ALIGNMENT BETWEEN INTENSITY OF RISK AND LEVEL OF COLLABORATION IN PARTNERED ARCHITECTURE, ENGINEERING AND CONSTRUCTION PROJECTS: A QUANTITATIVE APPROACH TO TEST IMPACTS ON PROJECT PERFORMANCE OUTCOMES

By

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ABSTRACT

ALIGNMENT BETWEEN INTENSITY OF RISK AND LEVEL OF COLLABORATION IN PARTNERED ARCHITECTURE, ENGINEERING AND CONSTRUCTION PROJECTS: A QUANTITATIVE APPROACH TO TEST IMPACTS ON PROJECT PERFORMANCE OUTCOMES

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Risk is a typical characteristic of Architecture, Engineering, and Construction (AEC) projects; the intensity of which is influenced by factors such as the dynamic nature of project elements (e.g., fragmented multi-disciplinary project teams), interactions among these elements, and lack of clear project goals. Project Partnering is a project delivery practice, adopting which, two or more organizations commit to harboring an environment of collaboration in a structured approach, with the intention of achieving optimum shared project performance goals (e.g., reduced costs, delays).

Project management theory and practice both endorse that as the intensity of risk in a project increases, a higher level of collaboration among the multi-disciplinary project teams is desirable in order to achieve optimal project performance outcomes. However, a theoretical gap exists in providing empirical reinforcement supporting this assertion. The goal of this study is to conduct an empirical examination of the impact of the association between intensity of risk and adopted level of collaboration on performance outcomes of AEC projects.

This study investigated 127 partnered projects from the United States completed between 2010 and 2018. Literature study, exploratory data analysis, and coding were employed to develop models to assess the study variables (risk intensity, level of collaboration, fit between them and performance outcomes) and assign them to projects in the data set. The non-parametric Kruskal-Wallis test was used to compare performance outcome data across different risk-collaboration fit categories and results are presented accordingly.

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Go Green! Go White!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION

1.1 Background

An Architecture, Engineering and Construction (AEC) project can be considered to be a series of activities and tasks undertaken over a specific period of time (Syal, 2017) in which its stakeholders define goals, specific objectives, designs and specifications for the project; and then strive to achieve those goals with available and limited resources (e.g., budget, time, manpower).

Not only is there a high number of project elements (e.g., tasks, specialists, and subsystems) in AEC projects, but there also exists substantial variation and interdependency among them (Baccarini, 1996). This makes AEC projects complex. Moreover, there exist probable events, whose occurrences may affect the performance and successful completion of an AEC project. Poor performance of project elements or failure to achieve project goals can prove to be costly for its stakeholders (e.g., accidents, economic losses, damage to organizational image) (Anderson & Merna, 2003). Therefore, AEC projects are invariably characterized as being risky.

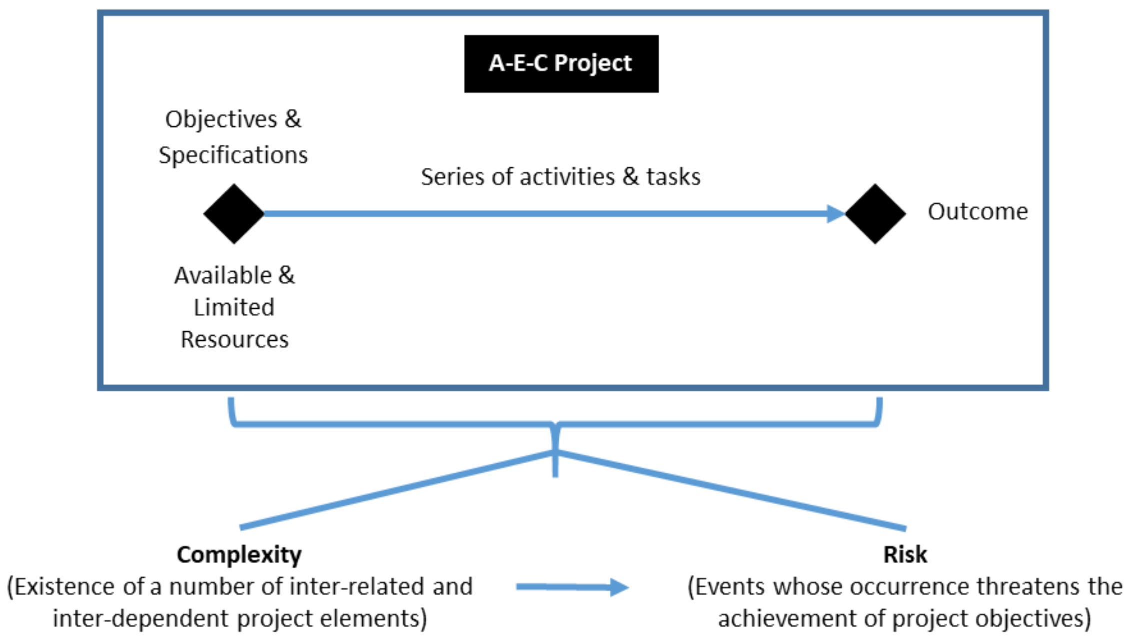

Figure 1 Depiction of an AEC project (Syal, 2017)

Risk cannot be eliminated from AEC projects, but it can be managed (Smith, Merna, & Jobling, 2014). The process of aiding project management decision-making by utilizing the practices of risk identification, analysis, response planning, and monitoring and control is called risk management (Project Management

Institute, 2009). Risk management is an integral component of project management, the effectiveness of which is associated with the performance of projects.

One vital part of AEC projects, which also constitutes a major portion of their complexity, is its multidisciplinary and fragmented project teams. They are required to work and coordinate with each other to achieve project goals and objectives. These teams usually have little to no prior experience of working together nor adequate time to develop relationships.

Over the last few decades, as construction projects have become riskier, there is a rise in the need and level of collaboration. The industry is observing a rise in the adoption of several collaboration-based project delivery methods (e.g., Design-Build, Integrated Project Delivery), technologies (e.g., BIM), and practices (e.g., Lean Construction, Project Partnering). Research shows that inter-organizational teamwork and level of collaboration among AEC project teams affects project performance (e.g., cost, schedule, quality, safety) (Chan, Ho, & Tam, 2001; Azmy, 2012).

1.2 Need Statement

In project and risk management literature, collaboration among project participants is often mentioned as a requirement for effective risk management (Al-Bahar & Crandall, 1990; Azmy, 2012; Hanna, Thomas, & Swanson, 2013). In fact, some researchers theorize that non-cooperative behavior is a threat to the effectiveness of risk management (Hanna, Thomas, & Swanson, 2013). However, although both researchers and practitioners commonly discern that collaboration is an effective risk management strategy, there exists a theoretical gap in providing empirical reinforcement supporting this assertion. A part of this gap is due to the lack of a structured framework for investigating collaboration. The practice of Project Partnering provides such a structured framework to study collaboration analytically.

Project Partnering is a project delivery practice; adopting which, two or more organizations commit to harboring an environment of collaboration (e.g., effective communication, shared vision, goal alignment, trust) in a structured approach, with the intention of achieving optimum shared project performance goals (e.g., reduced costs, delays, litigation).

Additionally, existing Partnering literature is largely qualitative and presents conceptual models, potential benefits to adopting Partnering, barriers to its adoption, critical success factors, and performance measurement and evaluation methods. Quantitative research in this domain is limited and has studied projects either coming largely from a single source of ownership (e.g., DOTs) or a project type (e.g., horizontal infrastructure projects) at a time. There is a lack in Partnering literature of evidence-based quantitative research that identifies specific factors linked to partnered-project success using data from a large and diversified sample of projects.

Thus, there was a need for an empirical assessment of the association between risk (specifically its intensity) and collaboration (or partnering), and its impact on project performance. This need prompted the undertaking of this study.

The outcomes of this study are twofold. Firstly, it adds to the body of knowledge of project and risk management via collaboration. The pragmatic significance is assistance to owners, stakeholders and project managers alike in setting and managing expectations of partaking in collaborative behavior; thus, helping them to make informed decisions when entering into collaborative arrangements for risk management on their projects. Secondly, this study adds to the theory of best practices in Partnering with respect to partnering for effective risk management.

1.3 Research Scope

As discussed in the previous section, it is rather difficult to capture the concept of collaboration across various types of projects in a structured and consistent manner for the purpose of such a study. Project Partnering offers a potential solution.

Partnering is a project delivery practice constituting a structured approach by which two or more organizations commit to harboring an environment of effective communication, shared vision and trust with the intention of achieving common project objectives (e.g., reduced costs, change orders, litigation). It is characterized by the use of several 'tools' such as periodic workshops, charters, alternative dispute resolution strategies, etc., usually with the help of a third-party neutral facilitator. As partnered projects possess a structured framework within which efforts for collaboration are systematized and assessable, this study focuses on studying projects that have adopted Project Partnering.

With respect to studying risk for this research, Tah and Carr (2000) support the assertion there are two types of construction project risks – internal and external. Internal risks (e.g., cost pressure) manifest from causes whose origins fall within the general management scope of the project and in general can be controlled. External risks (e.g., government shutdown) are usually not controllable because the factors causing them are outside the general management scope of the project. This research will primarily focus on risks internal to projects.

Due to lack of existence of predefined or commonly accepted terminology to capture the concept of this interplay between risk intensity and level of collaboration, the study proposed use of the construct 'fit'. Fit denotes the relation between risk intensity and level of partnering on a project: The higher the level of collaboration (i.e., partnering) with respect to intensity of risk in a project better is the fit.

Although due diligence was done during revision and subsequent verification of models to capture the constructs of risk intensity and collaboration (or partnering) level during this research, the study largely relied on existing literature about what contributes to risk and collaboration in a project. The primary focus of this research was to capture the interplay between these constructs and investigate its correlation with project performance. Hence, sophisticated methodology (e.g., factor analysis) for verifying the authenticity of the models was outside the scope of this research. Lastly, quantitative analysis was used to test the study hypothesis designed in adherence to research goals and objectives stated in subsequent sections.

In summary, the framework of Partnering is adopted in this research to facilitate the study of collaboration in a structured manner. Hence, the units of analysis for the study are partnered projects in the US. In the Partnering framework, 'collaboration' is synonymous with 'partnering' and therefore, 'level of collaboration' in a project will henceforth be referred to as 'level of partnering' or simply as the 'Partnering level'.

1.4 Research Goals and Objectives

Responding to the need statement stated in Section 1.2, the goal of the research was to investigate partnered projects for the impact of the fit between their intensity of risk and adopted partnering level on their performance outcomes (e.g., cost, schedule). The need statement and goal of this research can be effectively assimilated into the research question:

> ***'In partnered AEC projects, does the fit between risk intensity and level of partnering correlate with performance of the project?'***

To answer this question, the following hypothesis was developed:

> ***''In a partnered project, better the fit between the intensity of risk and adopted partnering level, better is its performance.' (e.g., cost growth, schedule growth).'***

To achieve the study goal, the following objectives were delineated:

1. Via a literature review, identify and develop (if required) models to ascertain following constructs of interest:
    a. Risk intensity of a project;
    b. Partnering level of a project;
    c. Fit between risk intensity and partnering level of projects; and
    d. Project performance outcomes.
2. Using the outcomes of objective one, systematically code quantitative measures of these constructs from project details in the data set.
3. Conduct statistical hypothesis testing to ascertain if there exists a correlation between the fit between risk intensity and partnering level in partnered projects and its performance outcomes.

1.5 Overview of Research Methodology

Data collected and used for this research is archival in nature containing details of 127 partnered AEC projects from the United States completed between 2010 and 2018. These details comprise of answers to a questionnaire enquiring the project's description, challenges, partnering implementation, performance, etc. A detailed description of the data set is presented in Section 3.4.

For objective one, the researcher commenced a literature review to present the state-of-art theory about risk, collaborative practices (especially partnering) and effect of their interplay on project outcomes. Models used in the industry to assign risk intensity and partnering level to a partnered project were found as a result. Following the above finding, preliminary content analysis was attempted for a few projects in the data set, to code constructs of interest (e.g., risk intensity, partnering level) using these models within the available project data. However, it was realized that the models had limitations with respect to available project data in the data-set. Hence, exploratory data analysis was undertaken to address these limitations with the objective to revise the models per objective one. Additional literature review was conducted and revised risk intensity and partnering level assignment models were developed.

As the models found via literature study were revised, it was imperative to test the correctness of these models. For this, a survey was presented to experts (i.e., neutral third-party partnering facilitators) of the projects in the data set requesting them to assign values for risk intensity and partnering level to their project. Statistical analysis was used to test the hypothesis that the values assigned by the experts for both risk intensity and partnering level are not significantly different from those assigned via the revised models. It was proved that the hypothesis was true and hence, values for risk intensity and partnering level assigned using the theoretically developed models were used for further analysis.

Further, due to lack of predefined or commonly accepted terminology to capture the concept of this interplay between risk intensity and level of collaboration, the study proposed use of the construct 'fit'. Literature supports the introduction of such variables. For example, in economics, the variable 'demand elasticity' captures the association between change in demand versus the change in price of goods. Fit denotes the relation between risk intensity and level of partnering on a project. Fit level for a project was defined by the researcher as follows:

- Partnering level higher than intensity of risk indicated a 'positive fit';
- Partnering level equal to intensity of risk indicated a 'neutral fit'; and
- Partnering level lesser than intensity of risk indicated a 'negative fit'.

Thus, the product of completing objective one was development of models and procedures to be used to identify constructs of interest of this study viz., risk intensity, partnering level, fit, and performance outcomes.

For objective two, content analysis and coding were employed to systematically identify and assign values for the constructs of interest (risk intensity, partnering level, fit, and performance outcomes) using models and procedures developed via objective one. The product of completing objective two was that each project in the data set was assigned quantitative values for performance outcome metrics (e.g., schedule growth, cost growth); and was categorized into one of the three fit categories (positive, neutral and negative).

For objective three, the research hypothesis that 'In a partnered project, better the fit between the intensity of risk and adopted partnering level, better is its performance' was tested using statistical tests for comparison of samples across the three fit categories. For this purpose, a performance outcome metric of projects categorized into the three fit categories was considered as three different samples. For example, it was statistically tested whether values for the schedule growth metric was different for projects in at least two of the three fit categories (positive, neutral and negative). If a statistically significant difference was found, further statistical tests comparing two samples (or fit categories) at a time were conducted to identify which fit category performed better in terms of schedule growth compared to the other two fit categories.

Throughout the research, appropriate measures to maintain research quality were undertaken at every step. For example, construct validity was established via comprehensive literature review. Further, revised risk intensity and partnering level models were verified via a survey. During the coding exercise, inter-coder reliability was maintained by utilizing two coders followed by random cross-checks. Detailed description of quality efforts is outlined in Section 3.7.

1.6 Deliverables and Outcomes

The deliverables of this study are tools or models for risk intensity assessment and simultaneous determination of recommended level of partnering. The study was able to contribute to the body of knowledge of risk management via collaboration by providing empirical reinforcement to the association or lack of thereof between risk, collaboration and performance. Lastly, this study provides guidelines for best practices in Partnering contributing to effective risk management on AEC projects.

Decision-makers in the construction industry (e.g., owner organization, stakeholders) will be able to support to their request or demand to implement an intensity of collaborative efforts on projects with respect to assessed risk intensity. Owners will be able to manage their expectations with regards to the impact of collaboration on the risk of their project. In addition, empirical evidence about how risk and collaboration affect performance could assist in convincing other project team members like contractors and trades about the expectations and importance of partaking in collaborative behavior.

1.7 Reader's Guide

CHAPTER 1 of this research presented the background of the domain of risk management via collaboration. It was followed by establishing the need for such a study. Then, the scope of this study was delineated, and its goals and objectives mentioned. Planned research methodology to achieve these goals and objectives was explained and finally expected deliverables were laid out.

CHAPTER 2 presents the literature review conducted for this study. It presents existing theories about risk and approach to its management, an overview of various collaborative practices in the industry and details about the particular practice of Partnering.

CHAPTER 3 presents the research methodology, which expands on the goals and objectives of this research in detail as well as describes the data collection strategy, data coding efforts, approach and techniques used for data analysis. It concludes with explanation for the quality measures adopted at various stages in this study.

CHAPTER 4 presents the findings of the study. Beginning with descriptive statistics outlining relevant characteristics of the data set, it proceeds to explaining the process and results of exploratory data analysis. It presents details and results of hypothesis tests.

CHAPTER 1 concludes this thesis by presenting a summary of the findings, outlining lessons learned, reviewing expected and actual deliverables, presenting limitations of this study and recommending directions for future research.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature review for this research, based on which the researcher will provide perspective for selection of research methods and subsequent quantitative analysis. The literature review is divided into three parts – (i) theory and state of practice of risk & its management; (ii) overview of collaborative practices in the AEC industry; and (iii) description of the collaborative project delivery practice of Project Partnering.

The first section of the literature review covers aspects of risk and its management (e.g., risk definition, identification, risk analysis and approaches to risk management) in project management literature with a focus on AEC projects. At the outset, risk is defined and then the characteristics of AEC projects that contribute to risk are listed and classified. Then, risk analysis metrics, processes and ranking scales from existing studies are presented. Further, state-of-art approaches to risk management recognized in literature are presented. This part concludes with underlining the trend of rise in need for collaborative risk management in the AEC industry.

Keeping this trend of the rise in need for collaboration in mind, the second section presents an overview of the practices in the AEC industry that are characterized as 'collaborative'. It covers collaborative (i) information and communications technologies (e.g., BIM, cloud-based integration); (ii) project delivery practices (e.g., Design-Build, IPD); and (iii) project delivery practices (e.g., Lean Construction, Project Partnering). An effort is made to identify risk management aspects of these practices.

The third section presents the collaborative project delivery practice of Project Partnering in depth, which is the focus of this research. A brief history of Project Partnering is presented along with its definition, description of its tools and its critical success factors. A special effort is made to study the state-of-art risk management aspects of this practice. A risk identification, analysis and ranking matrix found in literature is presented and critiqued.

2.2 Risk in AEC Projects

2.2.1 Defining Risk

Risk is a critical characteristic of AEC projects, which determines the selection of suitable project managerial actions required to complete the project successfully (Baccarini, 1996). Project Risk

Management is a vital part of Project Management (Project Management Institute, 2009). There is significant debate and lack of consensus on the definition and composition of the term ‘risk’ in project management literature (Whitty & Maylor, 2009; Gratt, 1989). For the purpose of this research, the following definition of risk will be considered:

“Risk is a function of two major factors: (a) the probability that an event, or series of events of various magnitudes, will occur, and (b) the consequences of the event(s)” (Gratt, 1989).

Complexity is another characteristic of an AEC project and it is important to understand its role in contributing to risk. Complexity is defined as: “consisting of many varied interrelated parts”; and can be expressed in terms of differentiation (variety) and interdependency” (Baccarini, 1996).

As far as the relationship between complexity and risk is concerned, researchers suggest that complexity is a factor of project risk (Weidong & Lee, 2005; Vidal & Marle, 2008). Fang and Marle (2012) advocate that complexity of a project leads to the existence of a network of interdependent risks. In fact, construction companies are exposed to risk at a high level because of increasing complexity (Hanna, Thomas, & Swanson, 2013). This research considers complexity to be a component of risk.

Further, Tah & Carr (2000) support that there are two types of construction project risks – internal and external. Internal risks (e.g., cost pressure) manifest from causes whose origins fall within the general management scope of the project and in general can be said to be ‘controllable’. External risks (e.g., government shutdown) are usually uncontrollable because the factors causing them are outside the general management scope of the project. This research primarily deals with risks internal to the project.

2.2.2 Risk Identification and Classification

Risk identification is considered the first step in project risk management as it provides the basis for the next steps of risk management (e.g., risk analysis, risk response planning, and risk control) (PMI, 2007). Chapman (2001) opines that the process of risk identification has direct influence on the contribution that risk analysis and management makes to the overall project management of construction. Effective risk identification leads to effective risk management (Tchankova, 2002).

Generally, contractors rely on experience and rules of thumb when dealing with risk because there is a lack of a systematic way to prioritize risk and its elements (Al-Bahar & Crandall, 1990). Hence, it is important to not only identify risks but also classify them. Risk classification aids in expanding awareness about the risks involved for its stakeholders and deciding risk management strategies per the nature of risks (Al-Bahar & Crandall, 1990).

Several efforts have been made to identify and classify risks in the AEC industry. These efforts are usually part of a larger risk management model and the categories reflect the risk management tools or practices presented in those models. This research studied various risk factors and their risk classification categories in literature. A summarized list of the risk elements and their classification categories are presented in Table 1 below:

Table 1 List of Risk Elements and Risk Factor Categories in the Literature

Source	Risk Element	Risk Factors
Luo, He, Xie, Yang, & Wu, 2017	Organizational	Vertical and horizontal differentiation across organizations; degree of operational interdependencies and interaction; number of members, departments, organizations, regions, nations, languages, time zones; power structure, number and diversity of actors, diversity of the cultural human mindset, size, resources, project team, trust, and risk; contractual conditions, number of contract/work packages, coordination of stakeholders, and project planning and scheduling.
	Technological/ infrastructural	Variety or diversity of some aspect of a task; interdependencies among tasks and teams; technology, innovation system, uncertainty of the process or demand; density of activities in a spatial and temporal frame; building type, overlapping of design and construction works, and dependency on project operation; variety of technologies employed and technological newness of the project; site compensation and clearance, transportation systems, and qualifications required for contractors.
	Resource	Project scale; budget size.
	Directional/objective	Degree of independence when defining operations to achieve given goals; ambiguity related to multiple potential interpretations of goals and objectives; ambiguity of project scope, and project size in terms of capital; various project participants' requirements, project task complexity, and limited resources; difficulty in managing and keeping track of the large number of different interconnected tasks and activities.
	Sociopolitical	Administrative policies/procedures, number of applicable laws and regulations, local experience expected from parties, and influence of politics.
	Environmental	Local climatic conditions, geographic conditions, and environmental risks.
Al-Bahar & Crandall, 1990	Acts of God	Flood, earthquake, landslide, fire, wind, lightning.
	Physical	Damage to structure, damage to equipment, labor injuries, material and equipment fire or theft.
	Financial and economic	Inflation, availability of funds from client, exchange rate fluctuation, financial default of subcontractor, non-convertibility.
	Political and environmental	Changes in laws and regulations, war and civil disorder, requirements for permits and their approval, pollution and safety rules, expropriation, embargoes.
	Design	Incomplete design scope, defective design, errors and omissions, inadequate specifications, different site conditions.

Table 1 (cont'd)

Zavadskas, Turskis, & Tamošaitiene, 2010	External risk	Political - changes in government laws of legislative system, regulations and policy, improper administration system; economic - inconstancy of economy in the country, repayment situation in manufacture sphere, inflation, funding, and contractor could not properly assess either their probability or their cost impact; social, weather.
	Project risk	Time, cost, work quality, construction, technological, resource.
	Internal risk	Resource; project member - team member turnover, staffing build up, insufficient knowledge among team members, cooperation, motivation, and team communication issues; construction site, documents and information.
Baccarini & Archer, 2001	Method of establishing targets	The way cost targets were established; the way time targets were established; the way quality targets were established.
	Consequence of failure to meet targets	The effect if cost targets are not met; the effect if time targets are not met; the effect if quality targets are not met.
	Project features	Uniqueness of the product; complexity of deliverables; financing; adequacy of funds; project location; project surroundings; hazardous materials; definition of project; site availability; project justification; project approvals; client's experience; client's relationships; Availability and competency of contractors; procurement method; stakeholder interest.
International Partnering Institute, 2018	Project value	Scale of the project (e.g., mega, large, small); project budget.
	Complexity	Technical complexity, design complexity, construction complexity, schedule constraint, uncommon materials.
	Political significance	Visibility, oversight, strategic significance, organizational image at stake, size of client, importance of location of project.
	Relationships	New project relationships between owner, contractor, subcontractors, etc., turnover rate of subcontractors, potential for conflict, strained relationships, previous litigation.
	Desired Level of Engagement	Seeking risk mitigation, seeking high project efficiencies.

2.2.3 Risk Intensity and its Assessment

Some risks are more significant to the stakeholders than others are; and hence the risk analysis process is important step between risk identification and determination of risk management strategy (Al-Bahar & Crandall, 1990). There is a need to rank and prioritize risks in a project in order to focus the risk management effort on the greater risks (Baccarini & Archer, 2001).

If the definition that risk is a function of the probability of occurrence of an uncertain event and the severity of its impact is considered, it is then logical to say that higher the probability of occurrence of a risky event and more severe the impact of its occurrence, higher is the intensity of risk. Hanna, Thomas, & Swanson (2013) suggested the use of the following two parameters to grade risk: (i) probability of risk realization and (ii) extent of impact on project objectives if the risk realizes. Both the parameters were measured in percentage chance and a factor 'risk rating'; like risk intensity, was then defined as the product of the two parameters. However, in the AEC industry, there is no exact science to calculate probability of risk occurrence, nor estimate the severity of its impact. Moreover, different stakeholders may have different perception about the probability and severity of realization of a risk.

Nonetheless, risk intensity assessment is a vital step towards risk management and must be undertaken as an effective project management strategy. A preliminary literature search for existing risk intensity assessment models led to the finding of matrices (International Partnering Institute, 2018) developed by the International Partnering Institute (IPI) who administered the questionnaire for the collection of data used in this research. A discussion with a member of IPI (who was the Director at the time when the matrices were developed) affirmed that these models or 'scalability matrices' are developed by committees comprised of industry experts from the AEC industry (personal communication, March 04, 2019). These models have been presented below:

IPI Horizontal Construction Project Partnering Scalability Matrix

Scale your Partnering:
In order to determine the level of Partnering that you should apply to your construction project, take a moment to collaboratively asses
The higher the risk, the more intensive your Partnering efforts should be. When in doubt, scale your Partnering efforts upward to set y

	Risk Factors*				
Level	**Project Value**	**Complexity**	**Political Significance**	**Relationships**	**Desired Level of Engagement**
4	**Very Large/Mega** (multi-phased highway corridors, complex bridges and structures) **($250M-$500M+)**	Highly Technical and Complex Design and Construction	High Visibility/oversight Significant strategic project	New Project Relationships including: new contractors, sub, agencies, third-parties, high turnover rate of subs or other high potential for conflict (strained relationship, previous litigation, or high probability of claims)	Very High
3	**Large** (new design, new contracting method, or challenging rehabilitation/ renovation) **($10M-$250M)**	High Complexity (short timeline/schedule constraints, uncommon materials, new supply chain, etc.)	Probable - Organizational image at stake	New Contractors or CM, New subs/relationships	High
2	**Small ($5M - $10M)**	Moderate Complexity	Unlikely, depending on the size of the client and place of importance	Established relationships New CM, subs, agencies, or other key stakeholders	Moderate (seeking risk mitigation and project efficiencies)
1	**Micro ($0-$5M)**	Low Complexity	Unlikely, depending on the size of the client and place of importance	Established relationships new CM, subs, new agencies, or other key stakeholders	Moderate/High (seeking risk mitigation and project efficiencies)

*Risk factors will vary by project. Though these are the most common, additional factors should be considered if necessary.

Figure 2 Risk Scalability Matrix – I (adopted from International Partnering Institute)

IPI Vertical Construction Project Partnering Scalability Matrix

Scale your Partnering:

In order to determine the level of Partnering that you should apply to your construction project, take a moment to collaboratively asses
The higher the risk, the more intensive your Partnering efforts should be. When in doubt, scale your Partnering efforts upward to set yo

	Risk Factors*				
Level	**Project Value**	**Complexity**	**Political Significance**	**Relationships**	**Desired Level of Engagement**
5	**Very Large/Mega** (airport terminal, hospital, power plants, etc.) **($250M-$500M+)**	Highly Technical and Complex Design and Construction	High Visibility/oversight Significant strategic project	New Project Relationships including: new contractors, sub, agencies, third-parties, high turnover rate of subs or other high potential for conflict (strained relationship, previous litigation, or high probability of claims)	Very High
4	**Large** (new design, new contracting method, challenging rehabilitation/renovation) **($25M-$250M)**	High Complexity (short timeline/schedule constraints, uncommon materials, new supply chain, etc.)	Probable -- Organizational Image at stake	New Contractors or CM, New subs/relationships	High
3	**Medium ($10M - $25M)**	Increased Complexity	Likely, depending on the size of the client and place of importance	Established relationships New CM, subs, agencies, or other key stakeholders	Moderate/High (seeking risk mitigation and project efficiencies)
2	**Small ($5M - $10M)**	Moderate Complexity	Unlikely, unless in a place of importance	Established relationships New subs New Agencies New Stakeholders	Moderate (seeking risk mitigation and project efficiencies)
1	**Micro/Short Duration ($0-$5M)**	Standard Complexity	Unlikely, unless in a place of importance	Established relationships New subs New agencies New stakeholders	Low to Moderate for small budget and/or short timeline projects, Partnering can reduce risk and focus on project efficiencies

*Risk factors will vary by project. Though these are the most common, additional factors should be considered if necessary.

Figure 3 Risk Scalability Matrix – II (adopted from International Partnering Institute)

IPI Aviation Construction Project Partnering Scalability Matrix

Scale your Partnering:

In order to determine the level of Partnering that you should apply to your construction project, take a moment to collaboratively assess yo
The higher the risk, the more intensive your Partnering efforts should be. When in doubt, scale your Partnering efforts upward to set your

	Risk Factors*				
Level	**Project Value**	**Complexity**	**Political Significance**	**Relationships**	**Desired Level of Engagement**
5	**Very Large/Mega** (airport terminal, hotels, parking structures, etc.) **($250M-$500M+)**	Highly Technical and Complex Design and Construction, Public Private Partnership	High Visibility/oversight Significant strategic project	New Project Relationships including: new contractors, sub, agencies, third-parties, CM, PPP, high turnover rate of subs or other high potential for conflict (strained relationship, previous litigation, or high probability of claims)	Very High
4	**Large** (new design, new contracting method [D/B, CMAR, or other], or challenging rehabilitation/ renovation) **($25M-$250M)**	High Complexity (short timeline/schedule constraints, uncommon materials, new supply chain, baggage handling, controls projects, aircraft bridge, etc.)	Probable - Organizational image at stake	Public Private Partnership (PPP), multi-prime contract, new contractors or CM, new subs/relationships	High
3	**Medium ($10M - $25M)**	Increased Complexity	Likely, depending on the size of the client and place of importance	Established relationships New CM, subs, agencies, or other key stakeholders	Moderate/High (seeking risk mitigation and project efficiencies)
2	**Small ($5M - $10M)**	Moderate Complexity (ongoing operations)	Unlikely, unless in a place of importance	Established relationships New subs New Agencies New Stakeholders	Moderate (seeking risk mitigation and project efficiencies)
1	**Micro/Short Duration ($0-$5M)**	Standard Complexity	Unlikely, unless in a place of importance	Established relationships New subs New agencies New stakeholders	Low to Moderate for small budget and/or short timeline projects, Partnering can reduce risk and focus on project efficiencies

*Risk factors will vary by project. Though these are the most common, additional factors should be considered if necessary.

Figure 4 Risk Scalability Matrix – III (adopted from International Partnering Institute)

Before utilizing the matrices for further analysis, they were evaluated based on peer-reviewed risk assessment literature for validity. To do so, first, various characteristics of the models were observed and then their basis in literature, if any, was examined.

Observations about the models are as follows:

i. Separate matrices exist for horizontal (e.g., roads, bridges), vertical (e.g., commercial buildings) and aviation (e.g., runways, terminals). It is important to note that aviation projects include both vertical (e.g. terminal buildings, watch towers) and horizontal (e.g., runway) projects. The justification for a separate aviation category is that the number, structure and power to influence of stakeholders (e.g., security, customs) in aviation projects add an extra layer of risk, which is acknowledged via a separate category. However, it is observed that the models for vertical and aviation are practically similar. This suggests that risk intensity perception varies per project type (e.g., vertical, horizontal, aviation).

ii. In each matrix, various risk elements (e.g., project size, visibility, complexity) are identified which are then classified into risk factors (e.g., project value, complexity, political significance, relationships and desired level of engagement). Although the levels of risk are different per the project type, risk factors, constituent risk elements and their descriptions are common across all three matrices.

iii. The intensity of risk of a particular risk factor is graded on an ordinal scale of 1-4 for horizontal projects and 1-5 for vertical and aviation projects. Although no rule for identifying the overall intensity of risk is seen, overall risk intensity presumably is again scaled on a scale of 1-4 for horizontal projects and 1-5 for vertical projects based on consensus of project stakeholders involved in risk assessment exercise.

With regards to observation one, it is found that although the risk factors on a project are common across the AEC industry, their intensity varies depending on the type of project. For example, horizontal AEC projects experience a lower level of risk because of the high percentage of self-performed work. On the contrary, vertical and aviation projects usually consist of a prime contractor coordinating several trades or subcontractors who perform the work, thus adding an extra layer of risk to the project. Thus, there is basis in literature for the development of separate models for horizontal (e.g., roads, bridges), vertical (e.g., buildings) and aviation (e.g., runways, terminals). Of these, the models for vertical and aviation are practically similar and hence will be analyzed as one henceforth.

For observation two, Sections 2.2.1 and 2.2.2 have already presented the basis for risk identification and the need for classification. With respect to common risk factors and elements across all project types, there is evidence in literature that risk assessment models or processes (Hanna, Thomas, & Swanson, 2013; Kindinger & Darby, 2000; Baccarini & Archer, 2001) commonly consider a generic set of risk elements and classifications for risk assessment across project types.

For observations three, Kindinger & Darby (2000) recommend that risk analysis must be conducted using a graded approach with the intention of fitting the risk management approach to the needs of the project (e.g., project size, data availability, requirements of project team). Hanna, Thomas, & Swanson (2013) have used a 5-point Likert scale in their risk rating model to grade risk elements. Baccarini & Archer (2001) in their risk model have collected the ratings given by the different stakeholders and averaged the numbers to present risk factors and their corresponding grading scale.

In summary, it was concluded that there is support in peer-reviewed literature for the risk models developed by IPI. Hence, these models were used for preliminary content analysis in this study's data analysis phase.

2.2.4 Approaches to Risk Management

Risk Management is a systematic process of identification and assessment of risks and determination of strategies for risk mitigation and responses to occurrences of risk events over the life of a project with the objective of achieving project goals (e.g., cost, schedule, safety) and maximizing project value (e.g., participant satisfaction, quality) (Al-Bahar & Crandall, 1990). In the previous sections, the researcher elaborated on the methods of risk identification and risk analysis. In this section, a general overview of the approaches to risk management is presented.

2.2.4.1 Traditional Approach to Risk Management

Appropriate risk allocation – which refers to the contractual distribution of risk among project stakeholders (e.g., owner, designer, and contractor) often, seems to be the objective behind most of the risk management models.

Risk allocation is often seen as a contentious process in AEC industry because parties attempt to transfer as much risk as possible to other parties (Hanna, Thomas, & Swanson, 2013). Bargaining power or power imbalances influence risk allocation (Zhang, Zhang, Gao, & Ding, 2016) and in practice, most of the risk gets transferred to parties least capable of handling them because of their limited bargaining power (Chen & Hubbard, 2012). Risk misallocation negatively affects the cooperative behavior of stakeholders in AEC projects (Zhang, Zhang, Gao, & Ding, 2016).

However, the goal of optimal risk management should be to minimize the total cost of risks to a project, not necessarily the costs to each party separately (CII 1993) and risk-irrespective of whose risk it may be (ASCE 1979).

2.2.4.2 Collaborative Approach to Risk Management

The possibility of non-collaborative behavior seems to be inherent in the Risk Allocation approach towards risk modelling. Rahman & Kumaraswamy (2004) commented on this approach to risk modeling and set forth the following reasoning for adopting a collaborative approach towards risk modeling. According to them, first, a complete, definitive and exhaustive allocation of risks cannot be achieved because not all construction risks foreseeable at the outset. Second, quantification of foreseeable risks may be neither always possible nor correct because as a project progresses, the nature and extent of foreseeable risks may change, new risks may emerge, and existing risks may change in importance. Third, some of the risks may require the combined efforts of all contracting parties for their effective management.

Lehtiranta (2011) introduced the concept of a 'relational risk management' approach for modelling complexity of AEC projects. Her model is based on a new classification of risk suggested by Das & Teng, (2001). They suggested that all risk can be classified as either relational risk – relates to achieving the goals of collaboration or performance risk – achieving the goals of the technical undertaking provided that the collaboration functions properly. Lehtiranta's (2011) argument for adopting this classification while making a case for a collaborative approach to risk management was that technical solutions are well developed in the AEC industry and thus substantial potential for performance improvement is embedded in human interaction as well as rise in recognition for need for collaboration in the AEC industry.

The rise in the need for collaboration in the AEC industry has led to the development of various collaborative practices in the form of (i) technologies (e.g., BIM, Cloud-based integration); (ii) project delivery methods (e.g., Design-Build, Integrated Project Delivery); and (iii) project delivery practices (e.g., Lean Construction, Project Partnering). These collaborative practices are discussed in the next section.

2.3 Collaborative Practices in the AEC Industry

2.3.1 Collaborative Information and Communication Technologies (ICTs)

This section deals with Information and communications technologies (ICT) in the AEC industry. ICT refers to the extension of the use of information technology to include communication systems (e.g., wireless systems) and enterprise software that enable organizations to access, store, transmit and manipulate information. All these technologies help in facilitating efficient and error-free information exchange among project stakeholders and team members. Hence, they are characterized as being collaborative in nature.

ICT has witnessed applications in the AEC industry as response to a spectrum of organizational and managerial issues in project management. Some prime examples of ICT applications seen in the AEC industry are (Lu, et al., 2015): (i) Web Based Systems; (ii) Virtual/Augmented Reality Technologies; (iii) Wireless Technologies; (iv) Electronic Data Interchange/Electronic Data Management System; and (v) Building Information Modelling (BIM). A brief overview of these technologies, their collaborative implications and risk management aspects is presented below.

2.3.1.1 Web-Based Systems

Most ICT applications depend heavily on the web technology development in both the design and management process. Examples of web-based ICT applications include decision support systems, information management systems, and collaborative contract change management systems. The benefits of using web technology are generally focused on effective collaboration, communication and coordination, and the decision-making process (Lu, et al., 2015)

2.3.1.2 Virtual/Augmented Reality technologies

Virtual reality (VR) technology provides “a high-end user interface which is interactive, spatial, in real time and enables simulation and interaction through multiple sensorial channels (e.g., vision, sound, touch)” (Burdea and Coiffet, 2017). Augmented reality (AR) is a variation of VR that creates an environment in which digital information is inserted in a predominantly real-world view (Wang et al. 2013). Many studies have focused on the application of VR and AR technologies in the design and construction process. These studies provide evidence that VR/AR technology is effective (i) in promoting collaboration among participants such as during design review process (Hammad, Wang, & Mudur, 2009); (ii) monitoring construction progress (Golparvar-Fard, Peña-Mora, & Savarese, 2009); and (iii) improving organizational performance and decision making capacity for architecture design companies (Lu, et al., 2015).

2.3.1.3 Wireless Technologies

Wireless technology allows the transfer of information between two or more points that are not connected by an electrical conductor. Common wireless technologies in the construction industry include radio frequency identification technology, personal digital assistants (PDAs), and global positioning systems (GPS). All of these applications offer considerable benefits in terms of information collection, exchange and storing, thus improving collaborative work (Lu, et al., 2015); the decision-making process; and project performance (Wang L. , 2008). In addition, wireless technology can be integrated with other ICT applications. For example, the integration of wireless technology and agent-based systems can support collaborative work by providing real-time field data capturing (Lu, et al., 2015).

2.3.1.4 Electronic Data Interchange/Electronic Data Management System

Electronic data interchange (EDI) or electronic data management system (EDMS) is a seamless data interchange tool that enables communication among different computer systems or computer networks. As a result, various EDI systems in the construction industry are designed to remove the barriers for collaboration in a geographically fragmented industry.

2.3.1.5 Building Information Modelling (BIM)

Not all construction risks are foreseeable at the outset (Rahman & Kumaraswamy, 2004). Uncertainty in AEC projects arises because architects, engineers and constructors cannot completely visualize and therefore predict potential design, construction, or operational issues that could occur on the project.

Building information modeling (BIM) has emerged as an innovative way to virtually design and manage AEC projects. With BIM technology, an accurate virtual model of a building is digitally constructed which helps architects, engineers, and constructors visualize what is to be built in a simulated environment. BIM modelling has various applications or functionalities (Azhar, 2011) like: (i) Visualization (e.g., 3D renderings); (ii) Construction sequencing (e.g., 4D scheduling); (iii) Cost estimating (e.g., 5D cost estimation); (iv) Fabrication/Shop Drawings; (v) Code review (e.g., fire code review); (vi) Conflict detection; (vii) Forensic analysis; and (viii) Facilities management. Additionally, BIM encourages integration of the roles of all stakeholders on a project. It facilitates inter-organizational and intra-organizational collaboration, communication, and cooperation (Dossick & Neff, 2011).

Adoption of BIM greatly improves the predictability of building performance and operation thereby eliminating some uncertainty in AEC projects. The process of applying BIM is a systematic way for managing risks and is expected to play a significant role in facilitating risk management in AEC projects. (Zou, Kiviniemi, & Jones, 2015). Primarily, BIM has the potential to manage risks in the planning and design phase, where one significant risk is alignment of the design with project feasibility, cost estimates and constructability (Miller & Lessard, 2001). In addition, collaboration within project teams leads to reduction in financial risk (e.g., improved profitability, reduced costs), schedule risk (e.g., better time management) and relational risk (e.g., improved customer–client relationships).

2.3.2 Collaborative Project Delivery Methods

For AEC projects, which usually have numerous project players (e.g., owner, designer, contractor, supplier, stakeholders, financers, end-users), an operational structure is needed for smooth operations. This structure must account for appropriate selection of project players, assignment of tasks and roles for them highlight financing, processes and procedures and define hierarchies. Such a structure with legal agreements and lines of privity is called a project delivery method.

Design-Bid-Build (DBB) is considered the 'traditional' project delivery method wherein the owner contracts separately with the contractor and the designer and there exists no line of privity between the contractor and the designer. The contractor further contracts subcontractors. This method has several weaknesses (Sweet & Schneier, 2009) like: (i) lack of contractor input during the design process; (ii) longer project duration owing to linear sequencing of design and construction activities; and (iii) risk of adversarial and non-collaborative behavior by project players, among others.

This led to the evolution of variations to this delivery method like Design-Build (DB), Construction Manager as General Contractor (CM/GC) or at Risk (CMAR), Integrated Project Delivery (IPD), etc. Though these variations differ among themselves, one common undertone is an intention to facilitate collaboration.

This section highlights these 'collaborative' project delivery methods and project delivery practices. An effort is made to define them, highlight their collaborative nature and their advantages in terms of risk management.

2.3.2.1 Design-Build

Traditionally, AEC projects have been delivered via 'design-bid-build' (DBB) or the 'traditional' method of project delivery where the owner contracts separately with the designer or engineer to design the project and with a contractor to execute the design. One principal variation of this system involves combining both design and construction called the 'design-build' (DB) method of project delivery.

DB provides the means to overcome some of the fragmentation in the AEC industry as it inherently requires more collaboration. It fosters this collaboration among parties that normally harbor adversarial relationships (e.g., designer and contractor), and this facilitates the creation of shared project objectives and mutual goals (Yates, 1995).

Primary advantages of DB include (Sweet & Schneier, 2009; Yates, 1995; Koch, Gransberg, & Molenaar, 2010): (i) minimization of contractual lines of privity from three (owner, designer, constructor) to two (owner and design-construction entity); (ii) ability to fast-track the project; (ii) minimization of administrative task of owner; (iii) reduction of design risk; (iv) reduction in change orders; and (iv) facilitation of collaborative decision making leading to innovation.

There are some disadvantages to DB as well (Sweet & Schneier, 2009) like: (i) loss of the designer as a paid owner's representative that watches out for owner's interests; (ii) increase in allocated risk to the designer-constructor combined entity; (iii) contention between the owner and contractor on the whether the project should be fixed price or an open-ended cost contract; and (iv) potential problems with progress payments.

2.3.2.2 Construction Management

Construction Management developed as an alternative to the traditional project delivery because of the owner's perceived concern that designers had a casual attitude and lack of knowledge regarding construction details and its cost; and contractors sometimes lacked construction technique skills (Sweet & Schneier, 2009). This project delivery method is essentially characterized by the involvement of a 'Construction Manager (CM)' entity, which provides professional services to deliver a project within a Guaranteed Maximum Price (GMP) while acting as a consultant to the owner. Sometimes, the CM may also contract with subcontractors to provide part or whole of the construction services. These variations have been classified in two classifications or approaches to Construction Management – (i) Construction

Manager as Agent/Risk (CMAR); and (ii) Construction Manager as Constructor/General Contractor (CMGC).

Advantages of CM project delivery method include (Asmar, Hanna, & Loh, 2016; Gransberg, Shane, & Schierholz, 2013): (i) early involvement and input of CM before design is complete enabling stakeholder collaboration and minimizing design risk; (ii) improvement in project performance metrics (e.g., cost, schedule) in comparison to other delivery methods; and (iii) risk transfer to the CM.

One major disadvantage of the CMGC/CMAR project delivery method is that, like DBB, there is no contractual privity between the CM and the designer. This places the owner between these entities to resolve any issues that may arise. Other disadvantages include (Molenaar, Harper, & Yugar-Arias, 2014): (i) projects are not competitively bid but negotiated with the CM entity; and (ii) GMP may include large contingency to cover risk and incomplete design.

2.3.2.3 Integrated Project Delivery

Integrated Project Delivery (IPD) is a form of Relational Contracting mechanism that seeks to distribute equitably the responsibilities and benefits of the contract transparently between the parties, based on the underlying principle of collaboration. Matthews & Howell (2005) defined IPD as an “approach that aligns project objectives with the interests of key participants” and “creates an organization able to apply the principles and practices of the Lean Project Delivery System.”

IPD seeks to mitigate some issues with traditional project delivery methods (Forbes & Ahmed, 2011) like: (i) lack of field input in designing the project; (ii) inhibition of cooperation and innovation; and (iii) lack of coordination among planning systems. Mutual respect, mutual benefit, early goal definition, enhanced communication, clearly defined open standards, appropriate technology, high performance and leadership are some essential principles of IPD (AIA California Council, 2007).

2.3.3 Collaborative Project Delivery Practices

Operational structures for AEC projects with no legal obligations for the parties are called project delivery practices. Just like legal variations to the DBB project delivery method highlighted above, operational structures like Lean Construction and Project Partnering have been developed with the intent of mitigating the risk of non-collaborative behavior in DBB. Due to no associated legal structures to these structures, they can be implemented with any project delivery method.

The project delivery practice of Lean Construction has been highlighted in this sub-section. A separate section is dedicated to Project Partnering, as it is the focus of this research where it will be reviewed in detail.

Lean Construction is defined as the "application of a new way to design project-based production systems…to minimize waste of materials, time and effort in order to generate the maximum possible amount of value (in the construction industry)" (Koskela, Howell, Ballard, & Tommelein, 2002).

The Construction Industry Institute identified five principles of lean construction (Ballard, Kim, Jang, & Liu, 2007): (i) Customer focus; (ii) Culture and people; (iii) Workplace organization and standardization; (iv) Elimination of waste; and (v) Continuous improvement and built-in quality. The report stated that lean project delivery seeks to "continuously increase the capability of delivering what is of value to specific customers in their specific circumstances."

Various tools and techniques have been developed to implement the Lean Construction project delivery system (Ballard, Tommelein, Koskela, & Howell, 2002) during various phases of project delivery like: (i) Lean work structuring; (ii) Last Planner System; (iii) Lean design; (iv) Lean supply; (v) Lean assembly; and (vi) Lean installation. Lean construction applications are noted to be successful with forms of contract that reward collaboration. Collaboration among project team members is often listed as a requirement or an outcome of implementing Lean project delivery practices.

2.4 Partnering in AEC Projects

2.4.1 Background and Definition of Partnering

In the early 1980s, 'Partnering' was a term used by U.S. manufacturing and distribution industries to describe a contracting strategy characterized by "highly structured agreements between companies to cooperate in an unusually high degree to achieve their separate but complementary objectives" (Cook & Hancher, 1990). In 1987, the Construction Industry Institute (CII) established a task force to evaluate the feasibility of using Partnering in the construction industry. The task force concluded that Partnering offered many opportunities to improve the total quality and cost effectiveness of construction projects while developing an atmosphere conducive to innovation, teamwork, trust, and commitment (CII, 1989). It defined Partnering as a "long term commitment between two or more organizations for the purpose of achieving specific business objectives by maximizing the effectiveness of each participant's resources. The relationship is based on trust, dedication to common goals, and an understanding of each other's individual expectations and values."

Several other definitions of Partnering can be found in literature:

> "A structured management approach to facilitate team working across contractual boundaries…it should not be confused with other good project management practice, or with longstanding relationships, negotiated contracts, or preferred supplier arrangement, all of which lack the structure and objective measures that must support a partnering relationship" (Construction Industry Board, 1997).

> "Construction Partnering is a structured process that brings a design and construction team together regularly throughout the life of a project. Partnering provides a space for communication, improved strategy, and issue resolution. Over time, partnered teams build trust, a reliable predictor of high performing teams. Through Partnering, fragmented teams coalesce and unify around a shared objective: successful project delivery" (International Partnering Institute, 2018).

In summary, Project Partnering is a collaborative project delivery practice that encourages the development of communication, trust and mutual commitment among participating stakeholders with the objective of successfully achieving the goals of a project.

2.4.2 Partnering Elements and Tools

Various models for project Partnering in construction have been developed in literature. For example, Cheng & Li (2001), Crowley & Karim (1995), CII (1996), etc. These models present partnering processes, identify key factors affecting partnering processes and outline challenges to partnering implementation.

A summary of Partnering elements and tools used in the AEC industry is given below (California Department of Transportation, 2013):

2.4.2.1 Executive Sponsorship

Executive Sponsorship refers to the support of top management in implementing Partnering on the project. Usually financial in nature, executive sponsorship represents executive level commitment to the process of Partnering on the project which is identified as a key element in partnering success. Executive Sponsorship is utilized for Partnering activities such as training or team building activities.

2.4.2.2 Facilitation

A facilitator is an entity, which possesses knowledge about both Partnering and construction. The Facilitator is hired to facilitate the partnering process on a project. The facilitator is selected before the start of the Partnering process, which can be at any phase in the project. However, the ideal time to hire the facilitator is upon selection of the project team (e.g., general contractor, construction manager, designer. A facilitator can either be (i) In-House; or (ii) Third Party Neutral Facilitator. The selection is usually made based on the scale and desired level of collaboration deemed necessary for the project. The facilitator is selected by the project stakeholders either via a request for qualification process or prior working experience as well. Facilitator certifications are awarded by organizations such as IPI, etc. which assist project members make an informed selection.

Once selected, the role of the Partnering Facilitator is to: (i) arrange the Kick-off Partnering Workshop and facilitate subsequent Partnering Workshops; (ii) train and guide the participants in the Partnering process; (iii) assist the project stakeholders and team members to develop the Partnering Charter and update it as the project progresses; (iv) conduct team building activities; (v) administer partnering performance surveys and interpret responses to improve the partnering process; (vi) develop issue resolution process for the project.

2.4.2.3 Partnering Meetings/Workshops/Sessions

Partnering Meetings (also called Workshops or Sessions) are where project stakeholders and team members get together to discuss the progress of the project, forecast upcoming challenges and resolve existing challenges and disputes. There are three types of Workshops viz. (i) Kick-off; (ii) Interim; and (iii) Close-out

A Kick-off Workshop is the very first workshop, which signals the commencement of Partnering on the project. The workshop is attended by the project stakeholders, team members and supply chain parties. This workshop is formally facilitated, and its agenda includes deciding mutual goals and objectives for the project, outlining these in the Partnering Charter, formulating a dispute resolution plan and identifying key risks for project success.

Interim Workshops are Partnering Workshops held during the course of the project. The frequency of these workshops is decided during the Kick-off Workshop. It can be either monthly, quarterly, half-yearly or yearly depending upon various factors (e.g., risk level, desired level of collaboration on the project).

These workshops may or may not be facilitated. The agenda of these workshops is to follow-up on project and collaborating performance. Activities include updating the Partnering Charter, resolving disputes, holding team building events, holding Partnering performance evaluations, etc.

The Close-out Workshop signals the conclusion of Partnering on the project and sometimes even the end of the project itself. The objective of the close-out Workshop is to analyze, and record lessons learnt on the project and recognize efforts on the participants. Partnering Awards, which is the formal rewarding of exceptional Partnering performances on the project, is another practice that may or may not be held during the Close-out Workshops

2.4.2.4 Partnering Charter

The Partnering Charter is one of the key elements of the Partnering process. It is a document usually prepared at the Kick-Off Workshop. It highlights the goals and objectives set by the project stakeholders, team and supply chain parties for the project in terms of cost, quality, safety, as well as communication, trust, etc. Participants sign the Charter signifying their commitment to Partnering on the project. The Charter guides the Partnering process as the project progresses. The Charter may be updated at subsequent Workshops to reflect new goals. Partnering Charter can be used as a good measure of goal alignment on the project.

2.4.2.5 Alternative Dispute Resolution

Alternative Dispute Resolution practices are adopted in Partnering to resolve disputes and avoid claims or litigation. A Dispute Resolution Association/Board is set up consisting of member representative of all project stakeholders and teams. An Issue Resolution Ladder is also set up with ranks ranging from the field level, project manager level, executive level, upper management to owner level. Such a set up encourages dispute resolution at the field level where they arise and only for the serious issues to be escalated upwards. As the time an issue can stay at a level is fixed, speedy and effective resolution of disputes is seen on projects that implement this practice.

2.4.2.6 Evaluation Surveys

Partnering Surveys are used to evaluate the performance of Partnering efforts on the project. These surveys are usually administered during the Interim Workshops and the responses are collected by the Facilitator confidentially. He/ She then decides the future course of action by analyzing these responses.

A Facilitator Evaluation survey may also be conducted, usually at the Close-Out Workshop, to evaluate the performance of the Facilitator. This survey is collected by the owner agency.

2.4.2.7 Multi-tiered Partnering

Multi-tiered Partnering is an advanced Partnering tool. Under this tool, separate Partnering Workshops are held for the Executive, Core and Project Teams to discuss issues specially pertaining to those management levels.

2.4.2.8 On-Boarding/Off-Boarding

Another advanced Partnering tool, it can be applied to both subcontractors and stakeholders. This tool is most effective when many stakeholders and subcontractors are involved in the project and their roles in the project are expected to be intermittent. It refers to stakeholders/subcontractors involved in the Partnering Workshops when their roles are current and letting them go when their roles are over. This helps the Partnering Workshops be more focused towards on-going tasks and issues on the project.

2.4.2.9 Special Task Force

Special Task Force refers to the creation of a team involving stakeholders, team members, etc. to resolve a challenge or issue. The team is created to resolve that one issue, focused towards solving it and is dissolved once the solution is obtained. This tool helps in effective resolution of challenging issues that require specialized knowledge, time and focus to solve.

In summary, Project Partnering possesses a structured framework to implement collaborative practices. Hence, the researcher has chosen partnered projects as the focus of this research.

2.4.3 Partnering Level and its Assessment

As Partnering is a structured process for collaboration involving the implementation of its tools, the level of such collaboration can be regulated to a certain degree via the variations in the implementation of the tools. For example, partnered projects facilitated by a neutral third-party facilitator show a higher level of collaboration compared to a project that is facilitated by in-house project members. Another example is that partnered project participants are more likely to show increased cooperation when partnering sessions or workshops are held more frequently (e.g., monthly compared to quarterly or yearly). Thus, number and/or frequency of the implementation of the Partnering tools determines the ‘level of collaboration' on the project; sometimes also referred to as 'partnering intensity' or simply 'partnering level'.

The structured framework Project Partnering provides helps assigning a quantitative measure to the level of collaboration on an AEC project. The level of Partnering on an AEC project is a function of the whether various Partnering tools were used or not and the frequency of some tools. The International Partnering Institute (IPI) is a non-profit organization at the forefront of providing tools for Partnering implementation. A preliminary literature search led to Partnering Level assessment matrices developed by IPI (International Partnering Institute, 2018). These matrices have been presented below:

Partnering Structure and Elements	Benefits and Approx. Cost**
Professional neutral facilitator Partnering training required for all team members Project charter Multi-tiered Partnering (executive- core team - stakeholder) Monthly Partnering meetings (design through construction) Special task Forces for specific issue resolution Stakeholder on-boarding/off-boarding Subcontractor on-boarding/ off-boarding Monthly surveys Executive sponsorship Field-level decision making Issue resolution ladder and DRB Facilitated dispute resolution	Very high accountability, Issues tracked and decisions made timely, Momentum maintained as progress continues in spite of issues that arise Approx. $20,000/qtr.
Professional neutral facilitator Partnering training required for all team members Project charter Multi-tiered Partnering (executive- core team - stakeholder) Quarterly Partnering meetings (design through construction) Stakeholder on-boarding/off-boarding Subcontractor on-boarding/ off-boarding Monthly surveys Executive sponsorship Field-level decision making Issue resolution ladder and DRB Facilitated dispute resolution	More timely decision-making in field, Stakeholders phased in and out, Designers involved throughout process Approx. $10,000-$15,000/qtr.
Professional neutral facilitation ($5M and above) Required kick-off (quarterly follow-ups recommended) Minimum 2 Partnering surveys (monthly recommended) Project charter Executive sponsorship Field-level decision making Inclusion of stakeholders Issue resolution ladder and DRB Facilitated dispute resolution	Increased predictability, Reduced (zero) claims, Improved safety, Improved schedule, On or under budget Approx. $1,000 - $8,000/qtr.
Professional neutral facilitator optional Project charter Executive sponsorship Field-level decision making Stakeholder Involvement Issue resolution ladder and DRA/DRB Facilitated dispute resolution	Increased predictability, Reduced (zero) claims, Improved safety, Improved schedule, On or under budget Approx. $1,000/qtr.

Cost of facilitation based on $5,000/day and $500 per scorecard
Please note that daily rates for facilitators can vary widely

Figure 5 Partnering Level Assessment – I (adopted from International Partnering Institute)

Partnering Structure and Elements	Benefits and Approx. Cost**
Professional neutral facilitator Partnering training required for all team members Project charter Multi-tiered Partnering (executive- core team - stakeholder) Monthly Partnering meetings (design through construction) Special task Forces for specific issue resolution Stakeholder on-boarding/off-boarding Subcontractor on-boarding/ off-boarding Monthly surveys Executive sponsorship Field-level decision making Issue resolution ladder and DRB Facilitated dispute resolution	Very high accountability, Issues tracked and decisions made timely, Momentum maintained as progress continues in spite of issues that arise Approx. $20,000/qtr.
Professional neutral facilitator Partnering training required for all team members Project charter Multi-tiered Partnering (executive- core team - stakeholder) Quarterly Partnering meetings (design through construction) Stakeholder on-boarding/off-boarding Subcontractor on-boarding/ off-boarding Monthly surveys Executive sponsorship Field-level decision making Issue resolution ladder and DRB Facilitated dispute resolution	More timely decision-making in field, Stakeholders phased in and out, Designers involved throughout process Approx. $10,000-$15,000/qtr.
Professional neutral facilitator Partnering Training recommended Quarterly partnering meetings Project charter Monthly scorecards Executive and core team Partnering Executive sponsorship Field-level decision making Inclusion of stakeholders Issue resolution ladder and DRB Facilitated dispute resolution	Increased predictability, Reduced (zero) claims, Improved safety, Improved schedule, On or under budget Approx. $5,000 - $10,000/qtr.
Professional neutral facilitator <u>for kick-off</u> (minimum) Project charter 2 Project surveys (minimum) Executive sponsorship Field-level decision making Inclusion of stakeholders Issue resolution ladder and DRB Facilitated dispute resolution	Increased predictability, Reduced (zero) claims, Improved Safety, Improved Schedule, On or under budget Approx. $5,000 - $10,000/qtr.
Professional neutral facilitator optional Project charter Executive sponsorship Field-level decision making Inclusion of stakeholders Issue resolution ladder and DRA/DRB Facilitated dispute resolution	Increased predictability, Reduced (zero) claims, Improved safety, Improved schedule, On or under budget Approx. $1,000/qtr.

Cost of facilitation based on $5,000/day and $500 per scorecard
Please note that daily rates for facilitators can vary widely

Figure 6 Partnering Level Assessment – II (adopted from International Partnering Institute)

Partnering Structure and Elements	Benefits and Approx. Cost*
Professional neutral facilitator Partnering training required for all team members Project charter Multi-tiered Partnering (executive- core team - stakeholder) Monthly Partnering meetings (design through construction) Special task Forces for specific issue resolution Stakeholder on-boarding/off-boarding Subcontractor on-boarding/ off-boarding Monthly surveys Executive sponsorship Field-level decision making Issue resolution ladder and DRB Facilitated dispute resolution	Very high accountability, Issues tracked and decisions made timely, Momentum maintained as progress continues in spite of issues that arise Approx. $20,000/qtr.
Professional neutral facilitator Partnering training required for all team members Project charter Multi-tiered Partnering (executive- core team - stakeholder) Quarterly Partnering meetings (design through construction) Stakeholder on-boarding/off-boarding Subcontractor on-boarding/ off-boarding Monthly surveys Executive sponsorship Field-level decision making Issue resolution ladder and DRB Facilitated dispute resolution	More timely decision-making in field, Stakeholders phased in and out, Designers involved throughout process Approx. $10,000-$15,000/qtr.
Professional neutral facilitator Partnering Training recommended Quarterly partnering meetings Project charter Monthly scorecards Executive and core team Partnering Executive sponsorship Field-level decision making Inclusion of stakeholders Issue resolution ladder and DRB Facilitated dispute resolution	Increased predictability, Reduced (zero) claims, Improved safety, Improved schedule, On or under budget Approx. $5,000 - $10,000/qtr.
Professional neutral facilitator <u>for kick-off</u> (minimum) Project charter 2 Project surveys (minimum) Executive sponsorship Field-level decision making Inclusion of stakeholders Issue resolution ladder and DRB Facilitated dispute resolution	Increased predictability, Reduced (zero) claims, Improved Safety, Improved Schedule, On or under budget Approx. $5,000 - $10,000/qtr.
Professional neutral facilitator optional Project charter Executive sponsorship Field-level decision making Inclusion of stakeholders Issue resolution ladder and DRA/DRB Facilitated dispute resolution	Increased predictability, Reduced (zero) claims, Improved safety, Improved schedule, On or under budget Approx. $1,000/qtr.

Cost of facilitation based on $5,000/day and $500 per scorecard
Please note that daily rates for facilitators can vary widely

Figure 7 Partnering Level Assessment – III (adopted from International Partnering Institute)

Like risk intensity matrices, before utilizing the partnering level matrices for further analysis, they were evaluated based on peer-reviewed partnering level assessment literature for validity. To do so, first, various characteristics of the models were observed and then their basis in literature, if any, was examined.

Observations about the models have been noted below:

i. Separate matrices exist for horizontal (e.g., roads, bridges), vertical (e.g., buildings) and aviation (e.g., runways, terminals) out of which, the models for vertical and aviation are practically similar. This suggests that partnering level implementation varies per project type (e.g., vertical, horizontal, aviation).
ii. In each matrix, various partnering tools (e.g., facilitation, workshops) are identified which are then differentiated via their frequency (e.g., 2 project surveys, monthly surveys). Although the partnering levels are different per the project type, partnering tools and their frequency variations are common across all three matrices.
iii. The overall partnering level is graded on an ordinal scale of 1-4 for horizontal projects and 1-5 for vertical and aviation projects.

With regards to observation one, it is found that although the partnering tools on a project are common across the AEC industry, resultant level of collaboration varies depending on the type of project. For example, horizontal AEC projects, due to the rigid nature of contract types, long project durations and less number and variety of project stakeholder members, lesser level of collaboration is achieved with the use of same partnering tools and frequency as would be achieved on a horizontal or aviation project. In addition, if partnering level is to be aligned and selected based on the risk intensity then it makes sense to have the same separate matrices for partnering level as for risk level.

For observation two, Section 2.4.2 explains how partnering tools and practices have variations dependent on their use or lack of thereof as well as frequency of use.

For observation three, if partnering level is to be aligned and selected based on the risk intensity then it is natural that the partnering level scales must be on the same scale as those determined for the risk levels.

In summary, it was concluded that there is support in peer-reviewed literature for the partnering level models developed by IPI. Hence, these models were used for preliminary content analysis.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Introduction

CHAPTER 1 provided the background of the research topic followed by CHAPTER 2, which presented a literature review about its state-of-art. Combined, the chapters led up to providing peer-reviewed affirmation about the existence of an epistemological gap in the investigation into the collective impact of the interplay between risk and collaboration via partnering on project performance.

This chapter explains the study's research design. It furthers this study by outlining the research's goals, objectives and hypothesis, followed by describing the nature of this study and the research approach adopted. It also provides a detailed description of collected data, which is archival in nature. Further, it reports on the results of preliminary content analysis, subsequent exploratory data analysis, development of revised risk intensity and partnering level assessment models, and their validation via a survey. Lastly, it presents the analysis methods used and finally concludes with outlining research quality measures implemented in this study.

3.2 Research Goal and Objectives

Literature review showed that Partnering literature lacks evidence-based quantitative research that identifies specific factors linked to partnered-project success using data from a large and diversified sample of projects. In addition, in project management literature, there was a need for an empirical assessment of the association between risk (specifically its intensity) and collaboration (or partnering), and its impact on project performance. This twofold need prompted the undertaking of this study.

Responding to this need, the goal of the research was to investigate partnered projects for the impact of the fit between their intensity of risk and adopted partnering level on their performance outcomes (e.g., cost, schedule). The need statement and goal of this research can be effectively assimilated into the research question:

> ***'In partnered AEC projects, does the fit between risk intensity and level of partnering correlate with performance of the project?'***

To answer this question, the following hypothesis was developed:

> ***'In a partnered project, better the fit between the intensity of risk and adopted partnering level, better is its performance (e.g., cost growth, schedule growth).'***

To achieve the study goal, the following objectives were delineated:

1. Via a literature review, identify and develop (if required) models to ascertain following constructs of interest:
    a. Risk intensity of a project;
    b. Partnering level of a project;
    c. Fit between risk intensity and partnering level of projects; and
    d. Project performance outcomes.
2. Using the outcomes of objective one, systematically code quantitative measures of these constructs from project details in the data set.
3. Conduct statistical hypothesis testing to ascertain if there exists a correlation between the fit between risk intensity and partnering level in partnered projects and its performance outcomes.

3.3 Nature of Research and Approach

The nature of this research is explanatory, and the approach is quantitative. Constructs in the data set are primarily quantitative in nature. Literature review was used to identify an array of variables from the data to produce a hypothesis concurring with the research question. Content analysis was used to identify and encode constructs of interest in the data set. Further, quantitative analysis will be used to test the study hypothesis mentioned in the previous section, designed in adherence to research goals and objectives.

3.4 Data Collection

The population of interest for this study is AEC projects that implemented Project Partnering or 'partnered projects'. Partnered projects are a subset of larger pool of AEC projects that intentionally implement collaborative practices for project delivery. It is not possible to collect data from all these projects. Hence, sampling is needed to collect a representative sample of the population.

The researcher collected archival data for this research as the sample. This data was obtained from a single source – International Partnering Institute (IPI), which is a non-profit organization providing guidance, education, recognition and networking support to its member organizations comprising of owners, CM firms, designers, contractors, and facilitators, etc. in the domain of achieving better project performance in the construction industry via a culture of collaboration.

The data set includes 127 partnered projects' award application documents. These are projects completed in the US between 2010 and 2018. Each project, or data point, is an application for IPI's annual Partnered Project of the Year (PPY) awards. These applications were collected via the web and application was voluntary. A sample of the award application is presented APPENDIX A

Document collected for each project is in the form of responses to a questionnaire consisting of inquiries about the project's descriptive details (e.g., project type, location, delivery method, etc.) project performance metrics (e.g., original contract amount, final contract amount, planned duration, actual duration, etc.) and particulars of collaborative practices (e.g., frequency of partnering workshops, use of partnering charters, etc.). The documents per project varied between 20-40 pages in length. The partnered projects represented in these documents are the unit of analysis of this study.

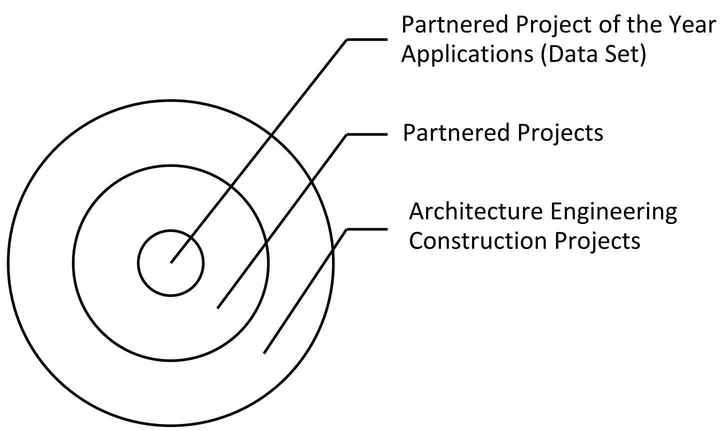

Figure 8 Collected (sample) data set with respect to population

Application to the PPY award were open to any partnered project completed within the previous year of the application and thus, the probability that a partnered project would apply for this award is assumed equal for all partnered projects). Thus, the sampling is considered random and hence, the use of statistical analysis tools is justified.

As IPI is a US-based organization, geographical bias might exist in the data in the sense that partnered projects from the US are more likely to apply than from outside US. To eliminate this bias, the researcher will present the results of the research as applicable to partnered projects in the US only. Hence, in conclusion, the sample of 127 projects is a random sample representative of all partnered projects in the US.

The following table shows the number of applications received sorted by year.

Table 2 Number of PPY Applications per Year

Year	Number of PPY Applications
2010	12
2011	1
2012	4
2013	13
2014	10
2015	27
2016	21
2017	14
2018	25
Total	127

This study also collected data in the form of risk intensity and partnering level assessment of the projects in the data set. This information was collected from partnering facilitators of the project, via an online survey. The survey was designed to assess perceived risk and partnering levels of the projects and distributed to all project partnering facilitators in the data-set (i.e., 50 facilitators for 127 projects). Survey participants received an email including consent form for participation, list of projects to fill out the survey for, and a survey. The survey requested assessment of overall risk intensity and partnering level of a given project using a Likert scale of 1-4 (for horizontal projects) and 1-5 (for non-horizontal projects) (i.e., 1=lowest level – 4 and 5=highest level).

Out of all 50 facilitators:

- 10 could not be reached (e.g., failure of email delivery, retirement)
- 16 responded (40% response rate) accounting for:
    - 53 out of the 127 projects (41.7%).

3.5 Study Variables

In accordance to the overall hypothesis of this study, the independent variable in this study is 'fit' (between risk intensity and partnering level), whereas measures of performance outcomes (e.g., schedule growth, cost growth) are the dependent or response variables. The description of these study variables is presented:

3.5.1.1 Independent Variable

Due to lack of predefined or commonly accepted terminology to capture the concept of the interplay between risk intensity and level of collaboration, the study proposed use of the construct ‘fit’.

Fit denotes the relation between risk intensity and level of partnering on a project. Fit level for a project was defined by the researcher as follows:

- Partnering level higher than intensity of risk indicates a ‘positive fit’;
- Partnering level equal to intensity of risk indicates a ‘neutral fit’; and
- Partnering level lesser than intensity of risk indicates a ‘negative fit’.

3.5.1.2 Dependent Variables

3.5.1.2.1 Cost Growth

Cost Growth (CO) is a common measure of project cost performance and is defined as the increase in the contract amount of a project with respect to the original contract amount. Mathematically, the calculation can be described as:

$$Cost\ Growth\ (CG) = \frac{(Final\ Contract\ Amount) - (Orginal\ Contract\ Amount)}{Original\ Contract\ Amount}$$

Cost growth is typically expressed in percentage and is positive if the project is over-budget and negative if it is under-budget. Along with details about the original and final contract amount, data for this research contained details about the cost (in dollars) associated with owner change orders and how much of it was due to owner scope changes. While comparing performance metrics across two decades of literature, Sullivan, Asmar, Chalhoub, & Obeid, (2017) observe that there are discrepancies in how studies account for impacts of owner scope additions on measuring performance outcomes. To capture a realistic idea of the actual cost performance of projects, the researcher subtracted the cost associated with owner change orders pertaining to scope changes from the final contract amount, when calculating the cost growth of projects in the data set.

3.5.1.2.2 Schedule Growth

Schedule Growth (SG) is a common measure of project schedule performance and is defined as the increase in the duration of a project with respect to the original planned duration. Mathematically, the calculation can be described as:

$$Schedule\ Growth\ (SG) = \frac{(Actual\ Duration) - (Orginal\ Planned\ Duration)}{Original\ Planned\ Duration}$$

Schedule growth is typically expressed in percentage and is positive if the project was delayed and negative if it was ahead of scheduled. Along with details about the original and final durations, data for this research contained details about the duration (in days) associated with owner change orders and how much of it was due to owner scope changes.

As expressed before, while comparing performance metrics across two decades of literature, Sullivan, Asmar, Chalhoub, & Obeid, (2017) observe that there are discrepancies in how studies account for impacts of owner scope additions on measuring performance outcomes. To capture a realistic idea of the actual schedule performance of projects, the researcher subtracted the days associated with owner change orders pertaining to scope changes from the final duration, when calculating the schedule growth of projects in the data set.

3.5.1.2.3 Increase in Participant Satisfaction

Leung, Ng, & Cheung, (2004) have presented the case for the use of metrics to emasure participant satisfaction in AEC proejcts, since construction is a service industry. The questionnaire used to collect data used in this research inquired about the overall satisfaction of participants of the project on a scale of 1 – 10 before and after the project. Thus, based on available data, the researcher construed the variable 'increase in participant satisfaction' to be measured in percentage, and computed as follows:

$$Participant\ Satisfaction\ Increase = \frac{(Final\ Satisfaction\ Score) - (Initial\ Satisfaction\ Score)}{Initial\ Satisfaction\ Score}$$

3.5.1.2.4 Number of Change Orders

A seminal study (Gransberg, Dillon, Reynolds, & Boyd, 1999) proposed the use of 'number of change orders' in addition to cost growth and schedule growth to compare performances across partnered projects. Note that the 'number of change order' metric used in this study refers to the summation of both owner-initiated and field-initiated change orders.

3.5.1.2.5 Additional Dependent Variables

In addition to the above performance metrics, the researcher looked at other standard metrics to measure project performance (e.g., safety performance). With respect to these metrics, not enough data was available to warrant their inclusion into the dependent variables considered in this study.

3.6 Data Analysis

The nature of this study is quantitative; and is associated with finding statistical evidence to either reject or support the hypothesis that, 'in a partnered project, better the fit between the intensity of risk and adopted partnering level, better is its performance (e.g., cost growth, schedule growth).'

O'Leary, (2018) recommends that the first step in effective data analysis is systematic logging and cleaning of data, followed by content analysis, data coding, summarizing descriptive statistics, selecting the appropriate statistical test and finally, assessing statistical significance of the analysis. This section describes quantitative data analysis procedures adopted in this study in accord with the abovementioned recommendation.

3.6.1 Data Logging and Cleaning

As described in Section 3.4, the population of interest for this study is AEC projects that implemented Partnering; and accordingly, collected data contained details about 127 such projects from the United States, completed between 2010 and 2018.

Data was received from the International Partnering Institute in the form of PDF and Word documents files sorted by application year. The researcher conducted a quality control check confirming that each project file belonged to the right year folder. Word files were converted to PDF for consistency of file type. Files within a folder were cross-checked for repetition and sorted accordingly. In the end, each file was assigned a serial identification number, which represented a unique partnered project.

3.6.2 Content Analysis

3.6.2.1 Preliminary Content Analysis

Content analysis is a process of systematic examination of collected data to identify and assign values to constructs of interest for further data analysis (Flick, Kardorff, & Steinke, 2010). Based on the background, scope, need and goals established, the interest of this study is quantitative measurement of the constructs 'risk intensity', 'partnering level' and 'performance outcome' indicators of AEC projects.

Objective 2 of this study is to code quantitative measures of these constructs from project details in the data set systematically. The researcher undertook the task of preliminary content analysis searching for and coding the sub-constructs from the models presented because of Objective 1.

After commencing the preliminary content analysis for risk intensity assessment, the researcher realized that, although a few sub-constructs in the model were straightforward to identify and code the data (e.g., project value in $ amount), some others were highly ambiguous (e.g., high desired level of engagement). Subsequently, other limitations of the models were discovered:

- The models seemed to lack a comprehensive list of risk elements and risk factors. Although, the researcher acknowledges that no model can comprehensively cover all risk elements and factors, a few more common and vital risk elements and factors could be included in the model (e.g. project approvals, safety risk).
- Some risk elements are not described in adequate detail for the purpose of the content analysis. A part of this limitation exists due to lack of definitions across the grading scale for each risk factor. For example, it is unclear and highly subject to open and varied interpretation as to what is meant by 'highly complex design and construction'. In addition, there are no descriptive indicators for differentiating between levels of metrics such as 'low' and 'moderate' complexity.
- Each risk factor has a scale from 1-4 or 1-5 but there is no rule regarding calculating the overall risk intensity of the project. For example, if the project budget is below $5M (level 1) but the complexity is high technical (level 5), it is unclear what final risk intensity level should be assigned to a project.

Similarly, limitations were discovered when conducting preliminary content analysis and coding for assessment of partnering level using the preliminary models:

- The level of collaboration via partnering is dependent on the use or lack of use of a group of partnering tools on a project. Such a single criteria rule for deciding partnering level of a project lacks robustness.
- Each group of partnering tools in the models is representative of a particular partnering level. However, it is unclear how to assign the overall partnering level if tools across two or three levels are used. For example, it is unclear as to what would be a project's final partnering level if it used only two partnering surveys (partnering level 1) but conducts quarterly partnering meetings (level 4).

3.6.2.2 Exploratory Data Analysis (EDA)

Preliminary content analysis and data coding efforts revealed limitations in the risk intensity and partnering level assessment models adopted from the literature. Hence, per objective one of the study design, there was a need to revise or develop revised processes or models to assess the risk intensity and partnering level of projects in the data set for the purpose of comprehensive content analysis. To do so, the researcher resorted to the literature to revise the existing IPI's models of risk intensity and partnering level assessment by addressing their limitations.

3.6.2.2.1 EDA for Revising Risk Intensity Assessment Model

To address the limitations of the model for risk intensity assessment identified in previous section, following solutions based on exploratory data analysis were proposed:

1. Limitation one of the risk intensity model was a seeming lack of an enough list of risk elements and risk factors. To address this, the research referred to the comprehensive list of risk elements and factors identified in Section 2.2.2 'Risk Identification and Classification' of this study and particularly in Table 1. The list was scrutinized for repetition of risk factors and constituent risk elements and they were combined and represented as one. For example, the risk factors 'sociopolitical risks' from Luo, He, Xie, Yang, & Wu, (2017) and 'political and environmental risk' from Al-Bahar & Crandall, (1990), effectively contained the same risk elements and thus were combined under the risk factor 'sociopolitical risk'. Later, these risk factors and risk elements were compared with those covered by the model for risk intensity assessment by IPI to identify further overlaps and maintain standard nomenclature. The result was a post-EDA list of risk factors and risk elements that fell within the scope of this study (internal risks controllable via project management). The list is presented in Table 3.
2. Limitation two of the model was lack of definitive descriptions across the scaling grade for each risk factor. To address this limitation, the researcher referred to the literature to identify scaling grades and their descriptions across each risk element represented in Table 3, preferably across a 4- and 5-point grading scale. The results of the exercise are presented in APPENDIX B It shows the various risk grading models and scales developed by various researchers and concludes with two comprehensive tables for horizontal and non-horizontal (vertical and aviation) projects separately depicting scaling for each risk element from the consolidated list represented in Table 3.

Table 3 Post-EDA list of Risk Factors and constituent Risk Elements

Risk factors	Risk element(s)	Description
Project value	Budget	Planned project budget (in $) (adjusted for inflation to CPI* 2018)
	Duration	Planned project duration (in calendar days)
	Work per day	Planned project budget (as above) /planned project duration (as above)
Project-based risk	Project approvals	Number of project approvals required and difficulty of obtaining them
	Site & environmental conditions	Probability, severity and controllability of occurrence of unfavorable site and environmental conditions
	Safety, accessibility & on-going operations	Probability, severity and controllability of occurrence of accidents; existence of on-going operations or access issues and severity of impact on construction activities and vice-versa
	Construction complexity	Probability, severity and controllability of occurrence of constructability challenges
	Design complexity	Probability, severity and controllability of incompleteness, omission, error, underdevelopment of design; uniqueness of project in terms of design
Sociopolitical risks	Third-party stakeholder & Public Interest	Number of third-party stakeholders & public, their level of interest in project and required level of interaction and interdependency for smooth operations
Project relationships	Inter-stakeholder relationships	Previous relationship between the owner, stakeholders, contractor designer, etc. because of working together; history of strained working relationships, litigation, etc.
Desired Level of Engagement	Cost pressure	The pressure on a project team to deliver the project within budget; based on: feasibility of budget, surety and adequacy of funding per the budget & contingency
	Schedule pressure	The pressure on a project team to deliver the project on schedule; based on: contingency in schedule; risk of missing deadlines
	Quality pressure	The pressure on a project team to deliver the project within strict quality norms; based on incentives for quality, quality plan detail, external reviews esp. federal, number of specs

*CPI = Consumer Price Index

Two categories of projects were classified – category 1 included horizontal projects (excluding aviation horizontal projects) and category 2 included vertical and aviation (including horizontal) projects. Separate grading scales for category 1 and category 2 projects were deemed necessary because in horizontal projects "most of the work is self-performed, whereas for buildings (vertical projects), the work is performed by sub-trades primarily with the Prime Contractor coordinating the trades". On the other hand, "aviation projects have both vertical and horizontal (projects) – but primarily are vertical" (personal communication, March 04, 2019). To accommodate for the increased risk intensity based on the need for an increased level of collaboration in vertical projects, the researcher added an extra level of risk intensity to this model. The process resulted in two variations of the model:

- Risk intensity assessment model for category 1 – horizontal projects (excluding aviation horizontal projects)
- Risk intensity assessment model for category 2 – vertical and aviation (including horizontal) projects.

3. Limitation three of the risk intensity models by IPI was unclear rules on calculating the overall risk intensity of the project. It was arbitrarily decided to use the average score of each risk element, round it up to the higher level and designate it as the overall risk intensity of the project. This does not indicate that the researcher assumes each risk element is of equal importance i.e. has equal relative weightage when contributing to overall risk of a project. Conducting a detailed analysis to determine the relative weightages of the risk elements was outside the scope of this study. Hence, an arbitrary rule to decide the overall risk intensity was used. This assumption was later validated using a survey, the details of which are presented in a later section 3.6.3

3.6.2.2.2 EDA for Revising Partnering Level Assessment Model

Based on exploratory data analysis to address the limitations of the partnering level assessment model identified in previous section, following solutions were proposed:

1. Limitation one of the partnering level assessment model by IPI was a single criteria rule for deciding partnering level of a project. The researcher observed that it was inadequate to determine the overall partnering level merely based upon the implementation or lack of thereof of partnering tools. During exploratory data analysis, it was observed that projects adopt partnering tools to improve areas of collaboration (e.g., dispute resolution, facilitation) per requirement of the project. Thus, it was more suitable to determine partnering level based on grading across 'partnering factors' (e.g., dispute resolution, facilitation) analogical to 'risk factors'. To address this limitation, the researcher sorted the partnering tools into 'partnering factors':
    - Dispute/Issue Resolution
    - Facilitation
    - Partnering Workshop Frequency
    - Partnering Survey Frequency
    - Goal Alignment & Team-Building
    - Stakeholder Involvement

These partnering factors are akin to the risk factors of the model for risk intensity assessment. The researcher believes that dividing partnering tools per the partnering factors and then developing a grading scale across them adds robustness to the model of partnering level assessment. It allows the choice to implement partnering tools of a higher level across a partnering factor (e.g., dispute resolution) depending upon the need of the project.

2. Limitation two of the partnering level assessment model by IPI was unclear rules on calculating the overall partnering level of the project. Before such a rule was established, the researcher developed a grading scale across each partnering factor above. The grading scale across each partnering factor can be seen in Table 4.

Later, rules were established to determine the overall partnering level. For example, the use of a third-party neutral partnering facilitator is one of the most important tools of the Partnering framework. Hence, one of the rules of deciding the overall Partnering level is that irrespective of the scores of other Partnering factors, the overall partnering level of a project shall not exceed the score of its 'Facilitation' factor. Other rules include bonus point for holding a close-out workshop and lessons learned workshop within Partneirng factors ‘Partneirng workshop frequency’ and ‘Partneirng survey frequency’ respectively.

Table 4 Post EDA grading scale across Partnering factors

Partnering factor	Level 1	Level 2	Level 3	Level 4
Dispute/issue resolution	Field-level decision making	Issue resolution ladder developed	Dispute resolution board formed	Facilitated dispute resolution
Facilitation	Self-directed	In-house or internal	NA	Third-party facilitation
Partnering workshop frequency	Kick-off only	More than once but less than quarterly	Quarterly or more but less than monthly	Monthly or more but less than weekly / weekly or more
Partnering survey frequency	At least once	More than once but less than quarterly	Quarterly or more but less than monthly	Monthly or more but less than weekly / weekly or more
Goal alignment & team-building	Charter developed	Goals revisited at least once	Partnering training	Partnering recognition/awards/ special task forces
Stakeholder involvement	Subcontractor on-boarding/off-boarding	Stakeholder on-boarding/off-boarding	Some form of stakeholder involvement	Executive sponsorship / multi-tier partnering

3.6.3 Data Coding

3.6.3.1 Coding for Risk Intensity Assessment

The outcome of the exploratory data analysis exercise was development of revised models for risk intensity assessment, which also served as the coding forms for final content analysis and coding. The revised coding forms for risk intensity assessment are presented below:

Table 5 Coding Form for Risk Intensity Assessment (Category 1 Projects)

Risk factor analysis and rating form for Category 1 projects						
Risk factors	Code	Risk element(s)	Level 4	Level 3	Level 2	Level 1
Project value	RF1	Budget	$250M - $500M+	$10M - $250M	$5M - $10M	$0 - $5M
	RF2	Duration	18–24+ months	12–18 months	6–12 months	<6 months
	RF3	Work per day	$100,000 - $200,000+	$50,000 - $100,000	$25,000 - $50,000	$0 - $25,000
Project-based risk	RF4	Project approvals	Large number of approvals required; high level of difficulty/stringency expected; may impact project severely	Some approvals of possible difficulty/stringency required; budget and schedule impact possible	Regular approvals required; no impact on project	Approvals pre-obtained; no impact on project
	RF5	Site & environmental conditions	History of differing site conditions that may affect schedule, cost, quality, or safety; moderate to extreme weather	No history of differing site conditions; controllable site conditions; will not affect schedule, cost, quality or safety; moderate weather	Favorable site conditions; minimal risk to schedule, cost, quality, or safety; precautions taken; minor weather delays expected	Favorable site conditions with no risk to the schedule, cost, quality or safety; no weather conditions expected
	RF6	Safety, accessibility & on-going operations	Risk of catastrophe/fatality; staging within occupied areas/on-going construction; challenging accessibility issues	Moderate risk; risk of disability; additions to occupied areas/staging adjacent to on-going operations; no accessibility issues	Minor risk of damage; well clear of occupied areas; no accessibility issues	Minor to no risk & greenfield site; no accessibility issues
	RF7	Construction complexity	Very high; new/innovative methods involved, constructability affected by external factors like location	Moderate; complex operations required	Low; minor constructability challenges expected	Very low; little to no constructability challenges expected
	RF8	Design complexity	Design & specs based on incomplete information; risk of design omissions	Designer is inexperienced or design team is improper; probability of design errors	Improper/incomplete design scheme communicated by client; experienced and competent designer	Design scheme well communicated by client; experienced and competent designer; proper design reviews completed
Sociopolitical risks	RF9	Third-party stakeholder & Public Interest	High level of political, community or media sensitivity; high profile of client	Third-party stakeholder groups may be involved	Project may attract stakeholder or media interest	Project unlikely to attract stakeholder or media interest
Project relationships	RF10	Inter-stakeholder relationships	New relationships; history of litigation; big joint ventures; less to no time for relationship development	No prior working relationship but sufficient time for relationship development before project start	Some previous working experience with neutral to good working relationships	Sufficient previous working experience with prior positive relationships

Table 5 (cont'd)

Desired Level of Engagement	RF11	Cost pressure	Unclear/insufficient budget, budget feasibility not established, lack of confidence regarding financing, strictly no scope for additional funds, little to no contingency	Budget feasibility not established, adequate funds and sources secured but request for additional funds would be lengthy and embarrassing, enough contingency	Budget feasibility established, adequate funds and sources secured and some scope for additional funds, enough contingency	Budget feasibility established using benchmarks, adequate scope for additional recurrent funds and sources secured, generous contingency
	RF12	Schedule pressure	The basis for the current schedule is unclear or the duration is likely to be inadequate	The basis for the schedule is clear, but there are indications that overruns are possible	Benchmarks were used to establish schedule; tight contingencies	Benchmarks used to establish the schedule and adequate contingencies exist
	RF13	Quality pressure	High contractual quality requirements; if unmet could affect cost & schedule significantly	Moderate contractual quality requirements; if unmet could affect cost & schedule moderately	Minor contractual quality requirements; if unmet, some probability of affecting cost & schedule	No special contractual quality requirements; if unmet, will not affect cost & schedule

Table 6 Coding Form for Risk Intensity Assessment (Category 2 Projects)

Risk factor analysis and rating form for Category 2 projects							
Risk factors	Code	Risk element(s)	Level 5	Level 4	Level 3	Level 2	Level 1
Project value	RF1	Budget	$250M - $500M+	$25M - $250M	$10M - $25M	$5M - $10M	$0 - $5M
	RF2	Duration	>24 months	18–24 months	12–18 months	6–12 months	<6 months
	RF3	Work per day	>$200,000	$100,000 - $200,000	$50,000 - $100,000	$25,000 - $50,000	$0 - $25,000
Project-based risk	RF4	Project approvals	Large number of approvals required; High level of difficulty/stringency expected; may impact project severely	Significant number of approvals required; Medium level of difficulty/stringency expected; may impact project significantly	Some approvals required; Possible difficulty/stringency expected; provisions in budget and schedule for delay	Minimal number of approvals required; Regular approvals (zero difficulty/stringency expected); no impact on project	No approval required or all have been obtained; no impact on project
	RF5	Site & environmental conditions	history of differing site conditions; Site conditions uncontrollable; may affect schedule, cost, quality or safety; Site location prone to acts of God, Extreme weather	history of differing site conditions; Controllable (planned for) site conditions but may affect schedule, cost, quality, or safety; Moderate to extreme weather	No history of differing site conditions; Controllable site conditions; will not affect schedule, cost, quality or safety; basic precautions taken; Moderate weather	Favorable site conditions; minimal risk to schedule, cost, quality, or safety;; precautions taken; Slight weather delays expected	Favorable; no risk to the schedule, cost, quality or safety; Established and known; no history of differing site conditions; no weather conditions expected
	RF6	Safety, accessibility & on-going operations	Risk of Catastrophe numerous fatalities & Activities in occupied areas/On-going operations; Challenging access issues	Risk of fatality; Staging within occupied areas/On-going construction; Challenging access issues	Moderate Risk; Risk of disability; Additions to occupied areas/Staging adjacent to on-going operations or construction; No access issues	Minor risk of damage; Well clear of occupied areas; No access issues	Minor to no risk & Greenfield site; No access issues
	RF7	Construction complexity	Very High; Never done before Innovative and risky operations required	High; Never done before but safe operations required	Moderate; Complex operations required	Low; Minor challenges expected	Very Low; Little to no challenge expected
	RF8	Design complexity	incomplete design and high probability of design change and review; underdeveloped specs	design & specs based on incomplete information; risk of omissions	designer is inexperienced or design team is improper; probability of design errors	improper/incomplete design scheme communicated by client; experienced and competent designer	design scheme well communicated by client; experienced and competent designer; proper design reviews completed

Table 6 (cont'd)

Sociopolitical risks	RF9	Third-party stakeholder & Public Interest	High level of political, community or media sensitivity	High profile client or project; Third-party stakeholder groups may be involved	Third-party stakeholder groups may be involved	Project may attract stakeholder or media interest	Project unlikely to attract stakeholder or media interest
Project relationships	RF10	Inter-stakeholder relationships	Client with no experience. New Relationships; History of Litigation; Joint Ventures; Less to No time for relationship development	Mixed experience amongst clients or client's rep; New Relationships, Less to no scope for developing relationships	Some experience amongst clients or client's rep but sufficient time for relationship development before project start	Some previous project experience and neutral to good working relationships & experiences	Sufficient previous working experience with prior positive relationships
Desired Level of Engagement	RF11	Cost pressure	No clear budget, budget seems insufficient, budget feasibility not established, inadequate funds or sources not secured, less to no contingency	Budget feasibility not established, adequate funds and sources identified but financing not secured, strictly no scope for additional funds, little to no contingency	Budget feasibility not established, adequate funds and sources secured but request for additional funds would be lengthy and embarrassing, sufficient contingency	Budget feasibility established, adequate funds and sources secured and some scope for additional funds, sufficient contingency	Budget feasibility established using benchmarks, adequate & sure scope for additional recurrent funds and sources secured, generous contingency
	RF12	Schedule pressure	There is no clear schedule, or the schedule is clearly insufficient	The basis for the current schedule is unclear or the schedule is likely to be inadequate	The basis for the schedule is clear, but indications are that overruns are possible	Benchmarks were used to establish schedule	Benchmarks were used to establish the schedule and adequate contingencies exist
	RF13	Quality pressure	High Quality requirements; if unmet could affect cost, schedule, project significantly	Moderate Quality requirements; if unmet could affect cost, schedule, project slightly	Minor contractual quality requirements; if unmet, some probability of affecting cost & schedule	Quality requirements not specifically mentioned; will not affect project	No mention about importance of quality requirements; will not affect project

Following rules were adopted for coding:

i. Firstly, the type of each project in the data-set was identified (category 1 or 2)
ii. Then, project details were examined by two different coders, to identify risk elements from the coding forms above
iii. Once identified, based on available data and the coding forms above, a grade (1-4 for category 1 and 1-5 for category 2 projects) was assigned for each of the identified risk element by the two coders
iv. Lastly, overall risk level was computed as the average of all scores of each risk element rounded off to the higher grade.

A snapshot of the coding sheet is provided in Table 7. The outcome of the secondary coding exercise was that each project in the dataset was assigned an overall risk intensity level on a scale of 1-4 for category 1 and 1-5 for category 2 projects.

Table 7 Snapshot of Coding for Risk Intensity Assessment

Sr. Number	Project ID	Type per Matrix	Budget	Duration	Work Per Day	Cost Pressure	Schedule Pressure	Quality Pressure	Project Approvals	Site & Environmental Conditions	Safety Risk	Construction Complexity	Design Complexity	Third-party Stakeholder & Public Interest	Relationships	Overall Risk Level: Average (Continuous)	Overall Risk Level: Average (Roundup)
SN	ID	TYP.	RF1	RF2	RF3	RF4	RF5	RF6	RF7	RF8	RF9	RF10	RF11	RF12	RF13	AVG.	AVG.
1	2018_01	1	3	4	4	2	4	3	2	4	4	4	4	2	3	3.31	4
2	2018_02	3	4	1	5	4	5	4	4	3	5	4	2	3	2	3.54	4
3	2018_03	3	4	5	4	2	5	4	2	4	4	3	2	2	5	3.54	4
4	2018_04	3	3	1	4	2	5	3	2	4	3	3	3	3	2	2.92	3
5	2018_05	1	1	2	1	2	2	2	2	3	4	3	2	3	2	2.23	3

3.6.3.2 Coding for Partnering Level Assessment

The outcome of the exploratory data analysis exercise was development of revised models for partnering level assessment, which also served as the coding forms for final content analysis and coding. The revised coding forms for partnering level assessment are presented in Table 8 and Table 9.

Following rules were adopted for coding:

i. Firstly, the type of each project in the data-set was identified (category 1 or 2)
ii. Then, project details were examined by two different coders, to identify use of partnering tools and their characteristics (e.g., frequency) from the coding forms above
iii. Once identified, based on available data and the coding forms above, a grade (1-4 for category 1 and 1-5 for category 2 projects) was assigned for each of the identified partnering factor by the two coders. Some additional rules for assigning the scores were as follows:
    a. Irrespective of the scores of other Partnering factors, the overall partnering level of a project shall not exceed the score of its 'Facilitation' factor
    b. Under the 'Partnering workshop frequency', one bonus point would be considered if the project implemented the 'close-out workshop' tool for a maximum of 4 or 5 points for category 1 and category 2 projects respectively
    c. Under the 'Partnering survey frequency', one bonus point would be considered if the project implemented the 'lessons learned workshop' tool for a maximum of 4 or 5 points for category 1 and category 2 projects respectively
iv. Lastly, overall partnering level was computed as the average of all scores of each partnering factor rounded off to the higher grade.

A snapshot of the coding sheet is provided in Table 10. The outcome of the secondary coding exercise was that each project in the dataset was assigned an overall partnering level on a scale of 1-4 for category 1 and 1-5 for category 2 projects.

Table 8 Coding Form for Partnering Level Assessment (Category 1 Projects)

Partnering level for category 1 projects

Partnering factor	Level 1	Level 2	Level 3	Level 4	Bonus points & other notes
Dispute/issue resolution	Field-level decision making	Issue resolution ladder developed	Dispute resolution board formed	Facilitated dispute resolution	NA
Facilitation**	Self-directed	In-house or internal	NA	Third-party facilitation	NA
Partnering workshop frequency	Kick-off only	More than once but less than quarterly	Quarterly or more but less than monthly	Monthly or more but less than weekly / weekly or more	Bonus: close-out workshop
Partnering survey frequency	At least once	More than once but less than quarterly	Quarterly or more but less than monthly	Monthly or more but less than weekly / weekly or more	Bonus: lessons learned analyzed
Goal alignment & team-building	Charter developed	Goals revisited at least once	Partnering training	Partnering recognition/awards/ special task forces	NA
Stakeholder involvement	Subcontractor on-boarding/off-boarding	Stakeholder on-boarding/off-boarding	Some form of stakeholder involvement	Executive sponsorship / multi-tier partnering	NA

Table 9 Coding Form for Partnering Level Assessment (Category 2 Projects)

Partnering level for category 2 projects

Partnering factor	Level 1	Level 2	Level 3	Level 4	Level 5	Bonus points & other notes
Dispute/issue resolution	Field-level decision making	Issue resolution ladder developed	Dispute resolution board formed	Facilitated dispute resolution	Na	NA
Facilitation*	Self-directed	In-house or internal	NA	NA	Third-party facilitation	NA
Partnering workshop frequency	Kick-off only	More than once but less than quarterly	Quarterly or more but less than monthly	Monthly or more but less than weekly	Weekly or more	Bonus: close-out workshop
Partnering survey frequency	At least once	More than once but less than quarterly	Quarterly or more but less than monthly	Monthly or more but less than weekly	Weekly or more	Bonus: lessons learned analyzed
Goal alignment & team-building	Charter developed	Goals revisited at least once	Partnering training	Partnering recognition/awards	Special task forces	NA
Stakeholder involvement	Subcontractor on-boarding/off-boarding	Stakeholder on-boarding/off-boarding	Some form of stakeholder involvement	Executive sponsorship	Multi-tier partnering	NA

*** Irrespective of the scores of other Partnering factors, the overall partnering level of a project shall not exceed the score of its 'Facilitation' factor*

Table 10 Snapshot of Coding for Partnering Level Assessment

Sr. Number	Project ID	Type per Matrix	Field-Level Decision Making	Issue Resolution Ladder (IRL)	Dispute Resolution Advisor (DRA)/ Board (DRB)	Facilitated Dispute Resolution (FDR)	Facilitation	Frequency of Workshops	Bonus Point - Close-Out Workshop Held?	Frequency of Surveys	Bonus Point - Lessons Learned Analyzed	Project Charter	Goals Revised/Revisited	Partnering Recognition/Awards	Partnering Training	Special Task Forces for Issue Resolution	Subcontractor On-Boarding/Off-Boarding	Stakeholder On-Boarding/Off-Boarding	Stakeholder Involvement	Executive Sponsorship	Multi-Tiered Partnering - Executive, Core & Stakeholder	Factor 1 (Dispute Resolution) Score	Level 2 (Facilitation) Score	Factor 3 (Workshop Frequency) Score	Factor 4 (Survey Frequency) Score	Factor 5 (Goal Alignment & Team Building) Score	Factor 6 (Stakeholder Involvement) Score	Overall Partnering Level: Factor Average Score	Overall Partnering Level: Average Roundup
1	2018_01	1	1	1	1	0	4	2	0	4	1	1	1	1	0	0	1	1	1	0	0	3	4	2	4	3	3	3.17	4
2	2018_02	3	1	1	0	0	5	4	1	4	1	1	1	0	0	1	1	1	1	0	0	3	5	5	5	3	3	3.92	4
3	2018_03	3	1	1	0	1	5	3	1	4	1	1	1	1	0	1	1	1	0	0	0	4	5	4	5	4	2	3.96	4
4	2018_04	3	1	0	0	0	5	5	1	1	1	1	1	1	0	0	1	1	1	1	0	1	5	5	2	3	4	3.38	4
5	2018_05	1	1	1	0	0	4	4	1	4	1	1	1	1	0	1	1	1	0	0	0	2	4	4	4	4	2	3.33	4

3.6.3.3 Coding for Project Performance Evaluation Metrics

Lastly, values for the various performance outcome metrics were coded for each project in the data-set. Several studies have undertaken the task of measuring or comparing performance of AEC projects. One such seminal study (Gransberg, Dillon, Reynolds, & Boyd, 1999) quantitatively analyzed performance of partnered projects via several performance indicators (e.g., cost growth, average cost per change order, time growth). Examining that list, and available data, following performance indicators were identified as relevant for this study:

- Cost Growth
- Schedule Growth
- Increase in Participant Satisfaction

As noted, projects in the data set were completed over a span of years (2010 to 2018). Thus, to achieve a fair comparison of their cost performance, it was necessary to adjust coded cost data for inflation. The researcher compared values for Consumer Price Index (CPI) published by the Bureau of Labor Statistics for each year with the CPI index value for 2018 and adjusted the cost data accordingly. To do so, the percent increase of CPI index was computed for each year (compared to 2018) and applied to the coded cost data of every year to compute cost adjusted for inflation. Thus, a uniform measure of cost with respect to project completion year was achieved.

A snapshot of the performance outcome coding sheet is provided in Table 11.

The outcome of the coding exercise was that each project in the dataset was assigned values for performance outcome metrics (e.g., cost growth, schedule growth) which were used during data analysis and hypothesis testing.

Table 11 Snapshot of Coding for Performance Outcomes

Sr. Number	Project ID	Schedule Growth	Schedule Growth minus CCO Time Extension	Cost Growth	Cost Growth Minus Owner's CO	Number of CO processed	Number of Owner Initiated CO	Number of Field Initiated CO	Number of Claims Accepted	Number of Unresolved Claims at Close-Out	Participation Satisfaction
1	2018_01	20%	0%	1.12%	-10.25%	140	77	63	2	0	-14%
2	2018_02	0%	0%	1.60%	0.00%	24	21	3	0	0	NA
3	2018_03	5%	5%	17.97%	17.96%	3	3	1	0	0	20%
4	2018_04	-31%	-31%	-15.42%	-20.11%	11	7	4	0	0	31%
5	2018_05	-1%	-1%	28.21%	5.25%	4	4	3	0	0	3%

3.6.4 Data Cleaning

After the data coding process, the researcher examined coded data sheets for irregularities. Outliers were identified and examined for clarifications for reasons the data point differed significantly from other observations. Following cleaning actions were performed:

- Projects that had missing data points for a dependent variable were removed during analysis concerning that variable. For example, out of the 127 projects in the data set, 3 projects did not contain measures to determine schedule growth and thus were removed during analysis of risk-partnering fit versus schedule growth.
- Schedule growth data was examined for reasons of delay. Projects that were delayed for reasons beyond human control were adjusted accordingly. For example, a project reported a 7-month delay due to unavailability of an aggregate naturally found in the earth's crust. The project had to wait until the aggregate was naturally formed in the earth's crust again. The schedule growth of the project was recalculated after discounting for that delay.

3.6.5 Validation of Revised Risk Intensity and Partnering Level Assessment Models

The outcome of the coding exercise was that every project in the data set was assigned a quantitative measure of risk intensity, partnering level and performance outcome indicators. The coding forms used for assessment of risk intensity and partnering level were derived from models based on the ones developed by IPI, which were revised via exploratory data analysis. Hence, before proceeding with data analysis, it was necessary to validate these revised models. The revised models are 'prediction models' because they use measures of variables to predict risk intensity and partnering level.

Validation is the process of assessing whether prediction of the construct of interest (risk intensity and partnering level in our case) is within the confidence interval deemed acceptable for the intended use of the model. Validation for prediction models can be accomplished by "directly comparing model results to physical measurements for the quantity of interest by carrying out a hypothesis test of whether or not the difference is significant" (National Research Council, 2012) as deemed by the intended use of the model. For this study, these physical measurements for the quantities of interest (risk intensity and partnering level) were obtained via a survey.

The survey was designed to assess perceived risk and partnering levels of the projects and distributed to all project partnering facilitators in the data-set (i.e., 50 facilitators for 127 projects). Survey participants received an email including consent form for participation (APPENDIX C), list of projects to fill out the survey for, and a survey (APPENDIX D). The survey requested assessment of overall risk intensity and partnering level of a given project using a Likert scale of 1-4 (for category 1 projects) and 1-5 (for category 2 projects) (i.e., 1=lowest level – 4 and 5=highest level).

Out of all 50 facilitators:

- 10 could not be reached (e.g., failure of email delivery, retirement)
- 16 responded (40% response rate) accounting for:
    - 53 out of the 127 projects (41.7%).

The response rate was deemed adequate for proceeding with model validation.

As prescribed by National Research Council (2012), revised risk intensity and partnering models were verified via statistical hypothesis testing utilizing Pearson's Chi Square Test of Homogeneity. The test is employed to a single categorical variable from two populations to determine whether distribution of frequency counts is identical across different populations. In this case, the single categorical variable is the measure of risk intensity measure and partnering level taken one at a time; and the two populations are the model output and survey responses. Because category 1 and category 2 projects are scaled differently, the test was conducted separately for survey data from category 2 and category 1 projects for both risk intensity and partnering level surveys.

3.6.6 Statistical Tests for Hypothesis Testing

The nature of this study is quantitative; and is associated with finding statistical evidence to either reject or support the following overall study hypothesis: ***In a partnered project, better the fit between the intensity of risk and adopted partnering level, better is its performance (e.g., cost growth, schedule growth).*** The hypothesis was modified for each performance outcome (i.e., dependent variable) and tested separately.

In this study,

- 'fit' is the explanatory variable, which is categorical in nature; while
- Performance outcome metrics (e.g., cost growth, schedule growth) are the response variables, which are continuous in nature.

So far, the outcome of content analysis and data coding exercise was that each project in the data set was assigned a measure for the construct fit (based on overall risk intensity and partnering level), and performance outcome metrics (e.g., schedule growth, cost growth). Thus, projects in the data set, and therefore their performance outcome measures were divided into 3 categories viz. positive, neutral and negative.

Thus, the problem of testing the hypothesis of this study reduces to the problem of comparing the frequency distribution of the groups of data representing performance outcome measures across the three categories of fit (positive, neutral, and negative). Note that the hypothesis will be tested separately for each performance outcome metric. If no difference in the frequency distributions were found, it would mean that for that performance outcome metric, there is no variability introduced because of fit i.e. there is no association between fit (between risk intensity and partnering level) and the performance outcome metric. Alternatively, if there were difference in the frequency distributions were found, it would mean that there is an association between fit and that performance outcome metric.

Several statistical parametric and non-parametric tests are available for comparing groups. The decision to choose a particular test depends on various factors like number of groups to be compared, existence of pairing between them, variable type, and normality (Motulsky, 1995).

In this study, there are three groups (dependent variables data across three fit categories) to be compared, they are independent samples. Shapiro-Wilk test for normality was conducted on these samples and the Kruskal-Wallis test was determined to be the most appropriate for testing the hypothesis of this study. The Kruskal-Wallis (Kruskal & Wallis, 1952) is a non-parametric statistical test that assesses the differences among three or more independently sampled groups on a single, non-normally distributed continuous variable. The null hypothesis of the Kruskal-Wallis specifies that the groups are subsets from the same population. To test this null hypothesis, the groups are combined into a single group and variable of interest are ranked based on their order. The new rank scores are summed by group and, along with group sample sizes, are used to calculate the H statistic, which reflects the variance in ranks between groups and closely resembles the chi-square distribution. When testing the null, H is compared by referring to a chi-square table with degrees of freedom equal to n (number of groups) minus one. If H exceeds a critical value, we may conclude that the groups do not come from the same population. For this study, the Kruskal-Wallis test was conducted using RStudio statistical software.

Once it is established that the groups do not come from the same population, it was further necessary to determine the order among the groups. For example, if it was found that schedule performance varies across fit categories, it is important to determine, which fit category shows better schedule performance compared to others. For this purpose, the researcher used the Dunn Test. It reports the results among multiple pairwise comparisons after a significant Kruskal-Wallis test for the number of groups (3 in our case).

3.7 Quality Measures

For the results of a study to be valid, a researcher must examine and address potential sources of error and reliability (Fellows & Liu, 2008). It is important to present the measures taken to ensure research quality for the findings to be used in other research and in application in practice.

As data collected for this research is archival in nature, it is important to check for potential bias in the data arising due to the data collection agency as well as the data collection process. Descriptive statistics were examined to observe bias arising due to the data collection agency (e.g., bias due to geography, project type, project delivery method). In addition, because the data set contained projects over a span of time (2010 to 2018), the researcher normalized values for constructs such as project budget using Consumer Price Index (CPI) adjustments.

Quality during content analysis was maintained via random quality checks and reliability checks. Two researchers conducted the data coding exercise. Researcher 1 is the investigator in this study, who is a graduate student of construction management, with prior experience in partnering and AEC industry research, while Researcher 2 is undergraduate student in civil engineering familiar with construction management terminology. Firstly, Researcher 1 and 2 reviewed the coding forms together and clarified any discrepancy in understanding the codes. Preliminary coding was then conducted by Researcher 2. Coded data was randomly checked by Researcher 1 for quality control. Most of the constructs in this study (e.g., performance measures and partnering tools used or not) are factual and hence had no researcher's bias component to them. Outliers in the data were examined separately for potential errors and fixed accordingly.

For this quantitative study, the researcher stated the confidence (or significance) levels to help determine the applicability of results.

CHAPTER 4 RESULTS AND FINDINGS

4.1 Descriptive Statistics

This section describes the characteristics of the archival data collected for this study. Overall, 127 AEC projects were studied. All these projects were completed in the United States between 2010 and 2018.

The following table shows the number of applications received sorted by their year of completion:

Table 12 Classification of Projects by Year of Completion

Year	Number of Projects Completed in the Year
2010	12
2011	1
2012	4
2013	13
2014	10
2015	27
2016	21
2017	14
2018	25
Total	127

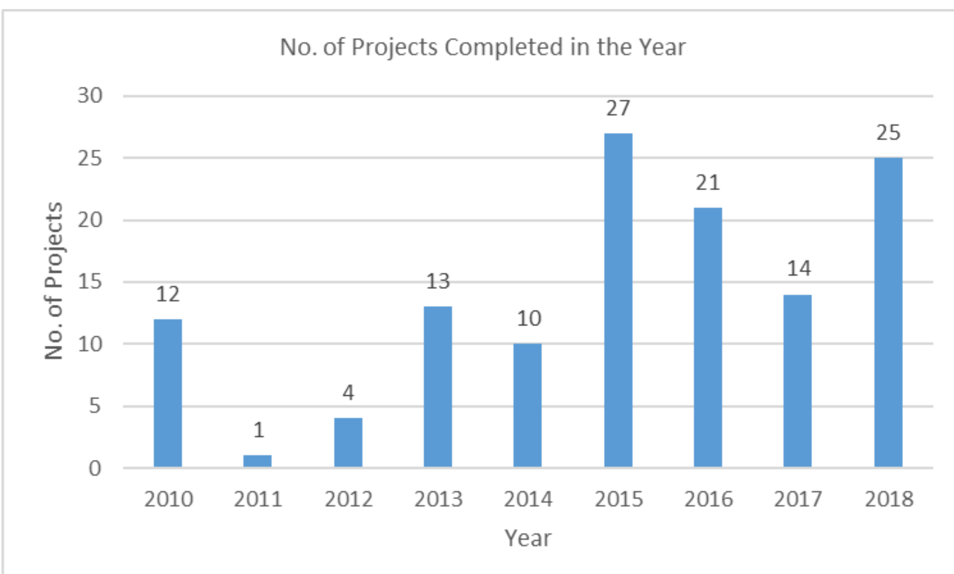

Figure 9 Number of projects by year of completion

Table 13 shows the state-wise distribution of the projects in the data-set.

Table 13 Classification of Project Locations by States

Project Location (State)	Number of Projects
CA	79
AZ	12
UT	11
NV	5
OH	5
CO	3
CT	3
MD	2
MI	2
NC	2
PA	1
TN	1
VA	1
Total Number of Projects	127

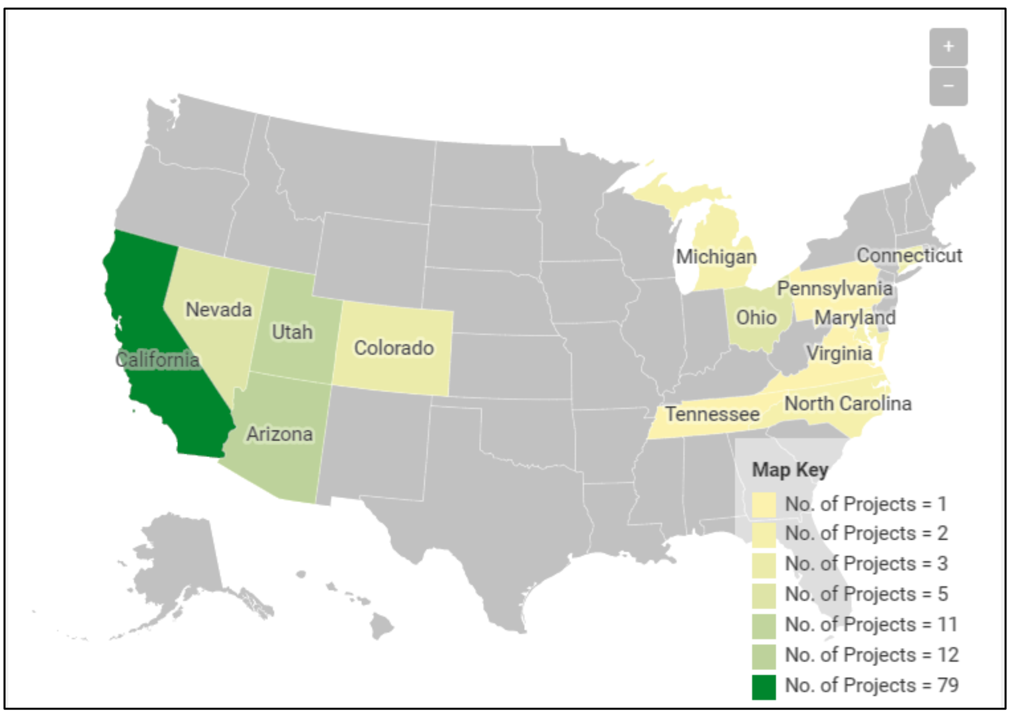

Figure 10 Number of projects per state

It is interesting to note that a majority of the projects (approx. 62%) were located in the state of California. One possible explanation for such a skew could be that the award agency IPI (from whom the data is collected) is based out of California. Thus, it is possible that applicants located close to the agency were more aware of the awards and hence applied in larger numbers. Alternatively, the skew can also be explained from observations from previous studies (National Academies of Sciences, Engineering, and Medicine, 2019) that a majority of partnered projects are located in the West Coast of the US.

Out of the 127 projects, 86 projects (68%) were horizontal type, 22 projects (17%) were vertical and the remaining 19 (15%) were aviation. Table 14 tabulates the distribution of projects in the data set per their project type.

Table 14 Classification of Projects per project type

Project Type	Number of Projects	% of Total number of Projects
Horizontal	86	68%
Vertical	22	17%
Aviation	19	15%
Total Number of Projects	127	100%

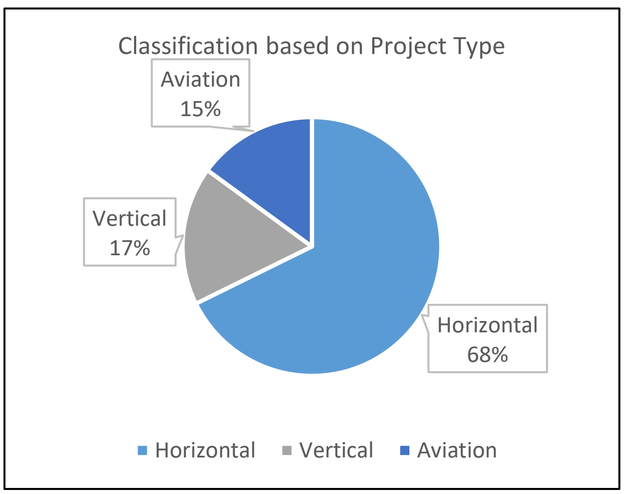

Figure 11 Classification per Project Type

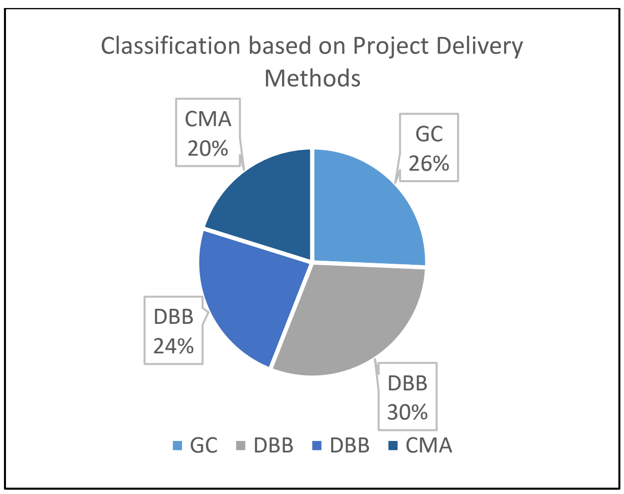

Figure 12 Classification per Project Delivery Method

Of the 127 projects in the data-set, 61 (48%) are Design-Bid-Build (DBB), 26 (21%) are Design-Build (DB), 22 (17%) are Construction Manager as Agency (CMA) and 18 (14%) are Construction Manager at Risk or as General Contractor (CMR/GC).

Table 15 below tabulates the distribution of projects in the data set per their project type.

Table 15 Classification of Projects per project delivery method

Project Delivery Method	Number	% of Total number of Projects
DBB	61	48%
DB	26	21%
CMA	22	17%
CMR/GC	18	14%
Total Number of Projects	127	100%

Based on original contract amount (not adjusted for inflation), the breakdown of the 127 projects is as presented in Table 16.

Table 16 Classification of Projects per budget category

Budget Category	Number	% of Total number of Projects
<$25M	52	41%
$25M-$250M	67	53%
$250M+	8	6%
Total Number of Projects	127	100%

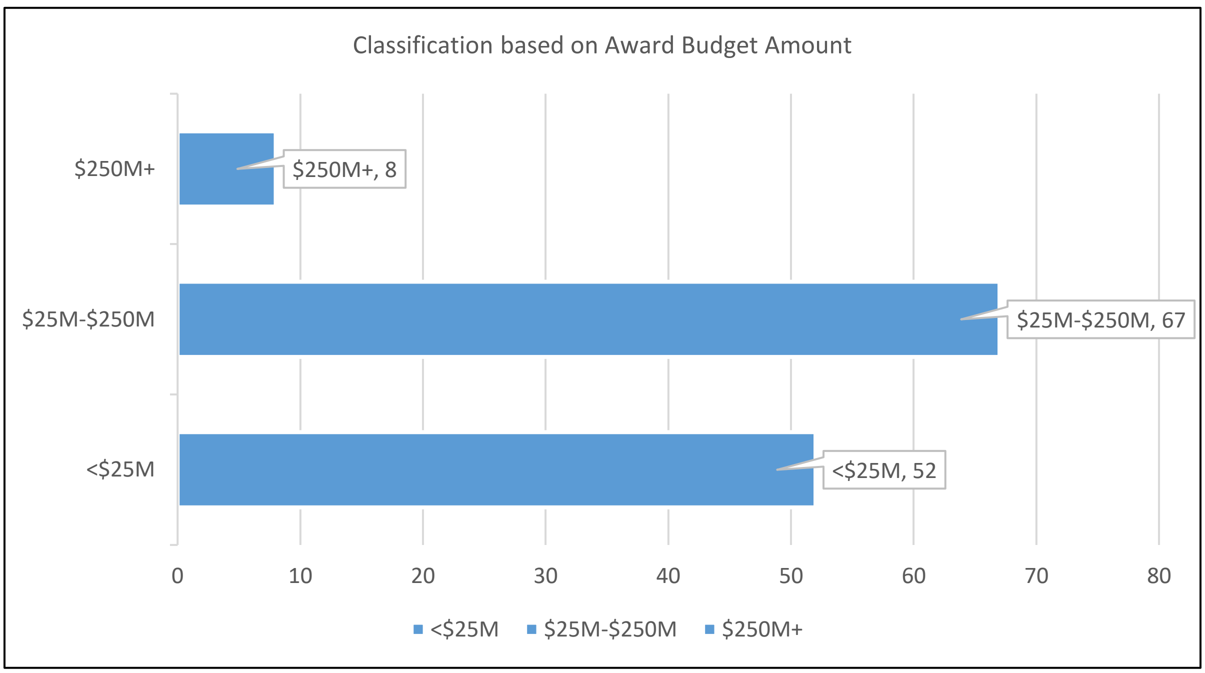

Figure 13 Classification of Projects per original contract amount

4.2 Exploratory Data Analysis

Objective one and two of this study were to identify and revise (if necessary) models or processes to measure the constructs of interest (risk intensity and partnering level). During the literature review, content analysis, exploratory data analysis and data coding exercises undertaken to achieve these objectives, following lessons were learned:

1. Ideally, risk intensity of a project should be determined prospectively i.e. before project start via identifying relevant risks and then determining their probability of occurrence and severity of impact upon realization. However, for the purpose of a study like this one, risk intensity has to be assessed retrospectively from project details via models.
2. Risk intensity assessment processes and models from peer-reviewed literature endorse the use of a risk register of common project risks to prospectively measure risk intensity of a project.
3. There exists literature that questions the appropriateness of using an ordinal scale of measurement for expressing risk intensity. However, when the outcome of a risk intensity model is to be used as a decision-model (e.g., to further determine a risk management strategy like selecting a partnering level), it is acceptable to use ordinal scale of measurement (e.g., 1-5 scale)
4. Although risk factors and their constituent elements are common across different project types, non-horizontal (e.g., vertical projects like commercial buildings and aviation projects like terminals and runways) projects experience higher risk intensity compared to horizontal (e.g., roads, utility) projects. This is because the number, interdependency and influence of stakeholders in non-horizontal projects is higher than horizontal projects thereby adding an extra layer of risk over the same risk factors.
5. It is inadequate to determine the overall partnering level merely based upon the implementation or lack of thereof of partnering tools. The researcher observed that projects adopt partnering tools to improve areas of collaboration (e.g., dispute resolution, facilitation) per requirement of the project. Thus, it was more suitable to determine partnering level based on grading across ‘partnering factors’ (e.g., dispute resolution, facilitation) analogical to ‘risk factors’.

4.3 Model Validation

The Chi Square Test of Homogeneity was conducted separately for horizontal and non-horizontal projects for both risk intensity and partnering level measures. In all four cases, the null hypothesis was:

$$H_0: P_{\text{measure via model output}} = P_{\text{measure via survey result}}$$

That is, the distribution of frequency counts of the measures of risk intensity and partnering level are distributed identically across the two populations (model output and survey responses), and the alternative being that the null hypothesis is false.

The results of the test are below.

Table 17 Pearson's Chi-Square Test Results

Model and Case	X^2	DF	p-value	Critical p-value	Observation	Result
Risk Intensity Model						
Case 1: Category 1 Projects	*6.593*	*3*	*0.086*	*0.05*	$p > p_{critical}$	H_0 *is not rejected*
Case 2: Category 2 Projects	*4.646*	*3*	*0.199*	*0.05*	$p > p_{critical}$	H_0 *is not rejected*
Partnering Level Model						
Case 1: Category 1 Projects	*7.769*	*3*	*0.051*	*0.05*	$p > p_{critical}$	H_0 *is not rejected*
Case 2: Category 2 Projects	*5.431*	*3*	*0.142*	*0.05*	$p > p_{critical}$	H_0 *is not rejected*

In both cases, since the p-value is greater than the decided significance level of 0.05, the null hypothesis cannot be rejected i.e., there is no statistically significant difference in the distribution of frequency counts of measures of risk intensity as well as partnering level between predicted values using the revised models and physical measurements received via expert survey responses.

Hence, it was decided that the measures of constructs of interest (risk intensity and partnering level) predicted via the researcher’s revised models for assessment of risk intensity and partnering level will be used for further data analysis.

4.4 Revised Models of Risk and Partnering

The outcome of the exploratory data analysis was the revision of models to determine measures of risk intensity and partnering level of AEC projects. Note that the revised models were validated via a survey followed by statistical model validation. The models are presented below:

4.4.1 Risk intensity assessment model

Table 18 below, contains a list of the risk factors and risk elements, with their description, that constitute the risk register for this model.

Following the risk register table are Table 19 and Table 20, representing the revised models for risk intensity assessment for horizontal and non-horizontal projects respectively. The steps for determining overall risk intensity of an AEC project are:

STEP 1. Identify the type of project –

a. Category 1 Project – A project is a horizontal project if most of its scope involves heavy civil construction whose length is longer than its height. Examples of such projects include bridges, roads, utility projects, etc.

b. Category 2 Project – Includes:

   i. Vertical projects – A project is a vertical project if a majority of its scope stretches vertically. Example of vertical construction projects include commercial buildings, hospitals, etc.

   ii. Aviation projects – A project is an aviation project if a majority of its scope involves construction on or close to airports and requires significant interaction with airport authorities. Examples of aviation projects include runways, control towers, terminals, etc.

Note: It is important to note that aviation projects may be both vertical and horizontal in scope. For the purpose of this research, if a project can be classified as aviation then it cannot be classified as Category 1.

STEP 2. Based on the project type determined above, choose the appropriate risk intensity assessment model – Category 1 or Category 2 project risk assessment model

STEP 3. Based on project details and characteristics, assign the risk level for each risk element identified in the model. For example, if your project is horizontal and its original contract amount is $300M, then its score for the 'Budget' risk element is Level 5. Similarly, assign levels for each risk element in the model.

STEP 4. Compute overall risk level as the average of all scores of each risk elements rounded up to the higher level.

Table 18 Risk register for the revised Risk Intensity assessment model

Risk factors	Risk element(s)	Description
Project value	Budget	Planned project budget (in $) (adjusted for inflation to CPI* 2018)
	Duration	Planned project duration (in calendar days)
	Work per day	Planned project budget (as above) /planned project duration (as above)
Project-based risk	Project approvals	Number of project approvals required and difficulty of obtaining them
	Site & environmental conditions	Probability, severity and controllability of occurrence of unfavorable site and environmental conditions
	Safety, accessibility & on-going operations	Probability, severity and controllability of occurrence of accidents; existence of on-going operations or access issues and severity of impact on construction activities and vice-versa
	Construction complexity	Probability, severity and controllability of occurrence of constructability challenges
	Design complexity	Probability, severity and controllability of incompleteness, omission, error, underdevelopment of design; uniqueness of project in terms of design
Sociopolitical risks	Third-party stakeholder & Public Interest	Number of third-party stakeholders & public, their level of interest in project and required level of interaction and interdependency for smooth operations
Project relationships	Inter-stakeholder relationships	Previous relationship between the owner, stakeholders, contractor designer, etc. because of working together; history of strained working relationships, litigation, etc.
Desired Level of Engagement	Cost pressure	The pressure on a project team to deliver the project within budget; based on: feasibility of budget, surety and adequacy of funding per the budget & contingency
	Schedule pressure	The pressure on a project team to deliver the project on schedule; based on: contingency in schedule; risk of missing deadlines
	Quality pressure	The pressure on a project team to deliver the project within strict quality norms; based on incentives for quality, quality plan detail, external reviews esp. federal, number of specs

*CPI = Consumer Price Index

Table 19 Revised Risk Intensity Assessment Model (Category 1 Projects)

Risk Intensity Assessment Model (Category 1 Projects)					
Risk factors	Risk element(s)	Level 4	Level 3	Level 2	Level 1
Project value	Budget	$250M - $500M+	$10M - $250M	$5M - $10M	$0 - $5M
	Duration	18–24+ months	12–18 months	6–12 months	<6 months
	Work per day	$100,000 - $200,000+	$50,000 - $100,000	$25,000 - $50,000	$0 - $25,000
Project-based risk	Project approvals	Large number of approvals required; high level of difficulty/stringency expected; may impact project severely	Some approvals of possible difficulty/stringency required; budget and schedule impact possible	Regular approvals required; no impact on project	Approvals pre-obtained; no impact on project
	Site & environmental conditions	History of differing site conditions that may affect schedule, cost, quality, or safety; moderate to extreme weather	No history of differing site conditions; controllable site conditions; will not affect schedule, cost, quality or safety; moderate weather	Favorable site conditions; minimal risk to schedule, cost, quality, or safety; precautions taken; minor weather delays expected	Favorable site conditions with no risk to the schedule, cost, quality or safety; no weather conditions expected
	Safety, accessibility & on-going operations	Risk of catastrophe/fatality; staging within occupied areas/on-going construction; challenging accessibility issues	Moderate risk; risk of disability; additions to occupied areas/staging adjacent to on-going operations; no accessibility issues	Minor risk of damage; well clear of occupied areas; no accessibility issues	Minor to no risk & greenfield site; no accessibility issues
	Construction complexity	Very high; new/innovative methods involved, constructability affected by external factors like location	Moderate; complex operations required	Low; minor constructability challenges expected	Very low; little to no constructability challenges expected
	Design complexity	Design & specs based on incomplete information; risk of design omissions	Designer is inexperienced or design team is improper; probability of design errors	Improper/incomplete design scheme communicated by client; experienced and competent designer	Design scheme well communicated by client; experienced and competent designer; proper design reviews completed
Sociopolitical risks	Third-party stakeholder & Public Interest	High level of political, community or media sensitivity; high profile of client	Third-party stakeholder groups may be involved	Project may attract stakeholder or media interest	Project unlikely to attract stakeholder or media interest
Project relationships	Inter-stakeholder relationships	New relationships; history of litigation; big joint ventures; less to no time for relationship development	No prior working relationship but sufficient time for relationship development before project start	Some previous working experience with neutral to good working relationships	Sufficient previous working experience with prior positive relationships

Table 19 (cont'd)

Desired Level of Engagement	Cost pressure	Unclear/insufficient budget, budget feasibility not established, lack of confidence regarding financing, strictly no scope for additional funds, little to no contingency	Budget feasibility not established, adequate funds and sources secured but request for additional funds would be lengthy and embarrassing, sufficient contingency	Budget feasibility established, adequate funds and sources secured and some scope for additional funds, sufficient contingency	Budget feasibility established using benchmarks, adequate scope for additional recurrent funds and sources secured, generous contingency
	Schedule pressure	The basis for the current schedule is unclear or the duration is likely to be inadequate	The basis for the schedule is clear, but there are indications that overruns are possible	Benchmarks were used to establish schedule; tight contingencies	Benchmarks used to establish the schedule and adequate contingencies exist
	Quality pressure	High contractual quality requirements; if unmet could affect cost & schedule significantly	Moderate contractual quality requirements; if unmet could affect cost & schedule moderately	Minor contractual quality requirements; if unmet, some probability of affecting cost & schedule	No special contractual quality requirements; if unmet, will not affect cost & schedule

Table 20 Revised Risk Intensity Assessment Model (Category 2 Projects)

Risk Intensity Assessment Model (Category 2 Projects)						
Risk factors	Risk element(s)	Level 5	Level 4	Level 3	Level 2	Level 1
Project value	Budget	$250M - $500M+	$25M - $250M	$10M - $25M	$5M - $10M	$0 - $5M
	Duration	>24 months	18–24 months	12–18 months	6–12 months	<6 months
	Work per day	>$200,000	$100,000 - $200,000	$50,000 - $100,000	$25,000 - $50,000	$0 - $25,000
Project-based risk	Project approvals	Large number of approvals required; High level of difficulty/stringency expected; may impact project severely	Significant number of approvals required; Medium level of difficulty/stringency expected; may impact project significantly	Some approvals required; Possible difficulty/stringency expected; provisions in budget and schedule for delay	Minimal number of approvals required; Regular approvals (zero difficulty/stringency expected); no impact on project	No approval required or all have been obtained; no impact on project
	Site & environmental conditions	history of differing site conditions; Site conditions uncontrollable; may affect schedule, cost, quality or safety; Site location prone to acts of God, Extreme weather	history of differing site conditions; Controllable (planned for) site conditions but may affect schedule, cost, quality, or safety; Moderate to extreme weather	No history of differing site conditions; Controllable site conditions; will not affect schedule, cost, quality or safety; basic precautions taken; Moderate weather	Favorable site conditions; minimal risk to schedule, cost, quality, or safety;; precautions taken; Slight weather delays expected	Favorable; no risk to the schedule, cost, quality or safety; Established and known; no history of differing site conditions; no weather conditions expected
	Safety, accessibility & on-going operations	Risk of Catastrophe numerous fatalities & Activities in occupied areas/On-going operations; Challenging access issues	Risk of fatality; Staging within occupied areas/On-going construction; Challenging access issues	Moderate Risk; Risk of disability; Additions to occupied areas/Staging adjacent to on-going operations or construction; No access issues	Minor risk of damage; Well clear of occupied areas; No access issues	Minor to no risk & Greenfield site; No access issues
	Construction complexity	Very High; Never done before Innovative and risky operations required	High; Never done before but safe operations required	Moderate; Complex operations required	Low; Minor challenges expected	Very Low; Little to no challenge expected
	Design complexity	incomplete design and high probability of design change and review; underdeveloped specs	design & specs based on incomplete information; risk of omissions	designer is inexperienced or design team is improper; probability of design errors	improper/incomplete design scheme communicated by client; experienced and competent designer	design scheme well communicated by client; experienced and competent designer; proper design reviews completed

Table 20 (cont'd)

Sociopolitical risks	Third-party stakeholder & Public Interest	High level of political, community or media sensitivity	High profile client or project; Third-party stakeholder groups may be involved	Third-party stakeholder groups may be involved	Project may attract stakeholder or media interest	Project unlikely to attract stakeholder or media interest
Project relationships	Inter-stakeholder relationships	Client with no experience. New Relationships; History of Litigation; Joint Ventures; Less to No time for relationship development	Mixed experience amongst clients or client's rep; New Relationships, Less to no scope for developing relationships	Some experience amongst clients or client's rep but sufficient time for relationship development before project start	Some previous project experience and neutral to good working relationships & experiences	Sufficient previous working experience with prior positive relationships
Desired Level of Engagement	Cost pressure	No clear budget, budget seems insufficient, budget feasibility not established, inadequate funds or sources not secured, less to no contingency	Budget feasibility not established, adequate funds and sources identified but financing not secured, strictly no scope for additional funds, little to no contingency	Budget feasibility not established, adequate funds and sources secured but request for additional funds would be lengthy and embarrassing, sufficient contingency	Budget feasibility established, adequate funds and sources secured and some scope for additional funds, sufficient contingency	Budget feasibility established using benchmarks, adequate & sure scope for additional recurrent funds and sources secured, generous contingency
	Schedule pressure	There is no clear schedule, or the schedule is clearly insufficient	The basis for the current schedule is unclear or the schedule is likely to be inadequate	The basis for the schedule is clear, but indications are that overruns are possible	Benchmarks were used to establish schedule	Benchmarks were used to establish the schedule and adequate contingencies exist
	Quality pressure	High Quality requirements; if unmet could affect cost, schedule, project significantly	Moderate Quality requirements; if unmet could affect cost, schedule, project slightly	Minor contractual quality requirements; if unmet, some probability of affecting cost & schedule	Quality requirements not specifically mentioned; will not affect project	No mention about importance of quality requirements; will not affect project

4.4.2 Partnering level assessment model

Table 21 contains a list of the partnering factors and constituent partnering tools, the implementation of which contributes to the partnering score of that factor. This table is akin to a risk register and the researcher chose to call it a 'partnering register'.

Following the list are Table 22 and Table 23, representing the revised models for partnering level assessment for horizontal and non-horizontal projects respectively.

The steps for determining overall partnering level of an AEC project are:

STEP 1. Identify the type of project –

a. Category 1 Project – A project is a horizontal project if a majority of its scope involves heavy civil construction whose length is longer than its height. Examples of such projects include bridges, roads, utility projects, etc.

b. Category 2 Project – Includes:

i. Vertical projects – A project is a vertical project if a majority of its scope stretches vertically. Example of vertical construction projects include commercial buildings, hospitals, etc.

ii. Aviation project – A project is an aviation project if a majority of its scope involves construction on or close to airports and requires significant interaction with airport authorities. Examples of aviation projects include runways, control towers, terminals, etc.

Note: It is important to note that aviation projects may be both vertical and horizontal in scope. For the purpose of this research, if a project can be classified as aviation then it cannot be classified as Category 1.

STEP 2. Based on the project type determined above, choose the appropriate partnering level assessment model – Category 1 or Category 2 project partnering level assessment model

STEP 3. Based on the partnering tools implemented on the project, assign a score (1-4 for Category 1 and 1-5 for Category 2) for each partnering factor per the model

STEP 4. Note that, irrespective of the scores of other Partnering factors, the overall partnering level of a project shall not exceed the score of its 'Facilitation' factor

STEP 5. Bonus points are available for implementing the tools 'close-out workshop' and 'formal lessons learned' for the factors 'Partnering workshop frequency' and 'Partnering survey frequency' up to the maximum possible points available for that factor

STEP 6. Compute overall partnering level as the average of all scores of each partnering rounded off to the higher level

Table 21 Partnering register for the revised Partnering Level assessment model

Partnering factor	Partnering Tools or frequency
Dispute/issue resolution	Field-level decision making
	Issue resolution ladder developed
	Dispute resolution board formed
	Facilitated dispute resolution
Facilitation	Self-directed
	In-house or internal
	Third-party facilitation
Partnering workshop frequency	Kick-off only
	More than once but less than quarterly
	Quarterly or more but less than monthly
	Monthly or more but less than weekly / weekly or more
	Close-out Workshop
Partnering survey frequency	At least once
	More than once but less than quarterly
	Quarterly or more but less than monthly
	Monthly or more but less than weekly / weekly or more
	Lessons learned analyzed
Goal alignment & team-building	Charter developed
	Goals revisited at least once
	Partnering training
	Partnering recognition/awards/ special task forces
Stakeholder involvement	Subcontractor on-boarding/off-boarding
	Stakeholder on-boarding/off-boarding
	Some form of stakeholder involvement
	Executive sponsorship / multi-tier partnering

Table 22 Revised Partnering Level Assessment Model (Category 1 Projects)

Partnering Level Assessment Model (Category 1 Projects)

Partnering factor	Level 1	Level 2	Level 3	Level 4	Bonus points
Dispute/issue resolution	Field-level decision making	Issue resolution ladder developed	Dispute resolution board formed	Facilitated dispute resolution	NA
Facilitation**	Self-directed	In-house or internal	NA	Third-party facilitation	NA
Partnering workshop frequency	Kick-off only	More than once but less than quarterly	Quarterly or more but less than monthly	Monthly or more but less than weekly / weekly or more	Bonus: close-out workshop
Partnering survey frequency	At least once	More than once but less than quarterly	Quarterly or more but less than monthly	Monthly or more but less than weekly / weekly or more	Bonus: formal lessons learned analyzed
Goal alignment & team-building	Charter developed	Goals revisited at least once	Partnering training	Partnering recognition/awards/ special task forces	NA
Stakeholder involvement	Subcontractor on-boarding/off-boarding	Stakeholder on-boarding/off-boarding	Some form of stakeholder involvement	Executive sponsorship / multi-tier partnering	NA

Table 23 Revised Partnering Level Assessment Model (Category 2 Projects)

Partnering Level Assessment Model (Category 2 Projects)						
Partnering factor	Level 1	Level 2	Level 3	Level 4	Level 5	Bonus points
Dispute/issue resolution	Field-level decision making	Issue resolution ladder developed	Dispute resolution board formed	Facilitated dispute resolution	Na	NA
Facilitation**	Self-directed	In-house or internal	NA	NA	Third-party facilitation	NA
Partnering workshop frequency	Kick-off only	More than once but less than quarterly	Quarterly or more but less than monthly	Monthly or more but less than weekly	Weekly or more	Bonus: close-out workshop
Partnering survey frequency	At least once	More than once but less than quarterly	Quarterly or more but less than monthly	Monthly or more but less than weekly	Weekly or more	Bonus: formal lessons learned analyzed
Goal alignment & team-building	Charter developed	Goals revisited at least once	Partnering training	Partnering recognition/awards	Special task forces	NA
Stakeholder involvement	Subcontractor on-boarding/off-boarding	Stakeholder on-boarding/off-boarding	Some form of stakeholder involvement	Executive sponsorship	Multi-tier partnering	NA

*** Irrespective of the scores of other Partnering factors, the overall partnering level of a project shall not exceed the score of its 'Facilitation' factor*

4.5 Characteristics and Normality Tests for Dependent Variables

Based on the hypothesis of this study, measures of the performance outcomes of cost growth, schedule growth, and increase in participant satisfaction, were identified as the dependent variables. This section presents descriptive statistics of those independent variables, including information about their statistical distribution.

Schedule Growth

Post data cleaning for non-responses and removal of outliers, schedule performance of 124 of the 127 projects in the data set was obtained. Out of the 124 projects,

- 35 (28.2%) belonged to the fit category 1 (‘negative’; i.e. showed a risk intensity higher than implemented partnering level),
- 72 (58.0%) belonged to the fit category 2 (‘neutral’; i.e. showed a partnering level equivalent to the risk intensity of the project); and
- 17 (13.7%) belonged to the fit category 3 (‘positive’; i.e. showed a partnering level higher than risk intensity on the project)

The highest average schedule growth of projects was observed in fit category 1 (negative) at 30.28%, followed by fit category 2 (neutral), where the average schedule growth across projects was 4.02%. Least average schedule growth per category was observed in fit category 3 (positive) at -3.52%. Negative schedule growth indicates that the project was completed ahead of its original planned schedule. The trend is graphically represented in Figure 14.

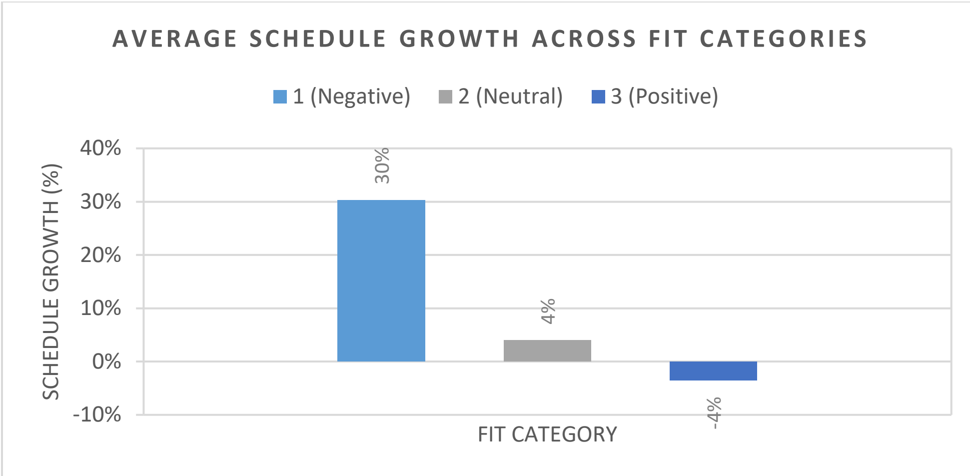

Figure 14 Average Schedule Growth across Fit Categories

The results of the Shapiro-Wilk test of normality for the schedule growth are presented in Table 24.

Table 24 Normality Test for Schedule Growth

Normality Test (Shapiro-Wilk) Characteristic	**Fit Category 1 (Negative)**	**Fit Category 2 (Neutral)**	**Fit Category 3 (Positive)**
p-value	1.01E-07	1.11E-08	7.94E-02
skewness	2.43	2.68	0.10
kurtosis	5.62	12.66	1.83
z	6.00	9.00	0.00
Result	Not Normal	Not Normal	Normal

As observed, $p < 0.05$ for categories 1 and 2, thus indicating that data in categories 1 and 2 are not normally distributed.

Cost Growth

Post data cleaning for non-responses and removal of outliers, cost performance of 118 of the 127 projects in the data set was obtained. Out of the 118 projects,

- 35 (29.6%) belonged to the fit category 1 ('negative'; i.e. showed a risk intensity higher than implemented partnering level),
- 66 (55.9%) belonged to the fit category 2 ('neutral'; i.e. showed a partnering level equivalent to the risk intensity of the project); and
- 17 (14.4%) belonged to the fit category 3 ('positive'; i.e. showed a partnering level higher than risk intensity on the project)

It is notable that across all fit categories, cost growth (adjusted for cost of owner's scope addition) is negative i.e. the final contract amount was lesser than the original contract amount, thus indicating savings. The highest average cost growth of projects was observed in fit category 1 (negative) at -1.24%, followed by fit category 2 (neutral), where the average cost growth across projects was -1.68%. Least average cost growth per category was observed in fit category 3 (positive) at -5.03%. The trend is graphically represented in Figure 15.

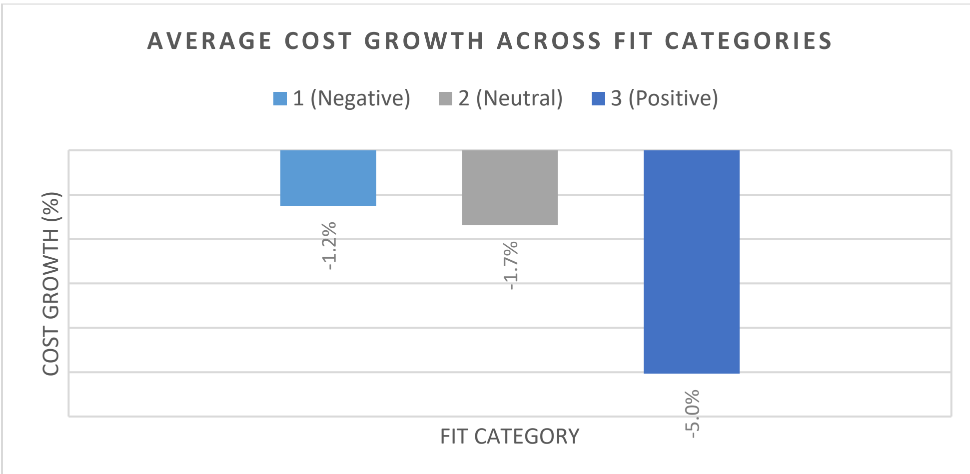

Figure 15 Average Cost Growth across Fit Categories

The results of the Shapiro-Wilk test of normality for cost growth are presented in Table 25

Table 25 Normality Test for Cost Growth

Normality Test (Shapiro-Wilk) Characteristic	**Fit Category 1 (Negative)**	**Fit Category 2 (Neutral)**	**Fit Category 3 (Positive)**
p-value	1.71E-08	4.96E-06	3.58E-03
skewness	3.87	-0.05	-1.80
kurtosis	19.89	1.59	3.97
z	10.00	0.00	-3.00
Result	Not Normal	Not Normal	Not Normal

As observed, $p < 0.05$ for categories 1, 2 and 3, thus indicating that data in all categories are not normally distributed.

Increase in Participant Satisfaction

Post data cleaning for non-responses and removal of outliers, increase in participant satisfaction performance of 80 of the 127 projects in the data set was obtained. Out of the 80 projects,

- 21 (26.2%) belonged to the fit category 1 ('negative'; i.e. showed a risk intensity higher than implemented partnering level),
- 48 (60%) belonged to the fit category 2 ('neutral'; i.e. showed a partnering level equivalent to the risk intensity of the project); and
- 11 (13.7%) belonged to the fit category 3 ('positive'; i.e. showed a partnering level higher than risk intensity on the project)

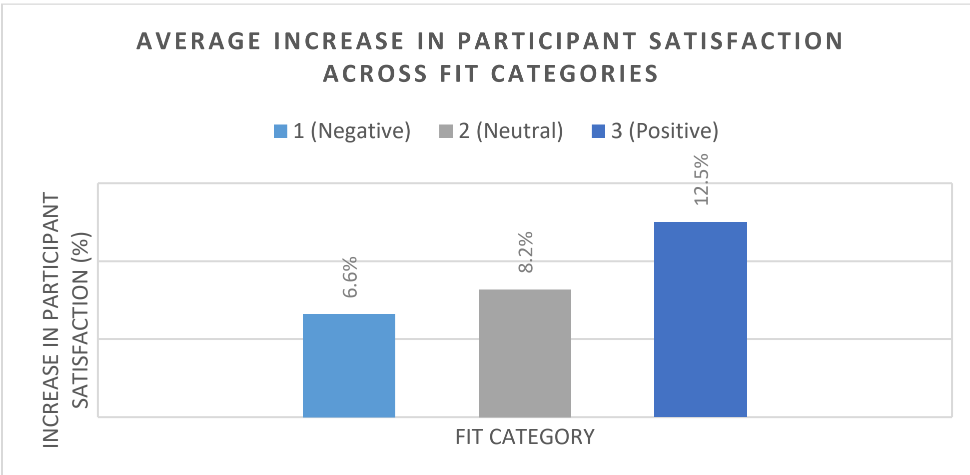

Figure 16 Average Increase in Participant Satisfaction across Fit Categories

It is notable that across all fit categories increase in participant satisfaction is positive i.e. the final participant satisfaction score was greater than the participant satisfaction score at the beginning of the project. The lowest average increase in participant satisfaction of projects was observed in fit category 1 (negative) at 6.6%, followed by fit category 2 (neutral), where the average increase in participant satisfaction across projects was 8.2%. The highest average increase in participant satisfaction per category was observed in fit category 3 (positive) at 12.5%.

The results of the Shapiro-Wilk test of normality for increase in participant satisfaction are presented in Table 26

Table 26 Normality Test for Increase in Participant Satisfaction

Normality Test (Shapiro-Wilk) Characteristic	**Fit Category 1 (Negative)**	**Fit Category 2 (Neutral)**	**Fit Category 3 (Positive)**
p-value	0.14	7.16E-05	0.01
skewness	0.95	1.60	1.07
kurtosis	1.71	4.54	-0.48
z	2.00	5.00	2.00
Result	Normal	Not Normal	Not Normal

As observed, $p < 0.05$ for categories 2 and 3, thus indicating that data in categories 2 and 3 are not normally distributed.

As observed, with respect to distribution of the population of performance outcomes, there is no basis for assuming their normality. Moreover, the Shapiro-Wilk test for normality for performance outcome measures across the three categories failed for most analyses. This eliminated the possibility of using parametric statistical tests (e.g., ANOVA) as they rely on the basis that the samples are normally distributed. Hence, the Kruskal-Wallis non-parametric statistical test was used, which does not require that data from the samples be normally distributed.

Number of Change Orders

Post data cleaning for non-responses and removal of outliers, number of change orders performance of 123 of the 127 projects in the data set was obtained. Out of the 123 projects,

- 36 (29%) belonged to the fit category 1 ('negative'; i.e. showed a risk intensity higher than implemented partnering level),
- 71 (58%) belonged to the fit category 2 ('neutral'; i.e. showed a partnering level equivalent to the risk intensity of the project); and
- 16 (13%) belonged to the fit category 3 ('positive'; i.e. showed a partnering level higher than risk intensity on the project)

The trend of number of change orders across the fit categories is graphically represented below

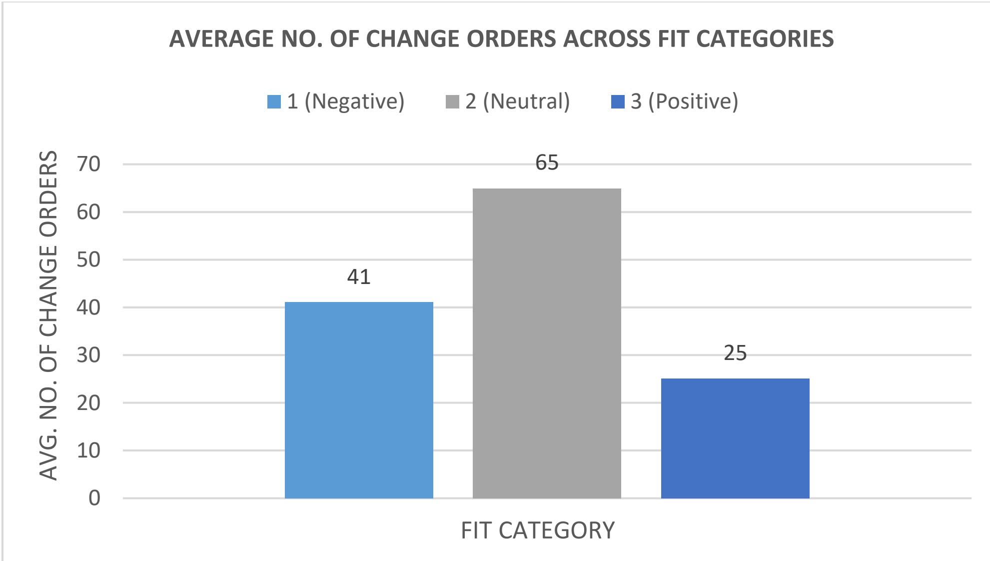

Figure 17 Average Number of change orders across Fit Categories

The results of the Shapiro-Wilk test of normality for number of change orders are presented in Table 27.

Table 27 Normality Test for Number of change orders

Normality Test (Shapiro-Wilk) Characteristic	**Fit Category 1 (Negative)**	**Fit Category 2 (Neutral)**	**Fit Category 3 (Positive)**
p-value	4.27E-06	1.11E-15	1.62E-01
skewness	1.93	6.56	3.21
kurtosis	3.63	49.51	11.09
z	5.00	23.00	6.00
Result	Not Normal	Not Normal	Not Normal

As observed, $p < 0.05$ for all categories, thus indicating that data in all categories are not normally distributed.

As observed, with respect to distribution of the population of performance outcomes, there is no basis for assuming their normality. Moreover, the Shapiro-Wilk test for normality for performance outcome measures across the three categories failed for most analyses. This eliminated the possibility of using parametric statistical tests (e.g., ANOVA) as they rely on the basis that the samples are normally distributed. Hence, the Kruskal-Wallis non-parametric statistical test was used, which does not require that data from the samples be normally distributed.

4.6 Hypothesis Testing

The overall study hypothesis of this study is that '*In a partnered project, better the fit between the intensity of risk and adopted partnering level, better is its performance (e.g., cost growth, schedule growth).'* For the purpose of statistical analysis, the study hypothesis can be paraphrased as *'The frequency distribution of measures for performance outcome metrics (schedule growth, cost growth and increase in participant satisfaction) differ across the risk-partnering fit categories (negative, neutral and positive).'*

The unit of analysis is partnered projects. The independent variable is 'fit', where:

- Fit category 1 represents 'negative fit' i.e. the project shows risk intensity higher than implemented partnering level,
- Fit category 2 represents 'neutral fit' i.e. the project shows a partnering level equivalent to the risk intensity; and
- Fit category 3 represents 'positive fit' i.e. the project shows a partnering level higher than risk intensity.

The dependent variables are cost growth, schedule growth and increase in participant satisfaction. Because the impact of the risk-partnering fit on project performance will be tested for each performance metric separately, three sub-hypotheses were generated from the overall study hypothesis.

Hypothesis 1: *'The frequency distribution of measures for schedule growth performance differ across the risk-partnering fit categories (negative, neutral and positive).'*

Hypothesis 2: *'The frequency distribution of measures for cost growth performance differ across the risk-partnering fit categories (negative, neutral and positive).'*

Hypothesis 3: *'The frequency distribution of measures for increase in participant satisfaction performance differ across the risk-partnering fit categories (negative, neutral and positive).'*

Hypothesis 4: *'The frequency distribution of measures for number of change orders differ across the risk-partnering fit categories (negative, neutral and positive).'*

4.6.1 Risk-Partnering Fit versus Schedule Growth

This involved examining if the risk-partnering 'fit' is correlated to the 'schedule growth' performance of partnered projects. For statistical testing, the assumed correlation is represented by **Hypothesis 1** that, *'The frequency distribution of measures for schedule growth performance differ across the risk-partnering fit categories (negative, neutral and positive).'*

The above hypothesis was considered as an alternative hypothesis (H_A) when conducting the Kruskal-Wallis test, where the null hypothesis (H_0) indicated that there is no difference in distribution of schedule growth measures (estimated via the median) across the risk-partnering fit categories' and was represented as:

$$H_0: \mu_{sg,positive\ fit} = \mu_{sg,neutral\ fit} = \mu_{sg,negative\ fit}\ ;\ where, \mu_{sg}: median\ schedule\ growth$$

Table 28 shows the results of the Kruskal-Wallis test:

Table 28 Kruskal-Wallis Test for Fit versus Schedule Growth

Kruskal-Wallis Test (Fit versus Schedule Growth)	
H_0	The samples come from populations with equal medians
H_1	The samples come from populations with medians that are not all equal
Observation	CHISQ = 5.12 > 4.605 (rejection region)
Hypothesis Testing	H_0 Rejected
p-value	0.08 < 0.1 (90% significance level)

Thus, as observed, the null hypothesis was rejected, thereby implying that the alternative hypothesis, which indicated that there is a variability introduced in schedule growth performance because of the risk-partnering fit of a project, is true. The result offers empirical evidence to assert that there exists a statistically significant (CHISQ = 5.12, $p < 0.1$) correlation between risk-partnering fit and schedule performance of partnered projects.

The researcher then sought to identify which of the categories differed from each other and the order between them. To achieve this objective, the Dunn-test was conducted. The results of the Dunn Test are tabulated in Table 29.

Table 29 Dunn Test for Fit versus Schedule Growth

	Difference	p-value	Result
Mean $_{\text{fit category 1}}$ **-** **Mean** $_{\text{fit category 3}}$	2.138072	0.0163	The difference **is significant** at 95% confidence level (CI)
Mean $_{\text{fit category 1}}$ **-** **Mean** $_{\text{fit category 2}}$	1.685832	0.0459	The difference is not significant at 95% CI, but is significant at 90% CI
Mean $_{\text{fit category 2}}$ **-** **Mean** $_{\text{fit category 3}}$	1.055765	0.1455	The difference is not significant at 95% CI

The results of the Dunn test can be interpreted as follows:

- *Schedule growth performance of projects in Fit Category 3 (positive fit) is statistically significantly less than that of projects Fit Category 1 (negative fit) at 95% confidence (p=0.01 < 0.05). That is, when it comes to the performance outcome metric of schedule growth, one can say that, 95% of the time, projects with partnering level higher than risk intensity (positive fit) perform better than projects with partnering level lower than risk intensity (negative fit).*
- Schedule growth performance of projects in Fit Category 3 (positive fit) is not statistically significantly different than that of projects Fit Category 2 (neutral fit) (p=0.14)
- Schedule growth performance of projects in Fit Category 2 (neutral fit) is not statistically significantly different from that of projects Fit Category 1 (negative fit) at 95% confidence (p=0.04). However, the difference is significant at 90% confidence interval. That is, one can say that, 90% of the time, projects with partnering level equal to risk intensity (neutral fit) perform better than projects with partnering level lower than risk intensity (negative fit).

Figure 18 below provides a visual representation of the values of schedule growth across the three fit categories.

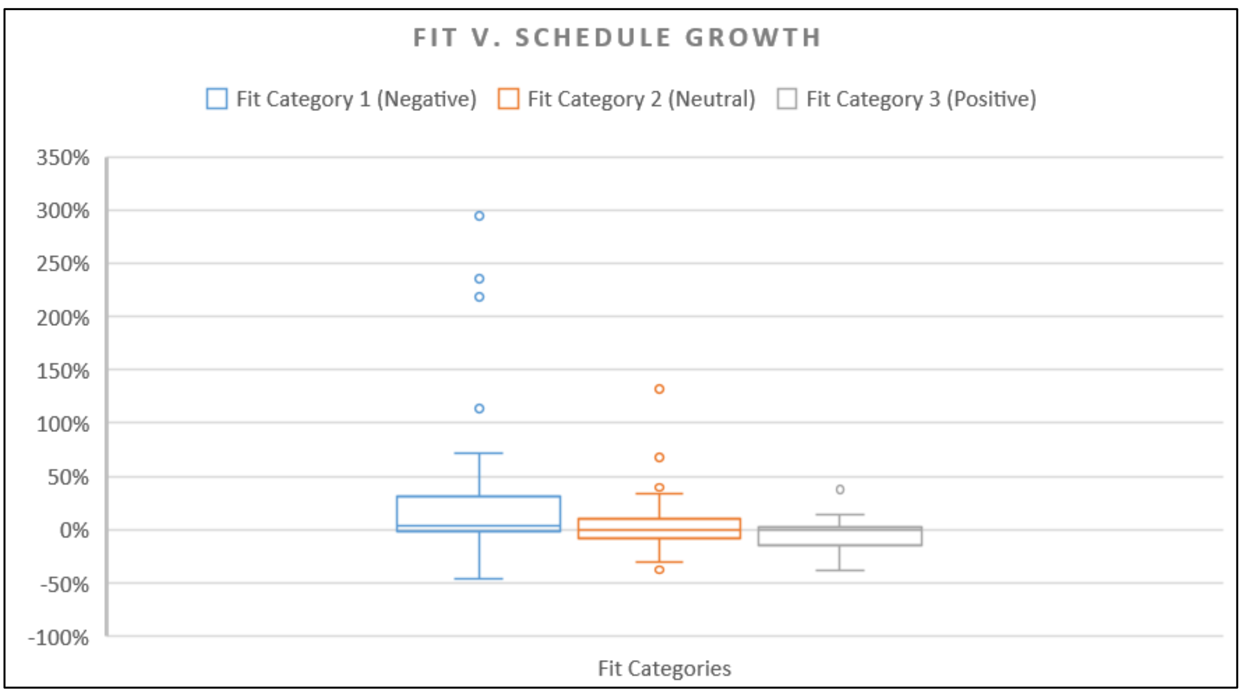

Figure 18 Fit versus Schedule Growth

4.6.2 Risk-Partnering Fit versus Cost Growth

This involved examining if the risk-partnering 'fit' is correlated to the 'cost growth' performance of partnered projects. For statistical testing, the assumed correlation is represented by **Hypothesis 2** that, *'The frequency distribution of measures for cost growth performance differ across the risk-partnering fit categories (negative, neutral and positive).'*

The above hypothesis was considered as an alternative hypothesis (H_A) when conducting the Kruskal-Wallis test, where the null hypothesis (H_0) indicated that there is no difference in distribution of cost growth measures (estimated via the median) across the risk-partnering fit categories' and was represented as:

$$H_0: \mu_{cg,positive\ fit} = \mu_{cg,neutral\ fit} = \mu_{cg,negative\ fit}\ ;\ where, \mu_{cg}: median\ cost\ growth$$

Table 30 shows the results of the Kruskal-Wallis test.

Table 30 Kruskal-Wallis Test for Fit versus Cost Growth

Kruskal-Wallis Test (Fit versus Cost Growth)	
H_0	The samples come from populations with equal medians
H_1	The samples come from populations with medians that are not all equal
Rejection Region	CHISQ > 5.991
Observation	CHISQ = 0.046 < 5.991
Hypothesis Testing	H0 Not Rejected
p-value	0.9772 > 0.1 (90% significance level)

Thus, as observed, the null hypothesis was not rejected, thereby implying that the alternative hypothesis, which indicated that there is a variability introduced in cost growth performance because of the risk-partnering fit of a project, is not true. Thus, the result provides no empirical evidence to assert that there exists a statistically significant correlation between risk-partnering fit and cost performance of partnered projects.

Figure 19 below provides a visual representation of the values of cost growth across the three fit categories.

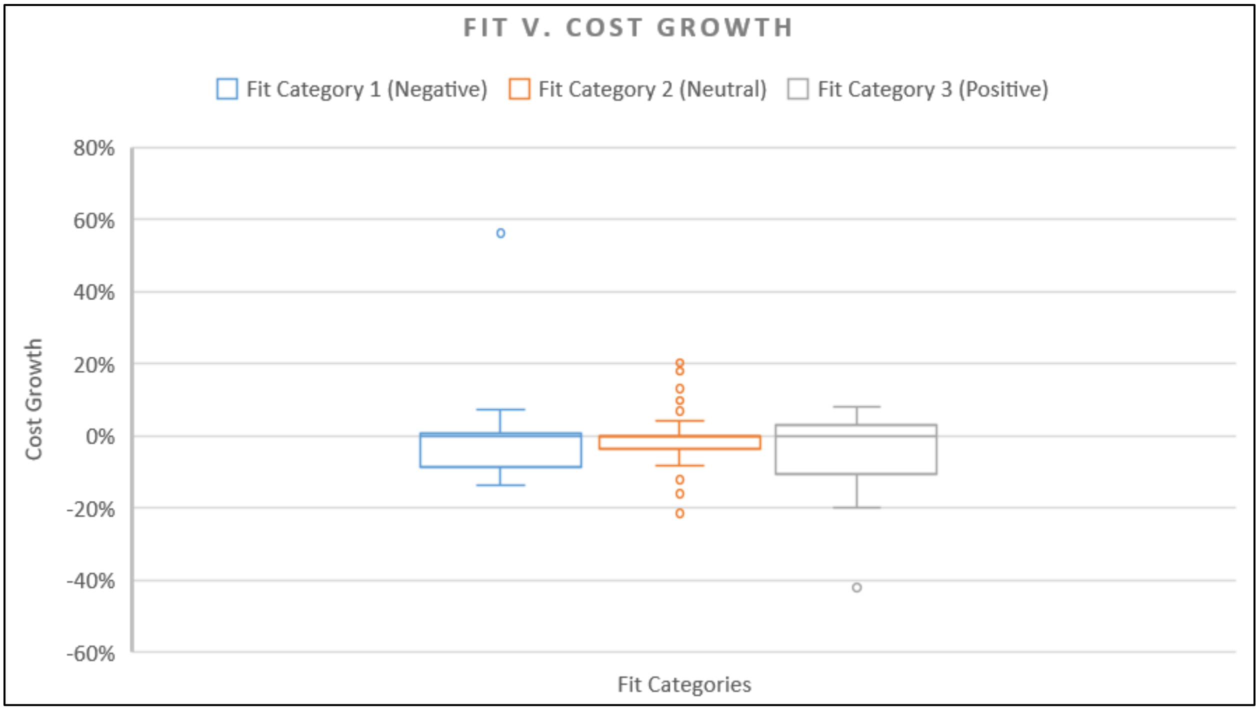

Figure 19 Fit versus Cost Growth

4.6.3 Risk-Partnering Fit versus Increase in Participant Satisfaction

This involved examining if the risk-partnering 'fit' is correlated to the 'increase in participant satisfaction' performance of partnered projects. For statistical testing, the assumed correlation is represented by **Hypothesis 3** that, ***'The frequency distribution of measures for increase in participant satisfaction performance differ across the risk-partnering fit categories (negative, neutral and positive).'***

The above hypothesis was considered as an alternative hypothesis (H_A) when conducting the Kruskal-Wallis test, where the null hypothesis (H_0) indicated that there is no difference in distribution of increase in participant satisfaction measures (estimated via the median) across the risk-partnering fit categories' and was represented as:

$$H_0: \mu_{ips,positive\ fit} = \mu_{ips,neutral\ fit} = \mu_{ips,negative\ fit}\ ;$$

$$where, \mu_{cg}: median\ increase\ in\ participant\ satisfaction$$

Table 31 shows the results of the Kruskal-Wallis test.

Table 31 Kruskal-Wallis Test for Fit versus Increase in Participant Satisfaction

Kruskal-Wallis Test (Fit versus Increase in Participant Satisfaction)	
H_0	The samples come from populations with equal medians
H_1	The samples come from populations with medians that are not all equal
Rejection Region	CHISQ > 5.991
Observation	CHISQ = 0.046 < 5.991
Hypothesis Testing	H0 Not Rejected
p-value	0.9772 > 0.1 (90% significance level)

Thus, as observed, the null hypothesis was not rejected, thereby implying that the alternative hypothesis, which indicated that there is a variability introduced in increase in participant satisfaction performance because of the risk-partnering fit of a project, is not true. Thus, the result provides no empirical evidence to assert that there exists a statistically significant correlation between risk-partnering fit and increase in participant satisfaction performance of partnered projects.

Figure 20 below provides a visual representation of the values of increase in participant satisfaction across the three fit categories.

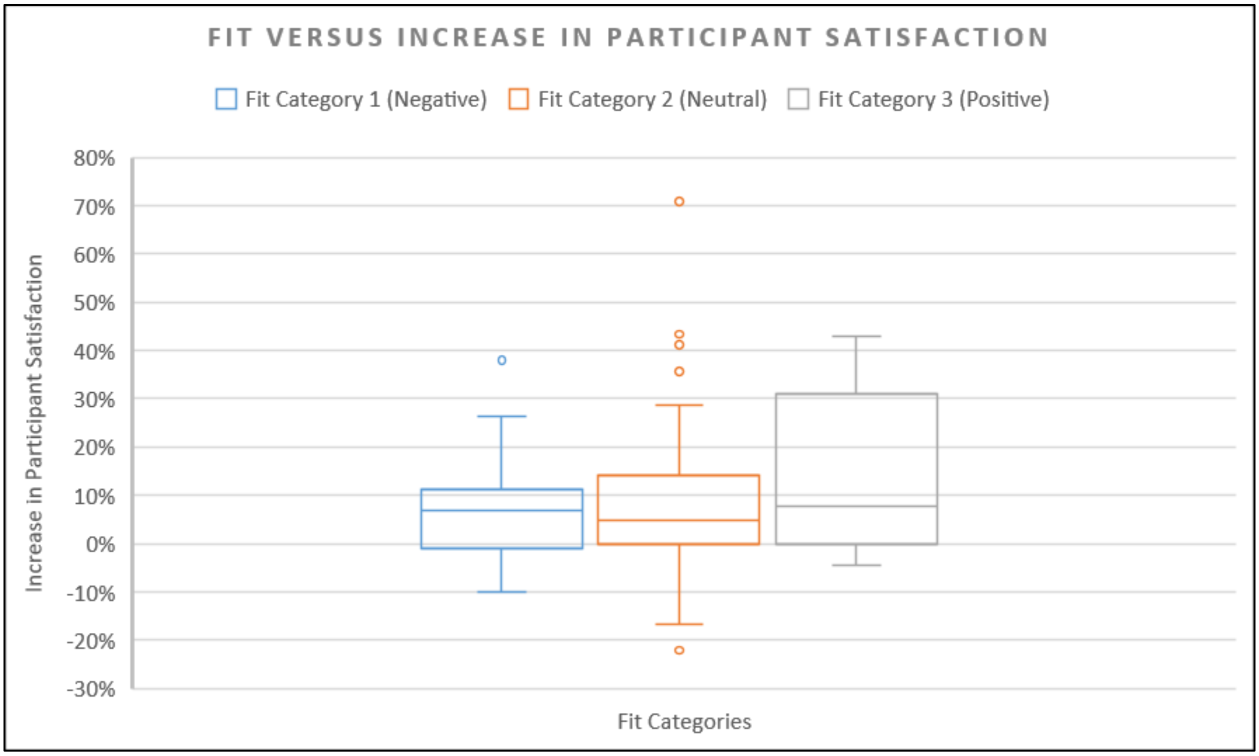

Figure 20 Fit versus Increase in Participant Satisfaction

4.6.4 Risk-Partnering Fit versus Number of change orders

This involved examining if the risk-partnering 'fit' is correlated to the 'number of change orders' on partnered projects. For statistical testing, the assumed correlation is represented by **Hypothesis 4** that, ***'The frequency distribution of measures for number of change orders performance differ across the risk-partnering fit categories (negative, neutral and positive).'***

The above hypothesis was considered as an alternative hypothesis (H_A) when conducting the Kruskal-Wallis test, where the null hypothesis (H_0) indicated that there is no difference in distribution of number of change orders measures (estimated via the median) across the risk-partnering fit categories' and was represented as:

$$H_0: \mu_{ips,positive\ fit} = \mu_{ips,neutral\ fit} = \mu_{ips,negative\ fit}\ ;$$

$$where, \mu_{cg}: median\ number\ of\ change\ orders$$

Table 32 shows the results of the Kruskal-Wallis test.

Table 32 Kruskal-Wallis Test for Fit versus Number of change orders

Kruskal-Wallis Test (Fit versus Number of change orders)

H_0	The samples come from populations with equal medians
H_1	The samples come from populations with medians that are not all equal
Rejection Region	CHISQ > 5.991
Observation	CHISQ = 2.98 < 5.991
Hypothesis Testing	H0 Not Rejected
p-value	0.2253 > 0.1 (90% significance level)

Thus, as observed, the null hypothesis was not rejected, thereby implying that the alternative hypothesis, which indicated that there is a variability introduced in number of change orders performance because of the risk-partnering fit of a project, is not true. Thus, the result provides no empirical evidence to assert that there exists a statistically significant correlation between risk-partnering fit and number of change orders performance of partnered projects.

Figure 21 below provides a visual representation of the values of number of change orders across the three fit categories.

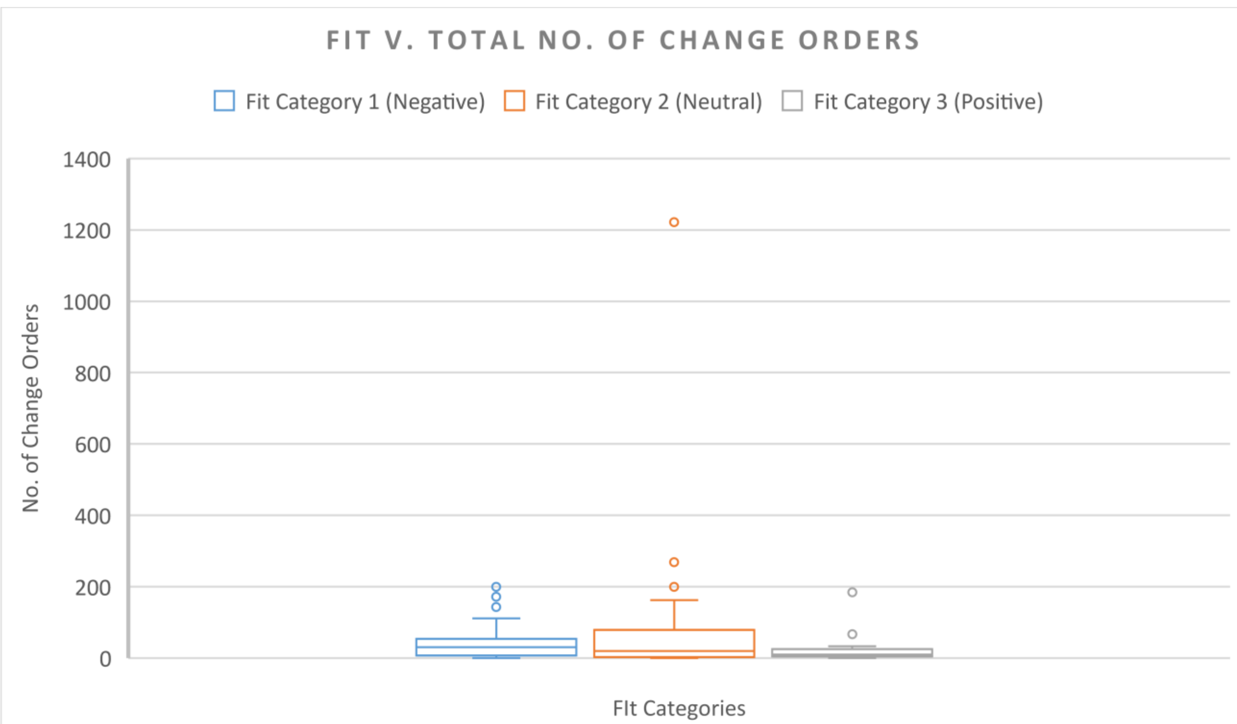

Figure 21 Fit versus Number of change orders

4.7 Summary

Descriptive characteristics of samples of project performance measures distributed across the three risk-partnering fit categories show that:

1. With respect to averages of schedule growth performance (after discounting for contractual time extensions granted on account of owner scope additions) across the fit categories,
   a. Mean schedule growth is least in projects in fit category 3 (positive), followed by fit category 2 (neutral) and then by fit category 3 (negative). This implies that on an average, schedule performance improves as the risk-partnering fit improves.
   b. Mean schedule growth is negative in projects in fit category 3 (positive), thus implying that on an average, projects that adopted a partnering level higher than risk intensity (fit category 3) completed the original scope of the projects ahead of the original planned duration.
2. With respect to averages of cost growth performance (after discounting for contractual change order costs accepted on account of owner scope additions) across the fit categories,
   a. Mean cost growth across the three fit categories was negative, thus implying that on an average, projects that adopt partnering complete the original scope of the projects under-budget compared to the original contract amount.
   b. Further, the mean cost growth is least in projects in fit category 3 (positive), followed by fit category 2 (neutral) and then by fit category 3 (negative). This implies that on an average, that as project as the risk-partnering fit improves, more savings are realized in partnered projects.
3. With respect to averages of increase in participant satisfaction performance across the fit categories,
   a. Mean increase in participant satisfaction across the three fit categories was positive, thus implying that on an average, on projects that adopt partnering, after completion, project participants leave the project with higher sense of satisfaction compared to the beginning of the project.
   b. Further, the mean increase in participant satisfaction is most in projects in fit category 3 (positive), followed by fit category 2 (neutral) and then by fit category 3 (negative). This implies that on an average, that as project as the risk-partnering fit improves,

project participants experience higher increase in project satisfaction in partnered projects.

Statistical testing of the study hypothesis yielded a significant result when tested for the impact of risk-partnering fit on schedule growth performance. It was discovered that schedule growth performance of projects in Fit Category 3 (positive fit) were found to be statistically significantly less than that of projects Fit Category 1 (negative fit) at 95% confidence ($p=0.01 < 0.05$). That is, 95% of the time, projects with partnering level higher than risk intensity (positive fit) perform better than projects with partnering level lower than risk intensity (negative fit).

Thus, there exists empirical evidence to support the assertion 'In a partnered project, better the fit between the intensity of risk and adopted partnering level, better is its schedule performance'

Although statistical testing of hypothesis for other performance measures (cost growth and increase in participant satisfaction) did not yield significant results, the researcher believes that if additional data to establish normality of the samples was collected, parametric statistical tests (e.g., ANOVA) would show significant results of trends like those discovered for schedule growth performance.

CHAPTER 5 CONCLUSIONS

5.1 Conclusions from Results and Findings

Following conclusions can be made from the results and findings of this study:

1. There exists statistical evidence to the existence of a correlation between risk-partnering fit and schedule performance (measured via schedule growth) of partnered AEC projects.
2. Partnered AEC projects that adopted a higher level of collaboration (via partnering) compared to the intensity of risk, demonstrate significantly improved schedule performance (measured via schedule growth) than projects that adopted a lower level of collaboration (via partnering) compared to the intensity of risk.
3. Statistical evidence was not found to assert a correlation between risk-partnering fit and other performance outcomes considered in this study, i.e., cost performance (measured via cost growth) and increase in participant satisfaction.
4. Descriptive characteristics of the variables (cost growth and increase in participant satisfaction) clearly exhibit a trend showing that as the fit category improved, average values for both variables demonstrated improved cost and participant satisfaction performance.

5.2 Deliverables and Implications

This study offers the following deliverables to the theory of project (specifically risk) management via collaboration:

1. Revised models for risk intensity and partnering level assessment, which are statistically verified via surveys, presented to industry experts.
2. The study filled the gap by conducting the empirical investigation into the impact of the interplay between risk and collaboration (via partnering) on project performance.
    a. The results of this study support the claim that partnering is an effective project delivery practice for improved collaboration and subsequent improvement in project performance.
    b. The researcher observed that projects encountering significant risk intensity could reduce its probability of occurrence and/or the severity of its impact in case it materializes to prevent it from affecting project performance.

c. It was also observed that a significant portion what could be classified as technical risk (e.g., constructability, design) comprised of risk of mistrust or non-collaborative behavior when determining its intensity. This paves a way for understanding the causality between collaboration and risk management.
d. By empirically demonstrating how risk is managed and project performance improved by adopting the appropriate level of partnering, this study adds ‘implementation of a level of partnering equal to or higher than risk intensity’ to the theory of best practices in Partnering. Although, previous researchers recommended this best practice, there did not exist empirical reinforcement to the same. In addition, this research supports the use of Partnering as an effective structured approach to achieve collaboration on AEC projects. Currently, partnering seems to be the only structure via which collaboration can be stratified, adjusted and adopted into various ‘levels’

In addition to the above, the outcomes of this study offer the following pragmatic deliverables to AEC industry practice as well:

1. This study presents models to assess risk intensity and partnering level of projects, which can be utilized by project stakeholders (owner organization, construction manager, etc.) to assess the intensity of risk on their project and decide a level of collaboration (via partnering) to adopt, with the goal of achieving improved project performance outcomes.
2. The results of this study demonstrate tangible benefits (e.g., improvement in cost and schedule performance) of implementing the appropriate level of collaboration (via partnering). These results can help project managers or stakeholders convincing upper management about the benefits of implementing a structured collaboration practice like Partnering.

5.3 Limitations and Discussion

It is important that to recognize the limitation of this study and discuss their origin and possible solutions. Such a discussion would assist future researchers in this field to be mindful about the limitations; and therefore, account for them in their research design.

Following are potential limitations encountered in this study and discussions about them:

- One might argue the choice of partnered projects as the unit of analysis to study collaboration in this research. The researcher acknowledges this argument but counters that there is a lack of availability of other generally acceptable and structured models to implement and study collaboration. Moreover, available literature strongly suggests that Partnering is possibly the only framework to study collaboration in an analytical manner for the purpose of quantitative research in the domain of collaboration.

- There are some inherent limitations to using archival data for research. The researcher had no control over the design or standard of the questionnaire used to collect data. For example, the questionnaire did not directly request data about risk or its intensity to its respondents. Although the researcher developed a validated model to assess risk intensity from available project details in the data-set, it is possible that some risk elements were not reported in those details.
- Descriptive statistics show that a large number of projects (62%) were located in California. Although this a cause for concern regarding location bias, the researcher finds no connection as to how that would affect the results of this research as none of the study constructs (risk intensity, partnering level, project performance) are known to be location-dependent. Nevertheless, the researcher has provided explanations justifying the bias in Section 4.1.
- Risk assessment of projects that are already completed, or 'retrospective' risk assessment has inherent drawbacks. Risk assessment should ideally be conducted at or before the beginning of a project. As the data set contained projects that had already been completed, it is possible that details about issues that had occurred in these projects skewed the coder's perspective about the probability of occurrence of the risk elements or severity of their impact. Although reliability checks were conducted to maintain the quality of coding, the researcher recommends that the risk intensity model presented in this study be used for assessing risk intensity level before commencement of the project. Alternatively, risk assessment methods suggested by Hanna at al. (2013) could be used.
- There is a debate regarding ordinal measurement or quantification of risk. It is argued that risk cannot be graded on scales of say 1 – 5 because, for example, it is difficult to perceive with certainty how a risk of level of 4 is exactly doubly as risky as a level 1 risk. However, this study presented several peer-reviewed journals support research using ordinal scales for risk assessment and measurement. In addition, helpful statistical analysis is difficult to conduct on continuous data.
- Further, it is tricky to assign one number representing the overall risk intensity or partnering level of a project. However, it might be necessary to do so when making a decision like which partnering level to adopt based on the risks of the project. As recommended in the later section, further

research in this domain might suggest a one to one correspondence between the intensity of individual risk element and level of individual partnering tool to be selected. However, based on available theory, this researcher considered it apt to use ordinal measurement to represent overall risk intensity level and partnering level of a project.

5.4 Recommendations for Future Research

This research initiated an empirical investigation into the impact of the interplay between risk and collaboration on project performance. During the study, there were several lessons learned, limitations experienced as well as avenues identified for further research. Based on them, the researcher suggests following strategic research directions:

1. **Refinement of Risk Intensity and Partnering Level assignment models** – Survey-based research efforts followed by factor analysis can be taken to refine the accuracy of risk intensity and partnering level assignment models used in this study. By reaching out to a variety of project participants like owners, stakeholders, designers, contractors and trades, the objective of such a study could be to understand if there is a difference in how risk intensity and partnering level assignments are perceived by project participants with different roles. The study could also attempt to assign weightages to the risk and partnering factors with the aim to develop a stand-alone decision-making tool for prospective risk intensity and partnering level assessment.
2. **Best Practices for Risk Management via Collaboration** – Using the models presented in this study, efforts can be taken to map usage of specific partnering tools to alleviate specific risk elements or factors. This effort could comprise of interview-based or case study research. The outcome would be a prescriptive model for decision-makers to select a particular partnering tool and its level to combat a certain identified risk and its intensity.
3. **Comparison of Partnered versus Non-Partnered Projects** – By conducting a data collection effort to collect data of similar nature from a similar variety of AEC projects that did not implement Partnering, one could compare the performance of partnered and non-partnered projects. Such a study would check if and how the adoption of partnering efforts improve specific performance outcomes of a project compared to those of non-partnered projects.
4. **Observing impacts on relational risk instead of standard project risks –** During content analysis, the researcher observed that the impact of collaboration on project performance via risk reduction appears to be indirect. That is, project details in the data-set often revealed that collaboration reduced the risk of non-collaborative behavior (e.g., mistrust, contentious

communication), which in turn led to reduction of the probability of occurrence and/or severity of impact of the standard project risk (e.g., construction and design complexity, unfavorable site conditions). Thus, a study similar to this one could be undertaken to firstly identify risk elements of non-collaborative behavior or 'relational risk' (defined by Lehtiranta, 2011); then develop models to determine relational risk intensity and correlate it to the level collaboration (via partnering) and proejct performance. Such a study might establish causal relations linking collaboration, risk reduation and proejct performance.

Continuing research in the domain of the interplay between risk, collaboration and performance will help decision makers adopt collaboration in a more informed and structured manner. It will allow for the development of metrics by which the outcomes of adopting collaboration could be anticipated, predicted and measured. The researcher hopes that such developments will ultimately help the AEC industry to be recognized as a collaborative industry and consequently produce innovative and sustainable built-environment solutions as a result.

APPENDICES

APPENDIX A Sample project award application

International Partnering Institute

John L. Martin
Partnered Project of the Year Award

2018 Application

INTERNATIONAL PARTNERING INSTITUTE

For projects completed between
January 1 and December 31, 2017

Application Deadline: February 5, 2018

291 McLeod Street
Livermore, CA 94551
925-447-9100

www.partneringinstitute.org

PURPOSE

The International Partnering Institute's (IPI) Partnered Project of the Year Award is an annual recognition of completed projects that best exemplify the principles of partnering. The purpose of the award is to celebrate successes, share lessons learned and best practices and to acknowledge the collaborative efforts of teams who achieve extraordinary results.

BACKGROUND

IPI is a 501(c) 3 non-profit charitable organization. The mission of IPI is to transform the construction industry to achieve exceptional results through a culture of collaboration. IPI is funded by revenue generated from member contributions, seminars and educational resources.

PARTNERING DEFINITION

Construction Partnering is a structured process that, through consistent application, develops a culture of collaboration through which construction project teams:

- Co-create project goals and strategies to meet them
- Measure progress toward goals
- Resolve issues and disputes
- Identify barriers and opportunities for project success
- Gather lessons learned from the project upon closeout.

Tangible deliverables of the Construction Partnering process include a charter (including core and project-specific goals and a signature page), an issue resolution process, action plans and commitments, and evaluation methods.

BENEFITS

In addition to being honored at the IPI Annual Awards Celebration, winners will:

- Be recognized as leaders in Partnering excellence
- Receive information regarding strengths and opportunities that will drive improved effectiveness
- Have the opportunity to network with peers in the industry committed to Partnering excellence
- Know they have contributed to continuous improvement of Partnering as a business process.

PARTNERED PROJECT OF THE YEAR AWARD CATEGORIES

IPI Partnered Projects of the Year Awards are granted to Projects in two sectors and three categories. In order to be eligible, the project must have utilized a structured Partnering process:

Sectors

Civil Construction:

Your project was one of the following: highways/state routes, freeways, roads and streets including reconstruction, an expansion or widening of existing roadways, bridges, interchanges, overpasses, road tunnels, transit or light rails, etc.

Buildings/Public Infrastructure:

Your project was one of the following: buildings, public infrastructures, commercial, healthcare, historical restoration, industrial, institutional, pre-engineered buildings, public works/environmental, renovation, restoration, public use buildings, utilities, water treatment, pipeline or other construction.

Budget Categories

Category 1 - Project Budget is less than $25 Million

Category 2 - Project Budget is between $25 and $250 Million

Category 3 – Mega Projects – Project Budget is over $250 Million

2018 ELIGIBILITY REQUIREMENTS

- Projects must be completed between January 1 and December 31, 2017
- Projects must be nominated by the Owner, Designer, Contractor, Construction Manager or Facilitator
- Projects must have followed a structured Partnered process in accordance with the IPI Model[1]

[1] Visit the IPI Website https://partneringinstitute.org/what-is-construction-partnering/ for more information on the IPI Model

AWARD PROGRAM GUIDELINES

Award Process

The IPI Partnered Project of the Year Award process is led by the IPI Awards Committee, volunteers from all walks of the construction industry with in-depth understanding of construction Partnering. The Awards Committee establishes the standards for award winning projects, reviews the awards applications and determines the level of recognition awarded to applicants.

Submittal requirements are clearly outlined each year and judging criteria is open for review by all applying entities.

The award recipients are recognized each year at the annual International Partnering Institute's Awards Ceremony.

The steps of the process include:
1. Review submittals for eligibility and adherence to the guidelines
2. Judges' review of written award submittals against the criteria
3. Selection of finalists for the award
4. Verification/clarification of recipient information and results
5. Judges' final recommendations for award recipients
6. Presentation of the award at the IPI Awards Ceremony

Application Deadlines and Submittal Information

Applications and fee to be sent **by February 5, 2018 before 5:00 p.m. PST** to:

International Partnering Institute
291 McLeod Street
Livermore, CA 94550

Application fee: $500
Late applications cannot be accepted.

For questions contact us at 925-447-9100, or ed@partneringinstitute.org.

Selection Process
Applicants are expected to complete the standard application form on pages 9-12. Please answer each question completely, and present the competed application in accordance with the submittal guidelines below. All materials may be used in future IPI publications.

- Table of Contents
- Application form
- Application content **(15 pages maximum)**
  - One page summary describing why the project should receive an IPI Partnered Project of the Year Award (not included in the 15 page count), immediately preceding the Judges' Criteria (this write-up should be suitable for publication)
- Responses to all questions set forth in the Judges' Criteria **(maximum of 10 pages)** in the order the criteria are listed on page 5
- Attachments
  - Exhibits **(maximum of 5 pages)** such as press clippings, related special event material, photos, charts, graphs or tables to highlight results and a glossary of terms as needed
  - Copy of the Charter/Partnering Agreement attached including signature page (if applicable), core and project-specific goals
  - Copy of the survey form/evaluation tool for the partnership

Format for the submittal:
- Please submit the entire application contents in a three-ring binder or bound booklet
- Do not include pictures or graphics on the table of contents, application form or dividing tabs
- Font size of 12 pt. Arial with one-inch margins; 1.5 spacing
- A cover sheet with a photo or graphic may be used in front of the binder or as first page of submittal, but not both.
- Dividing tabs separating sections are encouraged
- Please submit one original and four hard copies of the entire application by the deadline, as well as one electronic copy (Word or PDF)
- Please do not use double side entry pages or use sheet protectors

Judges will carefully score the responses given against the criteria established and select winning applicants based on the quality of the application and not on its sophistication. If, in a given category, none of the applications receive winning scores, no award for that category will be given. Applications are scored in accordance with the Judges' Score Sheet (attached).

Applications received after the deadline will not be accepted.

Application Tips

- Review the judges' criteria, judges' score sheet and the point system before you begin the application process.
- Before and after pictures are a great way to showcase specific elements of your project. Keep in mind that pictures must be supported by the write-up you provide.
- Start the application early and complete it before going back to review and polish it.
- Have your partners look over the materials you prepare for additional comments or insights. Buy-in from principal stakeholders may strengthen your application.
- Make sure you submit your application by the deadline.
- The application must include all of the elements requested above in order to be considered. In cases where scores are close, the quality of the application may be the deciding factor. The information included should be concise, and well-articulated.
- Provide examples throughout the application. Examples are a descriptive and concrete way to show the judges how your project was exceptional. Show us, don't tell us.
- A panel of judges who may have no previous exposure to your project will review and evaluate your project write-up. The judging panel for each project category is made up of experienced and qualified professionals who can only evaluate what you present.
- Any inconsistencies between your description and other project elements may lead to lower scores. IPI staff may follow up with you prior to judging your application in order to clear up any confusing elements of the application. We strongly encourage you to take that opportunity to clarify and give your project the best possible chance at winning!

Good luck!

INTERNATIONAL PARTNERING INSTITUTE
2018 JOHN. L MARTIN PARTNERED PROJECT OF THE YEAR AWARD

Judges' Criteria	104 points maximum

The Judges Criteria include the following:

1. How Did You Partner This Project? (16 points)
   - Did you use a Professional Neutral Facilitator? For how many sessions? Please specify if you held a kick-off session, interim follow-up sessions and/or a close out lessons learned session, and if these sessions were facilitated.
   - Did the project use Surveys? If so, how many did your team use?
   - How did your team follow up on survey findings? If applicable, include an example of a decision the team made based on survey findings.
   - Did you use a DRA/DRB, FDR, or any other form of ADR to resolve a dispute?
2. Charter and Goals of the Partnership (16 points)
   - What were the team's goals relative to scope, schedule, quality, safety and budget? What project-specific goals did your team set?
   - How were the partnerships goals updated and evaluated throughout the project?

   Please include your Partnering Charter in the appendix (including signature page, core goals, project-specific goals, etc.).This does not count against the 15 page limit.
3. Issue Resolution (17 points)
   - Describe the issues that your team overcame through Partnering.
   - What was your team's issue resolution procedure? Please provide examples.
   - Please estimate the value of the issues resolved (in terms of cost and of schedule).
   - What issues were resolved by the field team closest to the issues?
4. Teamwork (13 points)
   - How did you develop team member relationships? Describe those relationships and how you maintained them.
   - How did you inform, educate and/or engage the public, third parties, or other project stakeholders? Describe those relationships and how you maintained them.
   - Please share specific examples of your partnership added value for the team and the stakeholders, including the end-users?
5. Value/Outcome (29 points)
   - How well did you meet the goals relating to scope, schedule, quality, safety and budget as well as the team's project-specific goals?
   - Did your outcomes exceed expectations in terms of scope, schedule, budget, safety, quality, personal fulfillment, etc.? If so, please provide details.
   - What were your lessons learned and how will you use them to improve future projects?
6. Innovation/Creativity (11 points)
   - What "out of the box," innovative/creative ideas were implemented on this project and/or in your partnering program?
   - Explain any special adaptations or refinements that were made to improve the project partnering process to fit this particular project.

7. Bonus Points (2 points)
    - One bonus point will be assigned if the application is signed by the owner, prime contractor and designer (if they are not an employee of the owner's organization). Digital signatures or ink signatures are acceptable (below). Please include the signatures of principal stakeholders (owner agency, contractor, and CM, designer and facilitator when applicable).
    - One point will be assigned if the Project Team includes IPI Members

Name/Signature	Title	Agency/Organization

Application Form (1 of 4)

Category

Note: See page 3 for eligibility requirements. Partnerships must have utilized a structured Partnering process. There may be multiple awards in each category.

Check only one category below:

Category 1 (Under $25M)
- ☐ Civil Construction
- ☐ Buildings/Public Infrastructure

Category 2 ($25M – $250M)
- ☐ Civil Construction
- ☐ Buildings/Public Infrastructure

Category 3 ($250M and above)
- ☐ Civil Construction
- ☐ Buildings/Public Infrastructure

Project Team IPI Member(s): ____

Applicant Information

Date Application Package Submitted for Consideration: ________________________

Project Name: ____

Project Location: ____

Team Members

(Please identify the Owner of the project, Prime Contractor, Designer, Construction Manager, and Partnering Facilitator)

Owner: ____

Mailing Address: ____

Contact Name and Title: ____

Telephone Number: ____

Email: ____

Application Form (2 of 4)

Prime Contractor: ____

Mailing Address: ____

Contact Name and Title: ____

Telephone Number: ____

Email: ____

Designer: ____

Mailing Address: ____

Contact Name and Title: ____

Telephone Number: ____

Email: ____

Construction Manager (if applicable):______________________________

Mailing Address: ____

Contact Name and Title: ____

Telephone Number: ____

Email: ____

Partnering Facilitator: ____

Mailing Address: ____

Contact Name and Title: ____

Telephone Number: ____

Email: ____

Please list Project Stakeholders (if applicable):
On a separate page, please list Subcontractor(s), Supplier(s), and/or any other Stakeholder Team Members involved in Project Partnering (Name, Title, Organization, Email and phone) on separate page (not considered within the 15 page limit):

Application Form (3 of 4)

Schedule Outcome:

A) Original planned start date ___________

B) Original planned completion date: _________________

C) Planned number of work days: __________

D) Actual start date (Notice to Proceed): _____________________

E) Actual completion date (if vertical, Certificate of Occupancy, if civil, Substantial Completion): _______________________

F) Actual number of work days: _________

Days Ahead or Behind Schedule (F-C): __________________

Please explain any schedule anomalies or considerations:
____
____

Project Budget Outcome:

A) Original Contract (or Guaranteed Maximum Price if applicable) Amount:

____

B) Final Contract Amount: _______________________

C) Project Cost Under or Over Budget A-B): ____________________

D) Cost Increase Associated with Owner Initiated Change Orders: ______________

Please explain any budget amendments or considerations:
____
____

Change Order Outcome:

Estimations are fine. This data provides context to the awards judges, and does not affect scoring.

Number of Change Orders Processed: _____________________

Number of Owner Initiated Change Orders: ____________________

Number of Field Initiated Change Orders: _____________________

Please describe any change order issues encountered and how the partnering process was used to address those issues in question 3 (Issue Resolution).

Claims Outcome:

Number of Claims Accepted: _________________

Number of Unresolved Claims (at close-out, ongoing?): _________________

Please describe any claim issues encountered and how the partnering process was used to address those issues in question 3 (Issue Resolution).

Safety Outcome:

OSHA Recordables: ________________

Lost-Time rate: _________________

Number of Fatalities: _________________

Comments regarding safety issues that occurred in the project:
____
____
____

Personal Fulfillment Outcome (from participant surveys):

Initial Participant Project Satisfaction Level: __________________________

Final Participant Project Satisfaction Level: ___________________________

Please describe how project participants felt about participating in the project and how partnering influenced their feelings about their work in question 5 (Value/Outcome).

Partnering Expense Analysis:

Total Cost of Project Partnering (Facilitator, meeting expenses, and surveys):
____

Final Project Cost: ___________________

Partnering Expense as a % of Project Budget: _________________

Estimated Savings due to Partnering: _________________

Partnering Expense / Saving Expense Ratio (e.g. $1/$40): ___________________

PAYMENT & DEADLINE INFORMATION

Deadline: Entries must be received by February 5, 2018 - before 5:00 p.m. PST. Late entries will not be accepted.

Send application with fee to:
International Partnering Institute
291 McLeod Street,
Livermore, CA 94550

Entry Fee Enclosed: ☐ $500 ☐ Additional Donation $__________

Amounts above the entry fee of $500 are a welcome donation. IPI is a 501(c) 3 non-profit organization. All donations are tax deductible and help fund our operations year-round, bringing Partnering to key stakeholders of the construction industry.

Please make checks payable to: **International Partnering Institute**

Note: Entry fee includes* ***two admissions *to IPI's Awards Ceremony and* ***three Project Trophies or Plaques*** *(Owner, Prime Contractor, and Facilitator). Winners may purchase additional trophies. Please contact IPI for details.*

The Awards Ceremony will be held during IPI's two-day conference – **COLLABORATION 2018**, May 17 – 18, 2018 at the Hilton San Francisco Airport Bayfront in Burlingame, California. Award winning teams may be asked to present on their projects during conference breakout sessions or during the Awards Ceremony.

Project teams will be notified in the first two weeks of April 2018 as to the status of their project. While teams will be notified in writing as to whether or not their project team is a winner, the specific level of each award will be disclosed at the IPI Awards Ceremony.

All submitted materials become the property of the International Partnering Institute's Partnered Project of the Year Award committee and may be used in education, marketing and promotion for the awards program.

APPENDIX B Risk scaling grades and measures in literature

Table 33 Exhibit-A of Risk Analysis Scale (Source: Hannah, Thomas & Swanson, 2013)

Scale	Probability Of Risk Realization	Risk Impact (extent of impact on project objectives if the risk realizes)	Product Score	Risk Rating Scale
1	Very low (< 10% chance)	Negligible and routine procedures sufficient to deal with the consequence (<5% impact)	0 – 5	1
2	Low chance (10% – 35% chance)	Minor and would threaten an element of the function (5–10% impact)	6 – 10	2
3	Medium (35% – 65% chance)	Moderate and would necessitate significant adjustment to the overall function (10–20% impact)	11 – 15	3
4	High (65% - 90% chance)	Significant and would threaten goals and objectives (20–50% impact)	16 – 20	4
5	Very High (> 90% chance)	Extreme and would stop achievement of functional goals and objectives (>50% impact)	20 – 25	5

Table 34 Exhibit-B of Risk Analysis Scale (Adopted from: Baccarini & Archer, 2001)

Risk Factor	Risk Rating Scale				
	5	4	3	2	1
The way the cost targets were established	There is no clear budget or the budget is clearly insufficient	The basis for the current budget is unclear or the budget is likely to be inadequate	The basis for the budget is clear, but indications are that overruns are possible	Benchmarks were used to establish budgets	Benchmarks were used to establish the budget and adequate contingencies exist
The effect if the cost targets are not met	No additional funds available and project will not proceed	No additional funds available and scope reduced	Request for additional funds would be lengthy and embarrassing	Some scope for additional funds	Additional funds available
Uniqueness of the product	Prototype incorporating new techniques	Unusual project (out of the ordinary)	Conventional project	Modifications to an existing design	One of a series of repetitions

Table 35 Exhibit-C of Risk Analysis Scale (Source: Kindinger and Darby, 2000)

Risk Analysis Scale		
Non/Low Risk	Medium Risk	High Risk
Risk factor can be tackled via Known resources and knowledge of the organization	Resources and knowledge need to the adapted to tackle the risk factor	New resources need to be procured or new knowledge needs to be developed to tackle the risk factor

Table 36 Post-EDA Risk Element Grading (Horizontal Projects)

Risk factor scaling grade for horizontal projects						
Risk factors	Risk element(s)	Level 4	Level 3	Level 2	Level 1	Source
Project value	Budget	$250m - $500m+	$10m - $250m	$5m - $10m	$0 - $5m	IPI, 2018
	Duration	18–24+ months	12–18 months	6–12 months	<6 months	IPI, 2018
	Work per day	$100,000 - $200,000+	$50,000 - $100,000	$25,000 - $50,000	$0 - $25,000	EDA observations
Project-based risk	Project approvals	Large number of approvals required; high level of difficulty/stringency expected; may impact project severely	Some approvals required; possible difficulty/stringency expected; provisions in budget and schedule for delay	Minimal number and regular approvals (no difficulty/ stringency expected); no impact on project	No approval required or all have been obtained; no impact on project	Baccarini & Archer, 2001
	Site & environmental conditions	History of differing site conditions; conditions may affect schedule, cost, quality, or safety; moderate to extreme weather conditions	No history of differing site conditions; controllable site conditions; will not affect schedule, cost, quality or safety; basic precautions taken; moderate weather	Favorable site conditions; minimal risk to schedule, cost, quality, or safety;; precautions taken; slight weather delays expected	Favorable; no risk to the schedule, cost, quality or safety; established and known; no history of differing site conditions; no weather conditions expected	Chan D. W., Chan, Lam, Yeung, & Chan, 2011
	Safety, accessibility & on-going operations	Risk of catastrophe/fatality; staging within occupied areas/on-going construction; challenging access issues	Moderate risk; risk of disability; additions to occupied areas/staging adjacent to on-going operations or construction; no access issues	Minor risk of damage; well clear of occupied areas; no access issues	Minor to no risk & greenfield site; no access issues	Baccarini & Archer, 2001
	Construction complexity	Very high; new/innovative methods involved, constructability affected by environment	Moderate; complex operations required	Low; minor challenges expected	Very low; little to no challenge expected	Based on EDA observations

Table 36 (cont'd)

	Design complexity	Design & specs based on incomplete information; risk of omissions	Designer is inexperienced or design team is improper; probability of design errors	Improper/incomplete design scheme communicated by client; experienced and competent designer	Design scheme well communicated by client; experienced and competent designer; proper design reviews completed	Baccarini & Archer, 2001
Sociopolitical risks	Third-party stakeholder & Public Interest	High level of political, community or media sensitivity; high profile client	External stakeholder groups involved; less to no level of sociopolitical sensitivity	Project may attract stakeholder or media interest	Project unlikely to attract stakeholder or media interest	Baccarini & Archer, 2001
Project relationships	Inter-stakeholder relationships	New relationships; history of litigation; joint ventures; less to no time for relationship development	New relationships, some scope for developing relationships	Some previous project experience and neutral to good working relationships & experiences	Lots of previous working experience and relationships developed.	Baccarini & Archer, 2001
Desired Level of Engagement	Cost pressure	Unclear/insufficient budget, budget feasibility not established, lack of clarity regarding financing, strictly no scope for additional funds, little to no contingency	Budget feasibility not established, adequate funds and sources secured but request for additional funds would be lengthy and embarrassing, sufficient contingency	Budget feasibility established, adequate funds and sources secured and some scope for additional funds, sufficient contingency	Budget feasibility established using benchmarks, adequate & sure scope for additional recurrent funds and sources secured, generous contingency	Baccarini & Archer, 2001
	Schedule pressure	The basis for the current schedule is unclear or the schedule is likely to be inadequate	The basis for the schedule is clear, but indications are that overruns are possible	Benchmarks were used to establish schedule	Benchmarks were used to establish the schedule and adequate contingencies exist	Baccarini & Archer, 2001
	Quality pressure	High quality requirements; if unmet could affect cost, schedule, project significantly	Moderate quality requirements; if unmet could affect cost, schedule, project slightly	Quality requirements not specifically mentioned; less to no probability of affecting the project	No mention about importance of quality requirements; will not affect project	Baccarini & Archer, 2001

Table 37 Post-EDA Risk Element Grading (Non-Horizontal Projects)

RISK FACTOR CODING FORM FOR NON-HORIZONTAL (VERTICAL & AVIATION) PROJECTS							
Risk factors	Risk element(s)	Level 5	Level 4	Level 3	Level 2	Level 1	Source
Project value	Budget	$250M - $500M+	$25M - $250M	$10M - $25M	$5M - $10M	$0 - $5M	IPI, 2018
	Duration	>24 months	18–24 months	12–18 months	6–12 months	<6 months	IPI, 2018
	Work per day	>$200,000	$100,000 - $200,000	$50,000 - $100,000	$25,000 - $50,000	$0 - $25,000	based on EDA observations
Project-based risk	Project approvals	Large number of approvals required; High level of difficulty/stringency expected; may impact project severely	Significant number of approvals required; Medium level of difficulty/stringency expected; may impact project significantly	Some approvals required; Possible difficulty/stringency expected; provisions in budget and schedule for delay	Minimal number of approvals required; Regular approvals (zero difficulty/stringency expected); no impact on project	No approval required or all have been obtained; no impact on project	Baccarini & Archer, 2001
	Site & environmental conditions	history of differing site conditions; Site conditions uncontrollable; may affect schedule, cost, quality or safety; Site location prone to acts of God, Extreme weather	history of differing site conditions; Controllable (planned for) site conditions but may affect schedule, cost, quality, or safety; Moderate to extreme weather	No history of differing site conditions; Controllable site conditions; will not affect schedule, cost, quality or safety; basic precautions taken; Moderate weather	Favorable site conditions; minimal risk to schedule, cost, quality, or safety;; precautions taken; Slight weather delays expected	Favorable; no risk to the schedule, cost, quality or safety; Established and known; no history of differing site conditions; no weather conditions expected	Chan D. W., Chan, Lam, Yeung, & Chan, 2011
	Safety, accessibility & on-going operations	Risk of Catastrophe numerous fatalities & Activities in occupied areas/On-going operations; Challenging access issues	Risk of fatality; Staging within occupied areas/On-going construction; Challenging access issues	Moderate Risk; Risk of disability; Additions to occupied areas/Staging adjacent to on-going operations or construction; No access issues	Minor risk of damage; Well clear of occupied areas; No access issues	Minor to no risk & Greenfield site; No access issues	Baccarini & Archer, 2001
	Construction complexity	Very High; Never done before Innovative and risky operations required	High; Never done before but safe operations required	Moderate; Complex operations required	Low; Minor challenges expected	Very Low; Little to no challenge expected	based on EDA observations

Table 37 (cont'd)

	Design complexity	incomplete design and high probability of design change and review; underdeveloped specs	design & specs based on incomplete information; risk of omissions	designer is inexperienced or design team is improper; probability of design errors	improper/incomplete design scheme communicated by client; experienced and competent designer	design scheme well communicated by client; experienced and competent designer; proper design reviews completed	Baccarini & Archer, 2001
Sociopolitical risks	Third-party stakeholder & Public Interest	High level of political, community or media sensitivity	High profile client or project	Stakeholder groups involved	Project may attract stakeholder or media interest	Project unlikely to attract stakeholder or media interest	Baccarini & Archer, 2001
Project relationships	Inter-stakeholder relationships	Client with no experience. New Relationships; History of Litigation; Joint Ventures; Less to No time for relationship development	Mixed experience amongst clients or client's rep; New Relationships, Less to no scope for developing relationships	New Relationships, Some scope for developing relationships	Some previous project experience and neutral to good working relationships & experiences	Lots of previous working experience and relationships developed.	Baccarini & Archer, 2001
Desired Level of Engagement	Cost pressure	No clear budget, budget seems insufficient, budget feasibility not established, inadequate funds or sources not secured, less to no contingency	Budget feasibility not established, adequate funds and sources identified but financing not secured, strictly no scope for additional funds, little to no contingency	Budget feasibility not established, adequate funds and sources secured but request for additional funds would be lengthy and embarrassing, sufficient contingency	Budget feasibility established, adequate funds and sources secured and some scope for additional funds, sufficient contingency	Budget feasibility established using benchmarks, adequate & sure scope for additional recurrent funds and sources secured, generous contingency	Baccarini & Archer, 2001
	Schedule pressure	There is no clear schedule or the schedule is clearly insufficient	The basis for the current schedule is unclear or the schedule is likely to be inadequate	The basis for the schedule is clear, but indications are that overruns are possible	Benchmarks were used to establish schedule	Benchmarks were used to establish the schedule and adequate contingencies exist	Baccarini & Archer, 2001
	Quality pressure	High Quality requirements; if unmet could affect cost, schedule, project significantly	Moderate Quality requirements; if unmet could affect cost, schedule, project slightly	Quality requirements not specifically mentioned; less to no probability of affecting the project	Quality requirements not specifically mentioned; will not affect project	No mention about importance of quality requirements; will not affect project	Baccarini & Archer, 2001

APPENDIX C Survey consent form

Research Participant Information and Consent Form

1. EXPLANATION OF THE RESEARCH and WHAT YOU WILL DO:

The purpose of this research is to investigate if and how the alignment between risk level and intensity of collaboration (or 'partnering intensity') of an Architecture-Engineering-Construction (AEC) project impacts its performance. The units of analysis are partnered AEC project applications submitted to the International Partnering Institute (IPI) for the annual Partnered Project of the Year (PPY) Awards from 2010 – 2018. Based on the risk level and partnering intensity assigned to each project by the researcher using a combination of content analysis and this survey, the following hypothesis will be quantitatively tested: 'better the alignment between project risk level and level of collaborative practices (or partnering intensity) in a partnered project, better are the project performance outcomes'

- You are being asked to indicate the project risk level and partnering intensity of the A-E-C project you were a part of
- You might be requested for a follow-up phone conversation if major discrepancy is found in the levels assigned by you and as identified by the researcher

The researcher will collect the responses of this survey to verify and assign a final risk level and partnering intensity for further quantitative analysis.

- You must be at least 18 years old to participate in this research.

2. YOUR RIGHTS TO PARTICIPATE, SAY NO, OR WITHDRAW:

- Participation in this research project is completely voluntary.
- You have the right to say no. You may change your mind at any time and withdraw.
- You may choose not to answer specific questions or to stop participating at any time.

4. CONTACT INFORMATION FOR QUESTIONS AND CONCERNS:

If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher:

Name : Harshavardhan Kalbhor
Designation : Graduate Research Assistant, MS Constr. Mgmt., Michigan State University
Mailing Address : 16789 Chandler Rd., Apt. #1614-D, East Lansing, MI 48823
E-mail Address : kalbhorh@msu.edu
Phone : +1-(517)-897-8680

5. DOCUMENTATION OF INFORMED CONSENT.

You indicate your voluntary agreement to participate by completing and returning this survey.

V17-02 (12-3-2017)

APPENDIX D Survey e-mail and design

Survey E-Mail:

Dear (survey respondent),

My name is H. (Harsh) Kalbhor, and I am a researcher with Dr. Sinem Mollaoglu at Michigan State University on an IPI-funded research project.

Our data shows that you were the Partnering Facilitator on one or more projects submitted as applicants for the Partnered Project of the Year Awards between 2010 and 2018, held annually by IPI.

For our current research examining the relation between a project's risk level, partnering intensity and performance outcomes, we request your participation in a short survey. Please find attached the following to this e-mail:

- Research Participant Information and Consent Form for your review
- Survey File – Please fill out the 10-minute survey and attach it back in a reply to this e-mail (to kalbhorh@msu.edu)

Your response is highly valued and would greatly benefit our study.

With best regards and thanks,

H. (Harsh) Kalbhor

Thank you for taking the time to take our survey!

For this survey, we have identified projects that you were the Partnering Facilitator on which were submitted as applicants for International Partnering Institute's annual Partnered Project of the Year Awards between 2010 and 2018.

For each of these projects, we request you to:

STEP 1. Verify our classification of the project into one of the following categories:

a. Horizontal
b. Vertical
c. Aviation

(If you feel that the project is wrongly classified, please mention so in the Comments section of that project)

STEP 2. Based on the above classification category, refer to the appropriate IPI's Scalability Matrix in Appendix A of this survey

STEP 3. Based on the Matrix, assign to each project its:

a. Overall Project Risk Level (on a scale of 1 to 5); and
b. Overall Partnering Intensity Level (on a scale of 1 to 5)

STEP 4. Save this file with your entries

STEP 5. Please send this file as an attachment to: kalbhorh@msu.edu

Name of Project	Year	Location (State)	Owner	Type of Project = Type of IPI Scalability Matrix to be used (see Appendix A)	Overall Project Risk Level *based on the relevant IPI matrix (on a scale of 1 – 5)	Adopted Partnering Intensity *based on the relevant IPI matrix (on a scale of 1 – 5)	Comments
					Level 1	Level 1	

REFERENCES

REFERENCES

Abedi, M., Fathi, M., & Rawai, N. M. (2012). Cloud Computing Technology for Collaborative Information System in Construction Industry. 18th International Business Information Management Association (IBIMA). Istanbul, Turkey.

AIA California Council. (2007). A Working Definition - Integrated Project Delivery. Sacramento: AIA California Council.

Al-Bahar, J. F., & Crandall, K. C. (1990). Systematic Risk Management Approach for Construction Projects. Journal of Construction Engineering and Management, 116(3), 533-546. Retrieved October 22, 2018, from https://ascelibrary.org/doi/abs/10.1061/%28ASCE%290733-364%281990%29116%3A3%28533%29

Anderson, D. K., & Merna, T. (2003). Project Management Strategy—project management represented as a process based set of management domains and the consequences for project management strategy. International Journal of Project Management, 21(5), 387-393. Retrieved 11 11, 2018, from https://ac.els-cdn.com/S026378630200087X/1-s2.0-S026378630200087X-main.pdf?_tid=1b260025-2bbb-42c1-ad9f-07de4dd4163e&acdnat=1541953168_5593fb20ca9d7f854caec86d9d19d6b6

Asmar, M., Hanna, A., & Loh, W.-Y. (2016). Evaluating Integrated Project Delivery Using the Project Quarterback Rating. Journal of Construction Engineering and Management, 142(1). Retrieved November 30, 2018, from https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%29CO.1943-7862.0001015

Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. Leadership and Management in Engineering, 11(3), 241-252. Retrieved 11 18, 2018, from https://ascelibrary.org/doi/10.1061/%28ASCE%29LM.1943-5630.0000127

Azmy, N. (2012). The Role of Team Effectiveness in Construction Project Teams and Project Performance. Ames, Iowa: Iowa State University. Retrieved November 29, 2018, from https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=3272&context=etd

Baccarini , D. (1996). The concept of project complexity - a review. International Journal of Project Managemen, 14(4), 201-204. Retrieved 11 11, 2018, from http://ieg.ifs.tuwien.ac.at/~aigner/projects/planninglines/evaluation/Project_Management/papers/baccarini96complexity.pdf

Baccarini, D., & Archer, R. (2001). The risk ranking of projects: a methodology. International Journal of Project Management, 19(3), 139 - 145. Retrieved 11 12, 2018, from https://www.sciencedirect.com/science/article/pii/S0263786399000745#TBL1

Ballard, G., Kim, Y.-W., Jang, J.-W., & Liu, M. (2007). Roadmap for Lean Implementation at the Project Level. Austin: Construction Industry Institute. Retrieved December 2, 2018, from https://www.researchgate.net/profile/Glenn_Ballard/publication/232322523_Roadmap_for_Lean_Implementation_at_the_Project_Level/links/00b7d52011d137218e000000/Roadmap-for-Lean-Implementation-at-the-Project-Level.pdf

Ballard, G., Tommelein, I., Koskela, L., & Howell, G. (2002). Lean construction tools and techniques. In R. Best, & G. Valence, Design and Construction: Building in Value (pp. 227-255). Oxford: Butterworth-Heinemann.

California Department of Transportation. (2019, January 05). Partnering with Caltrans. Retrieved from Caltrans Division of Construction: http://www.dot.ca.gov/hq/construc/partnering/documents/Field_Guide_to_Partnering_on_Caltrans_Construction_Projects_final.pdf

Chan, A. P., Chan, D. W., Chiang, Y. H., Tang, B. S., Chan, E. H., & Ho, K. S. (2004). Exploring Critical Success Factors for Partnering in Construction Projects. Journal of Construction Engineering and Management, 130(2), 188-198. Retrieved December 4, 2018, from https://ascelibrary.org/doi/10.1061/%28ASCE%290733-9364%282004%29130%3A2%28188%29

Chan, A. P., Ho, D. C., & Tam, C. M. (2001). Effect of Interorganizational Teamwork on Project Outcome. Journal of Management in Engineering, 17(1), 34-40. Retrieved November 11, 2018, from https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%290742-597X%282001%2917%3A1%2834%29

Chan, D. W., Chan, A. P., Lam, P. T., Yeung, J. F., & Chan, J. H. (2011). Risk ranking and analysis in target cost contracts: Empirical evidence from the construction industry. International Journal of Project Management, 29(6), 751 - 763. Retrieved 11 12, 2018, from https://www.sciencedirect.com/science/article/pii/S0263786310001201?openDownloadIssueModal=true

Chapman, R. J. (2001). The controlling in¯uences on e�ective risk identi®cation and assessment for construction design management. International Journal of Project Management, 19(3), 147-160. Retrieved 10 29, 2018, from https://ac.els-cdn.com/S0263786399000708/1-s2.0-S0263786399000708-main.pdf?_tid=6d32c5df-dd53-40ab-9474-0f909f5117c7&acdnat=1540819386_84c28a6fd5ebce8a85a852d76c2683d2

Chapman, R. J. (2001). The controlling influences on effective risk identification and assessment for construction design management. International Journal of Project Management, 19(3), 147-160. Retrieved November 25, 2018, from https://www.sciencedirect.com/science/article/pii/S0263786399000708

Chen, C., & Hubbard, M. (2012). Power relations and risk allocation in the governance of public private partnerships: A case study from China. Policy and Society, 31(1), 39-49. Retrieved 10 28, 2018, from https://www.tandfonline.com/doi/full/10.1016/j.polsoc.2012.01.003?scroll=top&needAccess=true

Cheng, E. W., & Li, H. (2001). Development of a conceptual model of construction partnering. Engineering, Construction and Architectural Management, 8(4), 292-303. Retrieved December 3, 2018, from https://doi.org/10.1108/eb021190

Cheng, E. W., & Li, H. (2002). Construction Partnering Process and Associated Critical Success Factors: Quantitative Investigation. Journal of Management in Engineering, 18(4), 194-202. Retrieved Decemeber 4, 2018, from https://ascelibrary.org/doi/abs/10.1061/(ASCE)0742-597X(2002)18:4(194)

CII. (1989). Partnering RT-018 (Archive). Retrieved from Construction Industry Institute: Knowledge Base: https://www.construction-institute.org/resources/knowledgebase/best-practices/partnering/topics/rt-018

CII. (1996). Model for Partnering Excellence. Construction Industry Institute.
Construction Industry Board. (1997). Partnering in the Team: A Report by Working Group 12 of the Construction Industry Board (CIB Reports). London: Thomas Telford Ltd.

Cook, E., & Hancher, D. (1990). Partnering: Contracting for the future. Journal of Management in Engineering, 6(4), 431-446. Retrieved November 25, 2018, from https://ascelibrary.org/doi/pdf/10.1061/(ASCE)9742-597X(1990)6%3A4(431)

Crowley, L. G., & Karim, M. A. (1995). Conceptual Model of Partnering. Journal of Management in Engineering, 11(5), 33-39. Retrieved December 3, 2018, from https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%290742-597X%281995%2911%3A5%2833%29

Das, T. K., & Teng, B.-S. (2001). A risk perception model of alliance structuring. Journal of International Management, 7(1), 1-29. Retrieved October 29, 2018, from https://pdfs.semanticscholar.org/5033/dbc8f302739444dccee0bdb73a7107231d77.pdf

Dossick, C., & Neff, G. (2011). Messy talk and clean technology: communication, problem-solving and collaboration using Building Information Modelling. The Engineering Project Organization Journal, 83-93. Retrieved November 19, 2018, from http://www.com.washington.edu/faculty/assets/neff_messy_talk.pd

Fang, C., & Marle, F. (2012). A simulation-based risk network model for decision support in project risk management. Decision Support Systems, 52(3), 635-644. Retrieved 11 11, 2018, from https://ac.els-cdn.com/S0167923611002016/1-s2.0-S0167923611002016-main.pdf?_tid=c40649e1-11a6-4496-ad44-935cc19ae7b1&acdnat=1541956447_049fb7873815644b4c7a7eaf8c1cb543

Fellows, R., & Liu, A. (2008). Research Methods for Construction (Third Edition ed.). Oxford, United Kingdom: Wiley-Blackwell. Retrieved January 8, 2019

Flick, U., Kardorff, E. v., & Steinke, I. (2010). A Companion to Qualitative Research. London: SAGE.
Forbes, L., & Ahmed, S. (2011). Lean Based Project Delivery Methods. In Modern Construction: Lean Project Delivery and Integrated Practices (pp. 167-201). Boca Raton, Florida: CRC Press.

Golparvar-Fard, M., Peña-Mora, F., & Savarese, S. (2009). Application of D4AR - A 4-Dimensional augmented reality model for automating construction progress monitoring data collection, processing and communication. Journal of Information Technology in Construction, 14(Special issue Next Generation Construction IT: Technology Foresight, Future Studies, Roadmapping, and Scenario Planning), 129-153. Retrieved December 2, 2018, from http://www.itcon.org/2009/13

Gransberg, D. D., Dillon, W. D., Reynolds, L., & Boyd, J. (1999). Quantitative Analysis of Partnered Project Performance. J. Constr. Eng. Manage., 125(3), 161-166.

Gransberg, D., Shane, J., & Schierholz, J. (2013). NCHRP Proejct 10-85: A Guidebook for Construction Manager-at-Risk Contracting for Higwhay Projects. Washington: Transportation Research Board.

Gratt. (1989). The Definition of Risk and Associated Terminology for Risk Analysis. In J. J. Bonin, & D. E. Stevenson, Risk Assessment in Setting National Priorities. Advances in Risk Analysis (Vol. 7). Boston, MA: Springer. Retrieved October 22, 2018, from https://link.springer.com/chapter/10.1007/978-1-4684-5682-0_73

Gratt, L. B. (1987). Risk Analysis or Risk Assessment; A Proposal for Consistent Definitions. In L. L. Covello V.T., Uncertainty in Risk Assessment, Risk Management, and Decision Making. Advances in Risk Analysis (Vol. 4). Boston, MA: Springer. Retrieved October 22, 2018, from https://link.springer.com/chapter/10.1007/978-1-4684-5317-1_20

Hammad, A., Wang, H., & Mudur, S. (2009). Distributed Augmented Reality for Visualizing Collaborative Construction Tasks. Journal of Computing in Civil Engineering, 23(6), 418-427.

Hanna, A. S., Thomas, G., & Swanson, J. R. (2013). Construction Risk Identification and Allocation: Cooperative Approach. Journal of Construction Engineering and Management, 139(9), 1098-1107. Retrieved October 22, 2018, from https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29CO.1943-7862.0000703

International Partnering Institute. (2018, November). Owner's Toolbox. Retrieved 11 11, 2018, from International Partnering Institute: https://partneringinstitute.org/owners-toolbox/

International Partnering Institute. (2018). What is Construction Partnering? Retrieved from International Partnering Institute: https://partneringinstitute.org/about/what-is-construction-partnering/
International Partnering Institute. (n.d.). IPI Owner's Toolbox. Retrieved from https://partneringinstitute.org/owners-toolbox/#toggle-id-4-closed

Kindinger, J., & Darby, J. L. (2000). Risk factor analysis—a new qualitative risk management tool. Project Management Institute Annual Seminars & Symposium. Houston, TX. Newtown Square, PA: Project Management Institute.

Koch, J. E., Gransberg, D. D., & Molenaar, K. R. (2010). Chapter 7: Design-Build Change Orders. In Project Administration for Design-Build Contracts: A Primer for Owners, Engineers, and Contractors (pp. 191-217). Reston, Virginia: American Society of Civil Engineers. Retrieved November 30, 2018

Koskela, L., Howell, G., Ballard, G., & Tommelein, I. (2002). The foundations of lean construction. In R. Best, & G. Valence, Design and Construction: Building in Value (pp. 211-225). Oxford, UK: Butterworth Heinemann. Retrieved December 2, 2018, from file:///C:/Users/SPDC/Desktop/OneDrive%20-%20Michigan%20State%20University/IPI%20Research%20Project/Literature/Koskela_Ch.14_Lean%20Construction.pdf

Kruskal, W. H., & Wallis, W. A. (1952). Use of Ranks in One-Criterion Variance Analysis. Journal of the American Statistical Association, 47(260), 583-621.

Lehtiranta, L. (2011). Relational Risk Management in Construction Projects: Modeling the Complexity. Leadership and Management in Engineering, 11(2), 141-154. Retrieved October 29, 2018, from https://ascelibrary.org/doi/10.1061/%28ASCE%29LM.1943-5630.0000114

Leung, M.-Y., Ng, T., & Cheung, S.-O. (2004). Measuring construction project participant satisfaction. Construction Management and Economics, 22(3), 319–331.

Lu, Y., Li, Y., Skibniewski, M., Wu, Z., Wang, R., & Le, Y. (2015). Information and Communication Technology Applications in Architecture, Engineering, and Construction Organizations: A 15-Year Review. Journal of Management in Engineering, 31(1). Retrieved December 2, 2018, from https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%29ME.1943-5479.0000319

Luo, L., He, Q., Xie, J., Yang, D., & Wu, G. (2017). Investigating the Relationship between Project Complexity and Success in Complex Construction Projects. Journal of Management in Engineering, 33(2). Retrieved October 27, 2018, from https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29ME.1943-5479.0000471

Matthews, O., & Howell, G. (2005, April). Integrated Proejct Delivery An Example of Relational Contracting. Lean Construction Journal, 2(1), pp. 46-61. Retrieved November 30, 2018, from http://www.leanconstruction.org/media/docs/lcj/LCJ_05_003.pdf

Miller, R., & Lessard, D. (2001). The Strategic Management of Large Engineering Projects. Cambridge, Massachusetts.: The MIT Press. Retrieved 11 19, 2018, from http://faculty.london.edu/icooper/assets/documents/StrategicManagement.pdf

Molenaar, K., Harper, C., & Yugar-Arias, I. (2014). Guidebook for Selecting Alternative Contracting Methodsfor Roadway Projects: Project Delivery Methods, Procurement Procedures, and Payment Provisions. Boulder: University of Colorado.

Motulsky, H. (1995). Ch. 45 Statistical Traps to Avoid. In Intuitive Biostatistics: A Nonmathematical Guide to Statistical Thinking (pp. 424 - 441). London: Oxford University Press Inc.

National Academies of Sciences, Engineering, and Medicine. (2019). Guidebook for Integrating Collaborative Partnering into Traditional Airport Practices. Washington, DC: The National Academies Press.

National Research Council. (2012). Ch. 5 Model Validation and Prediction. In Assessing the Reliability of Complex Models: Mathematical and Statistical Foundations of Verification, Validation, and Uncertainty Quantification (pp. 52 - 83). Washington, D.C.: The National Academies Press. Retrieved from https://doi.org/10.17226/13395

O'Leary, Z. (2018). Steps in Quantitative Analysis. Retrieved June 8, 2019, from Sage Publishing: https://study.sagepub.com/oleary3e/student-resources/analysing-data/steps-in-quantitative-analysis

Project Management Institute (PMI). (2007). Construction Extension to the PMBOK® Guide. Newton Square, PA: Project Management Institute, Inc.

Project Management Institute. (2009). Practice Standard for Project Risk Management. Newtown Square: Project Management Institute, Inc.

Rahman, M. M., & Kumaraswamy, M. M. (2004). Potential for Implementing Relational Contracting and Joint Risk Management. Journal of Management in Engineering, 20(4). Retrieved 10 29, 2018, from https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%290742-597X%282004%2920%3A4%28178%29

Rahman, S. A., Endut, I. R., Faisol, N., & Paydar, S. (2014). The Importance of Collaboration in Construction Industry from Contractors' Perspectives. International Conference on Innovation, Management and Technology Research. 125, pp. 414-421. Malaysia: Procedia - Social and Behavioral Sciences. Retrieved from https://ac.els-cdn.com/S1877042814028778/1-s2.0-S1877042814028778-main.pdf?_tid=828abb04-270e-46a2-8b9b-90b448f22b8a&acdnat=1543778862_5901db1fa77b6d82ce261dbe7d4cf441

Smith, N. J., Merna, T., & Jobling, P. (2014). Managing Risk in Construction Projects (3rd ed.). Hoboken, NJ: John Wiley & Sons, Ltd. Retrieved 11 17, 2018, from https://media.wiley.com/product_data/excerpt/34/11183472/1118347234-4.pdf

Sparkling, A. (2014). A Research Synthesis Of Key Partnering Drivers And Performance Outcomes In Architecture, Engineering, And Construction Research. Michigan State University, Construction Management. East Lansing: Michigan State University.

Sullivan, J., Asmar, M. E., Chalhoub, J., & Obeid, H. (2017). Two Decades of Performance Comparisons for Design-Build, Construction Manager at Risk, and Design-Bid-Build: Quantitative Analysis of the State of Knowledge on Project Cost, Schedule, and Quality. J. Constr. Eng. Manage., 143(6).

Sweet, J., & Schneier, M. (2009). Combining Designing and Building. In Legal Aspects of Architecture, Engineering and Construction Process (pp. 365-369). Stamford, CT: Cengage Learning.

Syal, M. (2017). Introduction and Overview. In M. Syal, Construction Project Management (p. 5).

Tah, J. H., & Carr, V. (2000). A proposal for construction project risk assessment using fuzzy logic. Construction Management and Economics, 18(4), 491-500. doi:10.1080/014461900050024905

Tchankova, L. (2002). Risk identification – basic stage in risk management. Environmental Management and Health, 13(3), 290-297. Retrieved October 22, 2018, from https://www.emeraldinsight.com/doi/pdfplus/10.1108/09566160210431088

Tchankova, L. (2002). Risk identification – basic stage in risk management. Environmental Management and Health, 13(3), 290-297.

Tchankova, L. (2002). Risk identification - basic stage in risk mangement. Environmental Management and Health, 13(3), 290-297. Retrieved November 25, 2018, from https://www.emeraldinsight.com/doi/pdfplus/10.1108/09566160210431088

Vidal, L.-A., & Marle, F. (2008). Understanding project complexity: implications on project management. Kybernetes, 37(8), 1094-1110. Retrieved 11 11, 2018, from https://www.emeraldinsight.com/doi/pdfplus/10.1108/03684920810884928

Wang, L. (2008). Enhancing construction quality inspection and management using RFID technology. Automation in Construction, 17(4), 467-479.

Wang, S., Dulaimi, M. F., & Aguria, M. Y. (2004). Risk management framework for construction projects in developing countries. Construction Management and Economics, 22(3), 237 - 352. Retrieved 10 29, 2018, from https://www.tandfonline.com/doi/pdf/10.1080/0144619032000124689?needAccess=true

Weidong, X., & Lee, G. (2005). Complexity of Information Systems Development Projects: Conceptualization and Measurement Development. Journal of Management Information Systems, 22(1), 45-83. Retrieved 11 11, 2018, from https://www.jstor.org/stable/pdf/40398758.pdf?refreqid=excelsior%3A8f1aa6afc63608432bf1d4563e2292c4

Whitty, S. J., & Maylor, H. (2009). And then came Complex Project Management (revised). International Journal of Project Management, 27(3), 304-310. Retrieved 11 11, 2018, from https://ac.els-cdn.com/S0263786308000410/1-s2.0-S0263786308000410-main.pdf?_tid=52e8e450-531b-4002-a770-10624b2fc401&acdnat=1541954256_b750c8e648af43cafe7bc092d704a309

Yates, J. K. (1995). Use of Design/Build in E/C Industry. Journal of Management in Engineering, 33-38. Retrieved November 30, 2018, from https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%290742-597X%281995%2911%3A6%2833%29

Zavadskas, E. K., Turskis, Z., & Tamošaitiene, J. (2010). Risk assessment of construction projects. Journal of Civil Engineering and Management, 16(1), 33-46. Retrieved 10 28, 2018, from https://www.tandfonline.com/doi/pdf/10.3846/jcem.2010.03?needAccess=true

Zhang, S., Zhang, S., Gao, Y., & Ding, X. (2016). Contractual Governance: Effects of Risk Allocation on Contractors' Cooperative Behavior in Construction Projects. Journal of Construction Engineering and Management, 165(8), 854-863. Retrieved 10 28, 2018, from https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%29CO.1943-7862.0000175

Zhang, X., & Liu, Y. (2007). The Impact of ICT on Supplier-Buyer Relationship in Different Types of Supply Chain. International Conference on Wireless Communications, Networking and Mobile Computing, (pp. 4694-4697). Shanghai.

Zou, Y., Kiviniemi, A., & Jones, S. (2017). A review of risk management through BIM and BIM-related technologies. Safety Science, 97, 88-98. Retrieved 11 18, 2018, from https://www.sciencedirect.com/science/article/pii/S0925753516000072?via%3Dihub

Zou, Y., Kiviniemi, A., & Jones, S. W. (2015). BIM-based Risk Management: Challenges and Opportunities. Proc. of the 32nd CIB W78 Conference 2015, (pp. 847-855). Eindhoven. Retrieved 11 19, 2018, from https://livrepository.liverpool.ac.uk/3001636/