challenges in scope definition: How much of the engineering/design was completed at the start of construction. Was the scope clear to all the key project team members?
Project governance: Number of executive oversight entities above the project management team who will have decision-making authority over the project execution plan. Were there any joint venture partners on the project?
Project financing: How difficult was it to secure project funding.

Q22:

Alternate Scheduling Method: A scheduling method where the flow of activities and information are based on the request (pull) of downstream work. It is a tool to manage risk through detailed collaborative planning and continuous improvement and it is a means to ensure active involvement from all project stakeholders.

Co-location: An organizational placement strategy where the project team members are physically located close to one another in order to improve communication, working relationships, and productivity

Constructability planning in design phase: The input of construction knowledge and expertise throughout the planning, design, and procurement to improve the means and methods of improving the design intent.

Contract incentives that may include shared cost and reward: Contracts that combine the risks and rewards of all team members and incentivize collaboration in order to reach common project goals. These goals may vary but are usually associated with cost, schedule, and quality metrics commonly used to measure project success.

Design to Cost Approach or, Target Value Design (TVD): TVD is used to increase the value delivered to the owner by collaboratively designing to a 'detailed estimate' based on a given cost or the owner's allowable cost. Ultimately, in TVD, the design follows the allowable cost.

Frond end planning: The essential process of developing sufficient strategic information with which owners can address risk and make decisions to commit resources in order to maximize the potential for a successful project. FEP is often perceived as synonymous with front-end engineering design (FEED), front end loading (FEL), pre-project planning (PPP), feasibility analysis, programming and conceptual planning.

Joint Risk Assessment: Owner, contractor, and designer collaborate to identify, evaluate, and estimate the levels of risks involved on a project and determine an acceptable level of risk.

Mapping of all steps in the project delivery including material and information flow: May be referred to as Value Stream Mapping.

Multi-party agreements: An agreement where there is typically one contract for the entire project that is entered by the owner, architect, general contractor, and any other party who may have a primary role in the project.

No dispute charter: It states that there should be no litigation or arbitration between the key participants and a failure does not entitle to reimbursement.

Partnering sessions: A structured sequence of the principles initiated at the starting point of the project that is based on mutual objectives and applies specific tools and techniques such as conflict resolution techniques in order to achieve the agreed performance metrics of the project.

Pre-assembly or modular construction: Refers to the use of offsite construction and includes all substantial construction and assembly components and areas of the finished project.

Quality improvement process through elimination of process variation techniques: Also referred to as Six Sigma.

Rapid process improvement workshops: a collaborative and intensive workshop activities for developing rapid process improvement ideas. May be referred to as a Kaizen Event.

Standardized design techniques: Standardization of design to facilitate efficiencies in production and assembly.

Strategic Partnerships: A long-term commitment between two or more organizations as in an alliance or it may be applied to a shorter period of time such as the duration of a project. The purpose of partnering is to achieve specific business objectives by maximizing the effectiveness of each participant's resources.

Team building: A project-focused process that builds and develops shared goals, interdependence, trust and commitment, and accountability among team members and that seeks to improve team members' problem-solving skills.

Use of technology as an integration tool (3D modeling, BIM): The Technology Use and Integration practice addresses the level of automation and integration internally and externally for predefined tasks/work functions common to most projects.

Value engineering planning in design phase: A systematic and organized approach to provide the necessary functions in a project at the lowest cost. Value engineering promotes the substitution of materials and methods with less expensive alternatives, without sacrificing functionality.

Waste minimization techniques throughout design and construction phase: Focused activities aimed at removing non-value-added investment from the project scope. Collectively, VIPs are an organized approach to minimizing life-cycle costs while optimizing the life of a facility. May be referred to as Value Improving Practices.

Q27:

Value for Money: Value for Money has been reached when an organization has obtained the maximum benefit from the goods and services it both acquires and provides, within the resources available to it. It is the combination of risk transfer, whole-life cost and service provided by the facility.

APPENDIX C CASE STUDY PROTOCOL

CII RT-341

Advance Copy for Case Study Project

Scheduled Date:___________________________

Structured Case Study Protocol

Below are the various areas in which the researcher will be asking questions. Please have the data available at the time of the meeting. The information requested is an exhaustive list and we are aware that not every project collects the same data. Please provide as much project data as you can. We greatly appreciate your support for this important project.

CONTENTS

I. General Information:

1. Name of Company/Organization:

2. Participant's name and contact information (you may attach your business card):

II. Case Study Project Information:

1. Project Name and location:
2. Project scope of work: If you have a standard version of this, please provide it to the researcher.
3. What were the main drivers for this project? (schedule, cost, others?)
4. Total project duration:
5. Total project cost:
6. Briefly describe how complex was the project.

   Please consider the following items; a) Number of stakeholders, b) challenges of project location, c) adequacy of supply of resources, d) technology used, e) regulatory constraints, f) extents of infrastructure requirements, f) geographically dispersed teams, g) political, economic, or social influence, h) environmental influence, i) challenges in scope definition, j) project governance (e.g., joint ventures, owner partnerships, executive oversight entities), k) project financing, etc.

7. Briefly describe the project delivery method used on this project:
8. Briefly describe how key project team members were selected.
9. Briefly describe compensation methods used on this project (GMP, cost plus, fixed price-lump-sum, etc.)
10. Can we get a copy of the contract used between the major stakeholders of the project? (redacted):

Instruction for the following sections: Do you have documentation that you would be willing to share with the research team on the sources of your responses to this section?

III. PROJECT PERFORMANCE INDICATORS:

A. *Safety Factors: Please fill out the table below based on the project information.*

Safety Factors	Case Study Value	Average Value
Total number lost time accidents (DART)		
Total OSHA recordable incidents (TRIR)		
Total number of OSHA citations		

Q) Please describe major contributing factors to achieving this safety performance.

B. *Quality Factors:*

Quality Factors	Case Study Value	Average Value
Total number of non-compliance reports (NCRs)		
Total cost to remediate non-compliance reports		
Total duration for correcting non-compliance reports		
Total number of warranty call backs		
Number of RFI's during construction		
Number of Punchlist Items		

Q) PLEASE DESCRIBE ANY NOTABLE STRATEGIES, METHODS, AND TOOLS THAT HAVE LED TO ENHANCED PROJECT QUALITY, AND MINIMIZATION OF NCRS AND RFIS? Any cultural, behavioral, communication differences that you noticed?

C. *Cost Factors.*

Cost Factors	Value
Total Approved Budget at Scope Release	
Project Target Cost vs actual project cost	
Design Cost	
Original Construction contract amount	
Final Construction contract amount	
Total number/value of target cost changes	
Total number/value of all change orders	

Q) At what project development stage was your target cost fixed? How was this achieved? Please describe any notable strategies, methods and tools used to achieve early cost certainty. Any cultural, behavioral, communication differences that you noticed in the process?

Did early investment (upfront cost) pay off later by saving project costs or reducing project schedule, etc.?

How did this project compare with your average project with regards to cost savings and certainty from approved budget at scope release to final completion of construction?

D. SCHEDULE FACTORS:

Schedule Factors	Value
Total worker-hours expended	
Project Target Schedule	
Design Time	
Original Construction contract duration	
Actual Construction contract duration	
Number of days added by change orders	

Original completion date at funding vs actual completion date	

Q) At what project development stage was your schedule fixed? How was this achieved? Please dESCRIBE ANY NOTABLE STRATEGIES, METHODS, AND TOOLS THAT HAVE LED TO EARLY SCHEDULE certainty. Any cultural, behavioral, communication differences that you noticed?

How did this project compare with your average project with regards to schedule savings and certainty from approved budget at scope release to final completion of construction?

E. **Other Project Performance Factors**: Please discuss how you have measured each factor and provide any evidence if possible.

Performance Factors	Outcome
Overall Client Satisfaction	Satisfaction Surveys? Lessons learned, quality, end-user's view, post-implementation review? Repeat Business?
Profitability/ROI	
Speed to Market	
Lowest Initial Cost	
Lowest Life Cycle Cost	
Flexibility/Adaptability of the facility	
Production of the facility	
Environmental	
Ease of Startup	
Others:	

IV. COLLABORATION AND INTEGRATION STRATEGIES (IPD PILLARS)

Please fill out the table below based on the project information and provide some tangible evidence for each. If the strategy was not used, please skip to the next one. Rate on a scale of 1-5 how much each of these strategies was used on the case study project. (1-used much less than typical project, 3 – about the same, 5 – much more than a typical project. Completed for projects that are not included in the industry survey.)

<u>Collaborative Strategies Used:</u> Goal of strategies is to create a culture of best for project decision making.

Collaborative Strategies	**Comments**
Early involvement of key participants	If yes, which parties were involved early and why (the goals)? What stages of the project development were those parties involved? What were the outcomes of the use of this strategy? What activities were done? What methods and tools were used in the process? Joint planning system?
Continuous Communication and Issue Resolution process	Build teams to resolve conflicts internally. Was there a system setup to build teams and resolve conflict? If yes, how was this strategy implemented with what methods and tools during the project?
Collaborative and Equitable decision making	Involvement of key project members in decision making. If yes, what is the process? How was this strategy implemented with what methods and tools during the project? Any positive or negative impact on the project?
Access to Shared Information Systems	Leverage collaborative information technologies to inform team decision making. If yes, what information was shared between key participants? What system(s) was used?
Jointly Develop and Validate Targets	Develop and validate project performance objectives (i.e. KPI's)

<u>Integration Strategies:</u> The goal of these strategies are to align commercial interests among project stakeholders.

Integration Strategies	Comments
Shared Cost and Shared Reward	If yes, how was the reward or cost shared? What were the most challenging parts until every party finally came to the agreement of shared costs and rewards? Please describe any significant differences throughout the project due to this agreement that you have experienced compared with the projects that didn't have this component before.
Negotiated Risk Distribution (e.g., Mutual Liability Waivers)	How was the risk negotiated and distributed? Who were involved? What were the outcomes? How did this affect the project throughout the project delivery process?
Use of non-traditional multi-party relational contracting (e.g., IFOA, alliance)	If yes, what was the agreement? When was the agreement made by whom? How was the process? What specific issues were most difficult or easy to handle in the process? What was the overall impact on the project performance? Any notable example that this positively or negatively affected the project at any point in the project? Any significant cost or time savings, project quality enhancement?
Financial transparency among key participants	If yes, what information was shared between key participants? Please describe the process? Why was this requirement important for the project and the project participants? What were the outcomes? Discuss any positive and negative impact on the project.

V. Collaboration and Integration Methods and Tools:

Please fill out the table below. For each method and tool that was used in your project, please carefully think about how each method contributed to enhancing the level of team collaboration and the level of work process integration and describe it with tangible evidence, if possible. If the method or tool was not used, please skip to the next one. (1-used much less than typical project, 3 – about the same, 5 – much more than a typical project. Completed for projects that are not included in the industry survey.)

Methods and Tools	Comments
Alternate Scheduling Method (Last Planner, Pull Planning)	If yes, what methods were used? What benefits did you gain compared with using the traditional scheduling methods? Did the alternate method require more collaborative efforts from project participants? What were the impact on the project's schedule performance, communication, etc?
Team building activities	If yes, what were the activities? In your opinion, what were the outcomes? How did those activities affect the project performance? Can you provide some of your experience on positive or negative impact on the project?
Big Room	If yes, how was it used? How beneficial was it for the project?
Co-location of teams	If yes, where were parties co-located? What was the cost to co-locate? How long was co-location used? Was it a full time co-location of project teams? Or partial co-location (say, two days a week?). What were the outcomes? What changes and differences did you experience? Can you pick a couple of tangible benefits from this?
Constructability planning in the design phase	If yes, what is the process and who were involved and how frequently and how intensively was this method used? What were the outcomes and impact on the project? Can you pick a couple of tangible benefits from this? Can you provide some evidence of cost savings, schedule savings, and quality improvement by applying this method to your project?

Methods and Tools	Comments
Contract Incentives that may include shared cost and reward	If yes, what were the contract incentives? How did it work? Can you provide a couple of actual cases that happened in your project and explain how incentives were calculated on those cases? Was this method a strong motivation for the project team members to work more collaboratively and if so, why? What was the overall impact of this method on the project's outcomes, communication level, and problem solving.
Design to Cost Approach (e.g. target value design)	If yes, what was the process used? At what stage was this method used? Who were involved and how intensive was it? How effective was it? What were the outcomes? Can you pick a couple of examples in your project that demonstrate the value of this project? To make this method work for the project, what are the requirements from the project team members in terms of culture, knowledge and experience? Would this method work for industrial projects?
Front End Planning (e.g., Project Definition Rating Index (PDRI) tool)	If yes, how effective was it? What were the outcomes?
Joint Risk Assessment Tool	If yes, what was the method used to assess and assign project risk? How did it work? Was this tool able to effectively identify risks and come up with risk mitigation plans? What if this method is not actively used in the project? What project environment (project size, culture, communication, contracting methods, etc.) will maximize the value of this method ?
Value Stream Mapping	If yes, what processes were value stream mapped? What stakeholders were involved with this process? How effective was it? Do you think that this method is applicable to any project delivery method? What project environment or project delivery method would be able to maximize the value of this method?

Methods and Tools	Comments
Multi-Party Agreements	If yes, what was the contractual arrangement? How did it work? What were the most challenging part to make it work? How did you overcome those challenges? Any lessons learned? What would you have done differently? What project environments would benefit most from multi-party agreements and why? Did you experience any role or responsibility changes due to this agreement? What were the consequences and impact on the project?
No Dispute Charter	If yes, what was the charter and who signed the charter? How did it work? Did you experience any measurable benefits with this in your project?
Formal Partnering Sessions	If yes, what was the process? Who was involved with the process?
Pre-assembly or modular construction	If yes, what was pre-assembled? Who was involved with this process? Why was this done?
Six Sigma	If yes, what is the process? How often and intensively did you use this method? How did it help improving the project's performance? Is this method directly affected by project delivery method used?
Rapid Process Improvement Workshops (Kaizen Events)	If yes, what is the process?
Standardized Design Techniques	If yes, what is the process? What design was standardized? Who was involved with this process? Why was this done?
Strategic Partnerships (Alliance)	If yes, what is the partnership agreement? Who is involved in the partnership?
Team building activities	If yes, what were the activities?

Methods and Tools	Comments
Project health thermometer	If yes, what was the effect on the project team's communication and collaboration?
Advanced technology as an integration tool (3D modeling, BIM)	If yes, what are the tools used? How intensively were those methods used? Any tangible benefits or costs that you can share with us? What project environment and project delivery methods would maximize the value of these technologies?
Advanced communication and information sharing tools such as a shared central project management system	If yes, what system was used? Did every project team member buy in? How did it work? What benefits did you experience? Any area of improvements?
Pre-agreed dispute resolution methods	If yes, what is the process? Can you share any case that this method significantly helped the project's progress or performance?
Value Engineering planning in design phase	If yes, what is the process? Who were involved? Any tangible benefits that you can share with us?
Waste Minimization techniques throughout design and construction phase	If yes, what was the process? What impact did you observe on your project? What project environment (project characteristics) do you think this method will benefit most?
Others:	

VI. ROLES, RESPONSIBILITIES, AND ACCOUNTABILITIES:

a) What were the most notable changes in terms of roles, and responsibilities of the key project participants (owner, designer/engineer, contractor, and subcontractors)?

b) What were the roles and responsibilities of a third party project management team (or construction management team) hired by the owner? Did you observe any significant role and responsibility changes?

c) What types of knowledge, experience, and abilities do they (PM or CM team) have to possess to successfully get involved in a highly collaborative and integrated project?

d) Please answer the same question above (Q3) for a) design/engineering team, b) contractors, and c) major sub-contractors and equipment vendors.

e) Is there a change in the required leadership needed at the different levels of the project? i.e. Is there a heightened need for “Functional Leadership” throughout the project organizational structure?

f) Is there a heightened need for more long-term committed relationships amongst project stakeholder companies and organizations?

VII. CHALLENGES AND BARRIERS:

a) Were there some notable challenging issues and barriers (additional efforts required) in implementing those collaboration and integration strategies, methods and tools that you used in the project? How did you overcome them?

b) How was the selection process of designers and key contractors different from a traditional project? For example, was it challenging to develop and use a qualification based selection process when hiring key design firms, general contractors, and sub-contractors ?

c) How did the working relationships differ from IPD to a typical project?

d) Did you have to use any additional resources just because the project was delivered through IPD compared to a typical project?

e) What were the most significant differences you noticed and experienced in the IPD project compared to a typical project?

f) What did you do differently on the IPD project and why?

VIII. OTHER QUESTIONS:

a) Reviewing the decision making process in your project with respect to constructability issues, how did you deal with disagreements? Who has the final say?

b) How can the construction costs be saved with IPD compared with design-bid-build?

c) How could the cultural change (best for the project, not best for me) maximize the productivity of the entire project team? Any real example that you can share?

d) Did you make any changes in the workflows to enable the use of 3D models, BIM technologies, or central project management system in order to use them as early as possible? If so, how did it work? Were there any significant benefits?

e) Did IPD reduce design changes and enable more detailed manufacturing of prefabricated components?

f) Under highly collaborative and integrated project environment, was it necessary to hire a tech-savvy project team? Was it necessary to hire a third-party project manager to facilitate the collaborative processes and for clearer contractual responsibilities?

g) What was the procedure when a disagreement occurred? How was it different from a traditional project?

h) In your opinion, what types of project would least benefit from IPD and why? Would a small scale project benefit from IPD?

APPENDIX D INDUSTRY WORKSHOP STRUCTURED INTERVIEW PROTOCOL

CII RT341: Integrated Project Delivery for Industrial Projects

Workshop Protocol

Instruction:

1) This workshop is anticipated to take about three to four hours.
2) Recruit a group of highly experienced project managers who understand the value of collaboration of project members and integration of work processes for better project performance
3) The workshop facilitator (RT341 industry member) should designate a person who will be in charge of collecting and documenting discussion details and writing a report.
4) This workshop must be completed by October 20, 2017, and submit your workshop report to David Jeong (djeong@iastate.edu) by October 25, 2017.

A recent study completed by CII RT341 provides strong evidence that there is correlation between a project's performance and the amount of collaboration and integration methods and tools used. An analysis of survey results and testing of the same, show that a project's performance improves and the certainty of that performance increases as the number of collaboration and integration methods and tools used increase. Based on this finding, the research team wants to determine core principles that enable high collaboration of team members and high integration of work processes.

The Goal of this workshop is to discuss several principles, methods and tools that are identified to significantly promote and facilitate high collaboration of project team members (owners, designers, engineers, contractors, and vendors) and high integration of work processes throughout the project delivery process in order to improve the performance of project in terms of key project performance indicators.

Company Name:

____

Workshop Facilitator (CII RT 341 member):

____

Discussion Item 1) Discuss with workshop participants key project performance indicators and prioritize them and document why.

1. Safety
2. Schedule
3. Cost
4. Quality
5. Early schedule certainty
6. Early Cost certainty
7. Client satisfaction
8. Profit / Return on Investment (ROI)
9. Facility Production
10. Environmental
11. Ease of startup
12. Speed to Market
13. Adaptability
14. Lowest life Cycle Cost
15. Lowest Initial cost

Discussion Item 2) Below are several principles that can be applied throughout the project delivery process in order to significantly improve and facilitate collaboration of project team members (owners, designers, engineers, contractors, and vendors) and integration of work processes.

a) Discuss with workshop participants which principles are easier or more difficult to implement and document why. If some of the principles have already been used, discuss and document their experience. Are there other principles to be added for enhancing team collaboration and work process integration?
b) Discuss and document why and how each principle can enhance team collaboration and work process integration

At the end of the group discussion, please prioritize these principles in term of the difficulty of implementation.

1. Early involvement of Key Participants
2. Continuous communication and issue resolution process
3. Collaborative and equitable decision making
4. Access to shared information systems such as 3D modeling, and central project management system
5. Jointly developed and validated targets
6. Shared risk and shared reward
7. Negotiated risk distribution such as liability waiver
8. Relational contracting or multi-party contracting
9. Financial transparency among key participants (open book)

<u>Principles designed to create an environment of best for project decision making:</u>

1. Early involvement of Key Participants
2. Continuous communication and issue resolution process
3. Collaborative and equitable decision making
4. Access to shared information systems such as 3D modeling, and central project management system
5. Jointly developed and validated targets

<u>Principles designed to commercially align stakeholder's interests:</u>

6. Shared risk and shared reward
7. Negotiated risk distribution such as liability waiver
8. Relational contracting or multi-party contracting
9. Financial transparency among key participants (open book)

Discussion Item 3) Based on the results from the discussion item 2, please consider the following methods and tools that can help accomplish the goal of each principle. If there are other methods and tools that need to be added, please do so.

Methods and Tools:

1. Constructability Planning,
2. Team Building,
3. Multi-party Project Management Team,
4. Front End Planning / Project definition Rating Index (PDRI),
5. Use of Technology as an Integration Tool (3D modeling),
6. Co-location /Big room,
7. Value Engineering,
8. Standardized Design Techniques,
9. Pre-assembly /Modularization,
10. Value Stream Mapping,
11. Partnering Sessions,
12. Strategic Partnerships,
13. Contract Incentives,
14. Design to Cost (Target Value Design),
15. Alternative Scheduling Methods (Last planner or pull planning),
16. Waste Minimization Techniques,
17. Joint Risk Assessment Tool,
18. Quality Improvement Process,
19. Multi-party Agreements,
20. Rapid Process Improvement Process,
21. No Dispute Charter,
22. Pain share/Gain share in contract,
23. Liability waiver,
24. Open book policy,
25. Others.

In the Table below, please identify which methods and tools can be used to accomplish the goal of each principle. Please document the discussion results on why and how.

Principles (Motivation)	Methods and Tools
Early involvement of Key Participants	
Continuous communication and issue resolution process	
Collaborative and equitable decision making	
Access to shared information systems such as 3D modeling, and central project management system	
Jointly developed and validated targets	
Shared risk and shared reward	
Negotiated risk distribution such as liability waiver	
Relational contracting or multi-party contracting	
Financial transparency among key participants (open book)	

Discussion Item 4) Based on the results from the discussion items 2 and 3, discuss the barriers and challenges you see implementing each principle in your organization and why? Identify potential solutions to overcome those barriers and challenges?

1) Early involvement of Key Participants		
Barrier*	Solution	Remarks
Challenge*		
* Barrier – An aspect that will stop the given method/tool from being implemented. Challenge – An aspect that will make implementing the given method/tool difficult, but not impossible.		

2. Continuous communication and issue resolution process		
Barrier*	Solution	Remarks
Challenge*		
* Barrier – An aspect that will stop the given method/tool from being implemented. * Challenge – An aspect that will make implementing the given method/tool difficult, but not impossible.		

3. Collaborative and equitable decision making		
Barrier*	Solution	Remarks
Challenge*		
* Barrier – An aspect that will stop the given method/tool from being implemented. * Challenge – An aspect that will make implementing the given method/tool difficult, but not impossible.		

4. **Access to shared information systems such as 3D modeling, and central project management system**		
Barrier*	Solution	Remarks
Challenge*		
* Barrier – An aspect that will stop the given method/tool from being implemented. * Challenge – An aspect that will make implementing the given method/tool difficult, but not impossible.		

5. **Jointly developed and validated targets**		
Barrier*	Solution	Remarks
Challenge*		
* Barrier – An aspect that will stop the given method/tool from being implemented. * Challenge – An aspect that will make implementing the given method/tool difficult, but not impossible.		

6. Shared risk and shared reward		
Barrier*	Solution	Remarks
Challenge*		
* Barrier – An aspect that will stop the given method/tool from being implemented. * Challenge – An aspect that will make implementing the given method/tool difficult, but not impossible.		

7. Negotiated risk distribution such as liability waiver		
Barrier*	Solution	Remarks
Challenge*		
* Barrier – An aspect that will stop the given method/tool from being implemented. * Challenge – An aspect that will make implementing the given method/tool difficult, but not impossible.		

8. Relational contracting or multi-party contracting		
Barrier*	Solution	Remarks
Challenge*		
* Barrier – An aspect that will stop the given method/tool from being implemented. * Challenge – An aspect that will make implementing the given method/tool difficult, but not impossible.		

9. Financial transparency among key participants (open book)		
Barrier*	Solution	Remarks
Challenge*		
* Barrier – An aspect that will stop the given method/tool from being implemented. Challenge – An aspect that will make implementing the given method/tool difficult, but not impossible.		

A. Definitions of IPD Principles, Methods and Tools

IPD Principles: fundamental concept, norms, and values that represent what is intended and desirable for IPD projects and that govern the behavior of IPD project participants.

IPD Methods: processes and practices that are designed and used to achieve the IPD principles

IPD Tools: specific devices and/or means that aid in accomplishing IPD methods and principles

B. Short Descriptions for IPD Methods and Tools

Alternate Scheduling Method: A scheduling method where the flow of activities and information are based on the request (pull) of downstream work. It is a tool to manage risk through detailed collaborative planning and continuous improvement and it is a means to ensure active involvement from all project stakeholders.

Co-location / Big Room: An organizational placement strategy where the project team members are physically located close to one another in order to improve communication, working relationships, and productivity

Constructability planning in design phase: The input of construction knowledge and expertise throughout the planning, design, and procurement to improve the means and methods of improving the design intent.

Contract incentives: Contracts that combine the risks and rewards of all team members and incentivize collaboration in order to reach common project goals. These goals may vary but are usually associated with cost, schedule, and quality metrics commonly used to measure project success.

Design to Cost Approach or, Target Value Design (TVD): TVD is used to increase the value delivered to the owner by collaboratively designing to a ‘detailed estimate’ based on a given cost or the owner’s allowable cost. Ultimately, in TVD, the design follows the allowable cost.

Frond end planning: The essential process of developing sufficient strategic information with which owners can address risk and make decisions to commit resources in order to maximize the potential for a successful project. FEP is often perceived as synonymous with front-end engineering design (FEED), front end loading (FEL), pre-project planning (PPP), feasibility analysis, programming and conceptual planning.

Joint Risk Assessment: Owner, contractor, and designer collaborate to identify, evaluate, and estimate the levels of risks involved on a project and determine an acceptable level of risk.

Liability waiver: A legal document that remove legal liability from project participants.

Multi-party agreements: An agreement where there is typically one contract for the entire project that is entered by the owner, architect, general contractor, and any other party who may have a primary role in the project.

No dispute charter: It states that there should be no litigation or arbitration between the key participants and a failure does not entitle to reimbursement.

Open book policy: accounting records of key project participants are shared each other.

Pain Share/ Gain Share: Contracts that combine the risks and rewards of all team members. All or some profits or contingencies are used for pain share and gain share.

Partnering sessions: A structured sequence of the principles initiated at the starting point of the project that is based on mutual objectives and applies specific tools and techniques such as conflict resolution techniques in order to achieve the agreed performance metrics of the project.

Pre-assembly or modular construction: Use of offsite construction and it includes all substantial construction and assembly components and areas of the finished project.

Quality improvement process through elimination of process variation techniques: Also referred to as Six Sigma.

Rapid process improvement workshops: a collaborative and intensive workshop activities for developing rapid process improvement ideas. May be referred to as a Kaizen Event.

Standardized design techniques: Standardization of design to facilitate efficiencies in production and assembly.

Strategic Partnerships: A long-term commitment between two or more organizations as in an alliance or it may be applied to a shorter period of time such as the duration of a project. The purpose of partnering is to achieve specific business objectives by maximizing the effectiveness of each participant's resources.

Team building: A project-focused process that builds and develops shared goals, interdependence, trust and commitment, and accountability among team members and that seeks to improve team members' problem-solving skills.

Use of technology as an integration tool (3D modeling, BIM): The Technology Use and Integration practice addresses the level of automation and integration internally and externally for predefined tasks/work functions common to most projects.

Value engineering in design phase: A systematic and organized approach to provide the necessary functions in a project at the lowest cost. Value engineering promotes the substitution of materials and methods with less expensive alternatives, without sacrificing functionality.

Value Stream Mapping: Mapping of all steps in the project delivery including material and information flow:

Waste minimization techniques throughout design and construction phase: Focused activities aimed at removing non-value-added investment from the project scope. Collectively, VIPs are an organized approach to minimizing life-cycle costs while optimizing the life of a facility. May be referred to as Value Improving Practices.