ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

AN INVESTIGATION INTO THE CURRENT STATUS OF ADOPTION OF IPD CHARACTERISTICS AND BIM IN CONSTRUCTION PROJECTS TO OVERCOME PROCESS AND TEAM-RELATED PROBLEMS

M.Sc. THESIS

Hakan Taha ÇETİN

Department of Architecture

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

GÜNCEL İNŞAAT UYGULAMALARINDA SÜREÇ VE TAKIM İLE İLGİLİ PROBLEMLERİ GİDERMEYE YÖNELİK IPD ÖZELLİKLERİ VE BIM'İN BENİMSENMESİ ÜZERİNE BİR ARAŞTIRMA

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Hakan Taha Çetin, a M.Sc. student of İTU Graduate School student ID 502171410, successfully defended the thesis/dissertation entitled "AN INVESTIGATION INTO THE CURRENT STATUS OF ADOPTION OF IPD CHARACTERISTICS AND BIM IN CONSTRUCTION PROJECTS TO OVERCOME PROCESS AND TEAM-RELATED PROBLEMS", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 14 January 2022
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To my mother,

FOREWORD

I would like to express my sincere gratitude and respect to my supervisor, Prof. Dr. Begüm SERTYEŞİLIŞIK, for her precious guidance all through the process with her knowledge and experience. Furthermore, I would like to thank the professionals and academics who spare their valuable time and participated in the research methods.

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January 2022

Hakan Taha ÇETİN
(Architect)

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ABBREVIATIONS

BIM	: Building Information Modeling
PDS	: Project Delivery System
CI	: Construction Industry
CSF	: Critical Success Factor
IPD	: Integrated Project Delivery
SD	: Standard deviation
BEP	: BIM Execution Plan
GDP	: Gross Domestic Product
US	: The United States
DBB	: Design-Bid-Build
PP	: Project Partnering
CMAR	: Construction Manager at Risk
PA	: Project Alliancing
DB	: Design-Build

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AN INVESTIGATION INTO THE ADOPTION OF IPD CHARACTERISTICS AND BIM IN CURRENT CONSTRUCTION PROJECTS TO OVERCOME PROCESS AND TEAM-RELATED PROBLEMS

SUMMARY

Unless project teams are efficient, construction projects can encounter many problems and obstacles in the process. Project delivery systems (PDS) determine the relationships of project stakeholders and their engagement time. Traditional PDS in the construction industry (CI) are well-known with their adverse effects on the process and the team, which have become the chronic problems of the industry due to excessive use of traditional contracts. Many reasons especially technological advancements like BIM (Building Information Modeling), and demand for more reliable PDSs have led CI professionals to search for alternative and effective ways to collaborate. AIA (the American Institute of Architects) introduced the IPD (Integrated Project Delivery) to respond to the demand and need in the CI. IPD can contribute the CI by eliminating/minimizing the obstacles that prevent team integration. IPD principles have taken their place in the current practices of construction projects, with the effect of same motivations that led to the emergence of the IPD in the first place.

Projects are fundamental elements for organizations to cope with competitive market conditions. Various systems, like CSFs (Critical Success Factors), have been developed to evaluate and estimate the projects' outputs appropriately. Although various CSF lists have been prepared in construction projects, the lists prepared for traditional PDSs are not compatible with the IPD because of the different characteristics of the IPD. An IPD-specific CSF list covering the BIM and IPD team aspects is needed to reveal the level of importance of the factors on achieving project success.

This dissertation aims to investigate the adoption status of IPD principles in current construction projects, examine the impact of these principles on the process and team-related problems frequently encountered by the industry, and prepare the CSFs preliminary list for IPD projects. With this aim, the following objectives have been adressed: to determine the process and team related problems of the CI and examine their occurrence in construction projects; to determine the adoption of the IPD, BIM and IPD team characteristics in construction projects; and to determine the adoption of the IPD, BIM and IPD team characteristics in construction projects, respectively.

With the in-depth literature review, team and process-related problems and characteristics related to IPD, BIM, and IPD teams have been examined. In line with the first two objectives, online questionnaire surveys and interviews have been conducted with IPD and BIM experts and/or academics having publications on related subjects. Furthermore, for the accomplishment of the objectives 3, 4 and 5, the 4-round and 3 group Delphi method has been performed under 3 different category as IPD, BIM, and IPD team-related factors with IPD and BIM experts and/or academics having publications on the related topic.

The data obtained from the online questionnaire survey, interviews and the delphi method have been evaluated in 4 different categories based on the objectives of the research.

First of all, the findings revealed that the frequency of encountering team-related problems is less frequent than process-related problems. There is strong correlation between ineffective teams and other problems. Furthermore, according to the online questionnaire survey and interviews results, it has been revealed that the adoption status of BIM-related characteristics is high, and BIM is an essential driver for the adoption and implementation of IPD.

The CSFs preliminary list has been further developed based on the findings of the 4 round and 3 group delphi surveys covering the aspects of IPD, BIM, and IPD teams. The prepared list has revealed the collaboration-related characteristics of IPD, administrative issues and organizational needs for BIM implementation, and team environment among the main CSFs.

The CSFs preliminary list includes the factors that can be taken into account in the adoption and implementation of IPD and BIM projects. The complete application of these factors does not mean that project success can be achieved. Although these CSFs preliminary list may contribute to the process, they cannot influence the projects' output alone as each project consists of several sources and interconnected activities that have varying levels of impact on success. Project dynamics are constantly changing with the effect of new systems. Various additions, corrections, and/or removals can be made to the list over time, taking into account the changing conditions and the needs of projects.

These CSFs preliminary list can be used as a preliminary checklist for the stakeholders who plan to adopt the IPD and BIM, and for academics and researchers in the relevant field.

GÜNCEL İNŞAAT UYGULAMALARINDA SÜREÇ VE TAKIM İLE İLGİLİ PROBLEMLERİ GİDERMEYE YÖNELİK IPD ÖZELLİKLERİ VE BIM'İN BENİMSENMESİ ÜZERİNE BİR ARAŞTIRMA

ÖZET

Proje ekipleri verimli olmadıklarında, inşaat projeleri süreçte birçok problem ve engelle karşılaşabilir. Proje teslim sistemleri paydaşların proje süreci boyunca ilişkilerini ve projeye dahil olma zamanlarını belirleyen sistemlerdir. Geleneksel proje teslim sistemleri inşaat sektöründe sürece ve takıma olan ters etkileri ile bilinmektedir. Proje surecinde ve paydaş ilişkilerinde bütünsel bir değişim gerçekleşmedikçe inşaat projelerindeki süreç ve takımla ilgili problemler sektörün kronik problemleri haline gelmiştir. Yapı Bilgi Modellemesi (YBM) gibi teknolojik ilerlemeler ve daha güvenilir proje teslim sistemlerine olan talep inşaat sektörü profesyonellerinin alternatif ve etkin iş birliği arayışlarını ortaya çıkarmıştır. Amerikan Mimarlar Enstitüsü (AIA) tarafından Entegre Proje Yönetimi (EPY) inşaat sektörünün talep ve ihtiyacına cevap verebilmek için ortaya çıkmıştır. EPY inşaat sektöründe takım entegrasyonunu engelleyen/azaltan engelleri önlemeye katkı sağlayabilir.

Organizasyonların rekabetçi piyasa şartlarıyla başa çıkabilmelerinde projelerin önemi büyüktür. Zaman içinde projelerin çıktılarını değerlendirmek ve proje başarısının ölçülebilmesi için Kritik Başarı Faktörleri (KBF) sistemi gibi çeşitli sistemler geliştirilmiştir.

İnşaat projelerinde çeşitli KBF listeleri hazırlanmış olsa da geleneksel teslim sistemleri baz alınarak geliştirilen listeler EPY'nin yenilikçi özellikleri göz önüne alındığında EPY ile uyumlu değildir. EPY projelerinde faktörlerin proje başarısı üzerindeki etkisini değerlendirebilmek için EPY'ye özel bir KBF listesine ihtiyaç vardır.

Bu çalışma EPY ilkelerinin güncel inşaat projelerinde benimsenme durumunu, bu ilkelerin sektörün sıklıkla karşılaştığı süreç ve takımla ilgili problemler üzerindeki etkisini incelemeyi ve EPY projelerine yönelik bir KBF ön listesi hazırlamayı hedeflemektedir. Bu amaç doğrultusunda belirlenen hedefler şunlardır: inşaat projelerinde sıklıkla karşılaşılan takım ve süreçle ilgili problemlerin ve bu problemler ile güncel inşaat uygulamalarında karşılaşılma durumunun belirlenmesi; güncel inşaat uygulamalarında EPY, YBM ve EPY takımı ile ilgili karakteristiklerin benimsenme durumunun belirlenmesi; ve sırasıyla EPY, YBM ve EPY takımı ile ilgili faktörlerin proje başarısının elde edilmesi üzerindeki öneminin belirlenmesidir.

Yapılan derinlemesine literatür taraması ile takım ve süreçle ilgili problemleri ve EPY, YBM ve EPY takımı ile ilgili karakteristikleri içeren listeler oluşturulmuştur. Hazırlanan bu listeler ilk iki hedef doğrultusunda EPY ve YBM uzmanları ve/veya bu konuda yayınları olan akademisyenler ile çevrimiçi anket ve mülakat çalışmaları

yapılmıştır. Diğer hedefler doğrultusunda EPY ve YBM uzmanları ve/veya bu konuda yayınları olan akademisyenler ile 4 turluk 3 grupta delphi yöntemi çalışmaları yürütülmüştür.

Derinlemesine literatür taraması, çevrimiçi anket ve mülakat çalışmaları ile delphi metodundan elde edilen veriler çalışmanın hedefleri doğrultusunda 4 farklı kategoride değerlendirilmiştir.

İlk olarak, EPY, YBM ve EPY takımı ile ilgili karakteristiklerin benimsenmesi ile problemler üzerinde doğrudan bir ilişki bulunamamış olsa da takımla ilgili problemlerle karşılaşılma sıklığının süreçle ilgili problemlerden daha seyrek olduğu ortaya çıkmıştır. Anket bulguları sonucunda sözleşmesel EPY özelliklerinin iş birliği ile ilgili prensiplere göre daha sınırlı uygulandığı ortaya çıkmıştır. Takımlar entegre bir şekilde çalışmaya teşvik edilse de gerekli sözleşmesel ortam sağlanmadıkça entegrasyon seviyesi ve entegrasyonun süreç üzerindeki etkisi sınırlı kalacaktır. Ayrıca efektif olmayan takımlar ile diğer problemler arasında güçlü bir ilişki ortaya çıkmıştır. Takım entegrasyonunu arttırarak proje ekiplerini daha verimli hale getirmeyi hedefleyen EPY'nin yaygın kullanımı yaygın problemlerin etkisini azaltacaktır. Bunun yanı sıra, anket ve mülakat sonuçları doğrultusunda YBM ile ilgili özelliklerin benimsenme oranlarının yüksek olduğu ve YBM sürecinin EPY'nin uygulanması için önemli bir itici güç olduğu ortaya çıkmıştır.

İkinci olarak, Delphi yöntemi çalışması ile EPY ile ilgili KBF'ler belirlenmiştir. Belirlenen KBF'ler listesinde EPY sürecinin iş birliği ile ilgili ana özelliklerinin proje başarısına etki edebileceğini göstermiştir.

Üçüncü olarak, YBM ile ilgili KBF'leri Delphi yöntemi ile ortaya çıkarılmıştır. YBM ile ilgili KBF'ler YBM sürecindeki organizasyonel yapının ve yönetimsel özelliklerin önemini vurgulamıştır.

Son olarak, EPY takımı ile ilgili KBF'ler belirlenmiştir. Belirlenen KBF'ler takımların oluşturulmasının ve iş birliği içinde çalışmasının proje başarısı üzerinde etkili olduğunu göstermiştir. 3 farklı kategoride elde edilen KBF'ler tek bir listede toplanarak EPY projelerine yönelik bir KBF ön listesi hazırlanmıştır.

Sonuç olarak, elde edilen bulgular YBM'nin doğru bir şekilde uygulanabilmesi için gerekli olan organizasyonel yapıyı ve EPY'nin iş birliği ile ilgili özelliklerinin önemini vurgulamıştır. YBM iş birliği sürecinde etkin bir şekilde kullanılabilirken her iki sistemin de verimli bir şekilde uygulanabilmesi için takım içi ilişkilerin güçlendirilmesi, iletişim engellerinden kurtarılması, takımın entegrasyonunun teşvik edilmesi ve takım içindeki farklı disiplinlerin uzmanlık alanlarından faydalanmak gerekmektedir. Hazırlanan KBF ön listesi, YBM, EPY ve proje takımı arasındaki karşılıklı ilişkiyi yönetimsel, organizasyonel, sözleşmesel ve iş birliği üzerinden göstermektedir.

Hazırlanan KBF ön listesi, EPY ve YBM projelerinin benimsenmesinde ve uygulanmasında dikkate alınabilecek faktörleri içermektedir. Faktörlerin eksiksiz uygulanması proje başarısının elde edilebileceği anlamına gelmemektedir. Her proje başarı üzerinde değişen seviyelerde etkisi bulunan çeşitli kaynaklardan ve birbirine bağlı aktivitelerden oluşmakta olduğundan bu KBF'ler süreç üzerinde olumlu bir etkiye sahip olabilme ihtimaline rağmen, proje çıktısını tek başına etkileyemezler. Yeni sistemlerin de etkisiyle proje dinamikleri sürekli bir şekilde değişmektedir. Değişen koşullar ve projelerin ihtiyaçları göz önünde bulundurularak projeye özgü olarak zaman içinde listeye çeşitli eklemeler, düzeltmeler ve/veya çıkarmalar yapılabilir.

Son olarak, KBF ön listesi EPY ve YBM sistemlerini benimsemeyi planlayan paydaşlar için bir ön kontrol listesi olarak ve benzer konuda akademik çalışma yapan akademisyenler ve araştırmacılar tarafından kullanılabileceği düşünülmektedir.

1. INTRODUCTION

1.1 Background Information

The construction industry (CI), with its complex and multi-disciplinary nature, both affects and can be affected by the countries' Gross Domestic Product (GDP) (Cox and Townsend, 1998). Even though cultural and business shifts change almost all industries, the CI has remained relatively unchanged for more than one century (NASFA et al., 2010). Between 1964-1999, all non-farm industries increased their labor productivity by nearly 1.71% annually, whereas a 0.48% steady decrease occurred in the CI (Teicholz et al., 2001). The decline in productivity rate can be perceived as one of the main consequences of many problems that the CI faced and its unfavorable characteristics.

Construction projects are complex and need multi-disciplinary team involvement for the accomplishment of the final product (Fakhimi et al., 2016). Multi-disciplinary works and collaborative initiatives include a number of different individual disciplines, business structures, specialized terminologies, and processes (Baiden et al., 2006; Sive and Hays, 2009). A literature review about the CI's nature unveils some adversarial characteristics embedded in the industry, including its highly fragmented, multi-disciplinary, project-based, conservationist, complex, owner-driven, and environment-depended nature (Mokhtariani et al., 2017). Considering that these characteristics are rooted in the industry, their negative effects have become chronic problems. The relationship between the industry's frustration and their underlying causes have been a popular topic in the CM (Construction Management) literature (Lahdenperä, 2012). Researchers have made different associations to support their hypotheses within the scope of their study. For example, while Baiden et al. (2006) associated high fragmentation with conflicting interests between participants, non-transparent, and distrusted teamwork, Sive & Hays (2009) qualified fragmentation as an underlying reason for confusion and inefficiency. The underlying cause of some problems like fragmentation and disintegration is the adversarial impacts of selected project delivery system (PDS) because the PDS's type chosen designates the stakeholders' interactions throughout project's life-cycle and their relations with each other (El Asmar et al., 2013). Although several improvements have been made to PDSs over time, limited focus on advancements has prevented the desired result from obtaining (Azhar et al., 2014). The construction process, which a single master previously managed from start to finish, made different areas of expertise obligatory due to the rising complexity of buildings and technological innovations (Kent and Becerik-Gerber, 2010). New types of PDSs have appeared in various parts of the world, where level of collaboration has increased with the effect of a detailed examination of academia and the accumulated experience in the CI (Lahdenperä, 2012). CM, introduced in 1960s to eliminate the adverse effects of the traditional form of delivery, transferred its popularity to Design-Build (DB) in 1990s (Kent and Becerik-Gerber, 2010). As the software industry develops Agile Project Management to create more collaborative and trust-based teams, the CI also revealed IPD (Integrated Project Delivery) with the same motivations (De Marco and Karzouna, 2018). IPD offers relational contracting arrangements that promote pain and gain sharing, collaboration and integration incentives while eliminating the communication barriers to maximize projects' value (De Marco and Karzouna, 2018; Laurent and Leicht, 2019). While project success and stakeholders' success are necessarily not related in traditional forms, IPD aligns participant success with project success as it breaks separate responsibility silos (AIA, 2007).

IPD has emerged as a system that some CI stakeholders have started to implement in order to overcome the problems they frequently encounter or to reduce their adverse effects (Matthews and Howell, 2005). Cultural and technological drivers have a high impact on IPD's emergence (Sive and Hays, 2009). New tools advancing information sharing, communication and collaboration strategies, and cultural modifications in the working environment to support advancements in technology are the main drivers for IPD (NASFA et al., 2010; Sun et al., 2015). Even though it has been systematically applied in complex projects after being formulated by the AIA in 2007, its application in its pure form has not become widespread outside the USA due to legal barriers (AIA, 2007, 2010). Projects that select IPD as a PDS must have multiparty contractual arrangements to support more integrated and collaborated teams (Azhar et al., 2015; El Asmar et al., 2013; NASFA et al., 2010). Projects implementing some of the IPD principles in the absence of multiparty contracts are called as IPD-ish or IPD-lite (Sun et al., 2015; Yu et al., 2019). Technological and cultural changes that led to the emergence of IPD have also caused some features of IPD to be applied in construction projects over time to benefit from collaboration and integration without having relational contracting (NASFA et al., 2010).

Projects are the building blocks that ensure the correct functioning of organizations. The importance of the projects stems from the fact that in the absence of the projects, the organizations cannot cope with the competitive market and they can become outdated (Shenhar et al., 2001). Therefore, there is a need to evaluate the outputs of the project to help organizational goals. Examination of project success through CSFs (Critical Success Factors) is among the most widely used project performance assessment tools. Project success in general terms is the comparison of project outputs to project identified objectives (de Wit, 1988). Although the project success has tried to be measured via cost, time, and quality performance, these parameters are not sufficient by themselves (Atkinson, 1999; de Wit, 1988; Shenhar et al., 2001). For example, Sydney Opera House's project is perceived to be successful despite being tripled the planned duration of the project and five times greater cost compared to its planned cost (Shenhar et al., 2001). Over time, many researchers have created various CSF lists to effectively evaluate project success (e.g., Atkinson, 1999; Kog and Loh, 2012; T. A. Nguyen and Chovichien, 2013; Sanvido et al., 1992). However, these lists are insufficient considering the characteristics of the IPD. IPD aims for a behavioral and structural change in the construction teams and processes (AIA, 2007; NASFA et al., 2010). For this reason, CSFs prepared on traditional delivery systems are not compatible with the IPD.

1.2 Problem Statement

IPD revolutionizes the whole construction process, team dynamics and contractual arrangements in the CI (AIA, 2010; NASFA et al., 2010). IPD ties up project success with participants' success, and promotes risk and reward sharing among key participants (AIA, 2007). Factors leading to project success have been an important topic for the IPD literature (Alinezhad et al., 2020; Brennan, 2011; Elghaish et al., 2020; Hassan, 2013; Sun, 2013; Uihlein, 2016; Whang et al., 2019). Brennan (2011) carried out a Delphi survey to determine the relative importance of several constructions related CSFs to evaluate effectiveness of different delivery forms, including IPD but evaluated CSFs are not IPD specific. Sun (2013) focused on the IPD implementation in terms of the team's environment and communication. Hassan (2013) specified 12 factors to assist construction professionals' adoption process to IPD. Uihlein (2016) indicated the engineers' roles and responsibilities during an integrated approach to acquiring project success. Alinezhad *et al.* (2020) focused on different stakeholders' benefits for implementing IPD. Elghaish *et al.* (2020) listed factors for successful cost management. Whang et al. (2019) prepared an IPD-specific factor list from the AIA's IPD guide, and examined the relative importance of the factors over project success. Although the study of Whang et al. (2019) covers the major aspects, BIM and team-related factors are not evaluated. IPD's impact on project success cannot be considered efficiently without considering BIM and team characteristics. An IPD-specific CSF list covering the BIM and team characteristics will contribute to the accurate examination of project success in IPD.

It has been over 15 years since IPD has been formed as a PDS (Matthews and Howell, 2005). IPD, as a holistic system, has been seen as a solution to the widespread problems of the CI (e.g., fragmentation, high inefficiency, low productivity, and adversarial relationship) in the CM literature (De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; Yu et al., 2019; Zhang et al., 2013). Even if not fully implemented, some IPD principles have inevitably taken their place in the practices of construction projects under the influence of technological and cultural change (Ling et al., 2020). Ling *et al.* (2020) focussed on the adoption of IPD practices and their effects on project performance examining construction projects in Singapore. Adoption of IPD principles and their impact on widespread problems remain unanswered.

1.3 Research Aim and Objectives

This study aims to investigate the IPD characteristics' adoption in current practices of the CI and their impact on process and team related problems of the industry while creating an IPD specific CSF list to evaluate the effect of IPD, IPD-team and BIM on project success. With this aim, based on an in-depth literature review, CSFs related to BIM, IPD, and IPD-team, the list containing process and team related problems of the industry and main characteristics of IPD are prepared. An online questionnaire survey and interviews were conducted with professionals and academics having researches, and/or experience in BIM and IPD for determining the adoption of IPD principles in current practices and their effect on the occurrence of process and team related problems. Furthermore, four rounds of three groups of the Delphi Survey were conducted with professionals and academics having researches, and/or experience in BIM and IPD to examine the effects of BIM, IPD and IPD-team related factors on project success.

Table 1.1: Aims, objectives and research methods of the study.

Aims	Objectives	Research Methods
To investigate the IPD characteristics' adoption in construction projects and their impact on process and team related problems of the CI To prepare the CSFs preliminary list covering IPD, BIM and IPD team characteristics	To determine the process and team related problems of the CI and examine their occurrence in construction projects	RM1: Literature Review RM2: Questionnaire Survey RM3: Interviews
	To determine adoption of IPD, BIM and IPD team characteristics in construction projects	RM1: Literature Review RM2: Questionnaire Survey RM3: Interviews
	To determine IPD related CSFs and to examine their importance for project success in IPD projects	RM1: Literature Review RM4: Delphi Survey
	To determine BIM related CSFs in IPD projects and to examine their importance for project success in IPD projects	RM1: Literature Review RM4: Delphi Survey
	To determine and rank IPD team related CSFs in IPD projects	RM1: Literature Review RM4: Delphi Survey

1.4 Research Methods and Dissertation Content

In this study, an in-depth literature review based on articles, books, guides and reports has been carried out to determine common problems of the industry, IPD, BIM and IPD-team characteristics, and roles and responsibilities of the key stakeholders in compliance with the scope of research aims and objectives. The outputs of the literature review have established a ground for the preparation of the questions of the online questionnaire survey, structured interviews and the Delphi method. Subsequently, three research methods have progressed through three different branches. The samples of all methods were construction professionals with IPD and

BIM experience or academics with publications on related topics. Four rounds of the Delphi study have been carried out to identify IPD, BIM and IPD team related CSFs. Afterwards, the survey has been progressed to determine the adoption and implementation of IPD, BIM, and IPD team characteristics. Furthermore, effects of these characteristics and the roles and responsibilities of the main stakeholders on the problems frequently encountered in the CI were also examined within the scope of the survey. The change in frequency of encountering these problems over time with the adoption of IPD characteristics was the subject of the online interviews.

This dissertation consists of six consecutive chapters (Figure 1.1). The first chapter provides the background information, defines the literature gap, and identifies this research's aims and objectives.

The second chapter provides the literature review on the IPD's adoption. In the second chapter, the problems in the CI that led to the emergence of the IPD and the features of other PDSs are examined. Furthermore, drivers for and barriers against the adoption of IPD are investigated.

Chapter 3 provides the details of the research methods and sample characteristics of the conducted questionnaire survey, interviews and the Delphi Method.

In the Chapter 4, data obtained through the research methods are provided. First of all, statistical results of the online questionnaire survey with their reliability analysis are provided. Then, the results of the online interviews are presented by grouping the similar answers of respondents. After that, the results of each round of the Delphi study are provided under the related subtopics. Finally, the CSFs preliminary list is prepared by combining the results of the research methods.

Chapter 5 provides discussion based on research objectives. Interconnected characteristics and factors are examined in detail. Chapter 6 provides conclusions and recommendations regarding research objectives.

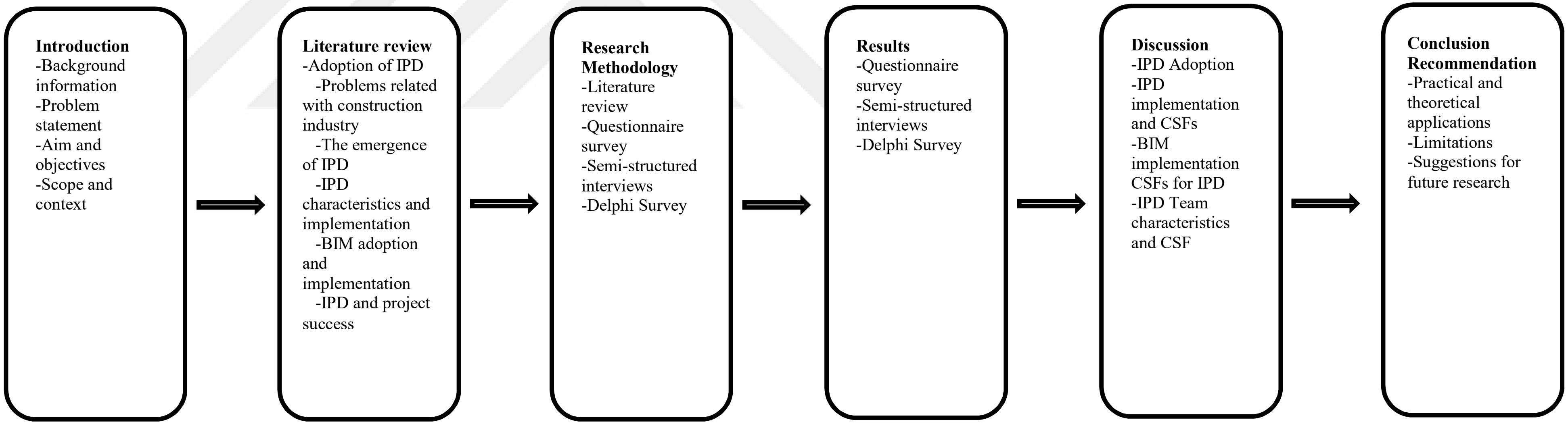

Figure 1.1 : Dissertation flow chart.

2. ADOPTION OF THE IPD

In this part of the dissertation, a detailed literature review on the adoption of the IPD is presented. First of all, frequently faced problems in the CI are reviewed and categorized under process and team related problems in order to comprehend the environment that leads the search for the new and advanced delivery systems. Then, the change and development in the PDSs were examined in detail to figure out the key features of systems and rising trends in the CI. A detailed factors lists associated with project success were prepared after the examination of IPD, IPD team and BIM characteristics.

2.1 Problems Related with the CI

The Business Research Company report unveils that the market shares of the CI worldwide are expected to grow to $12.5 trillion in 2021 by recovering from the unfavorable effects of the global pandemic (The Business Research Company, 2021). The CI is one of the industries with the largest share in GDP, regardless of the development level of the countries (National Research Council, 2009). Approximately 8% of the total United States (U.S.) workforce are in the CI or construction-related industries (National Research Council, 2009). Despite its significance in the local and global economy in terms of its share in GDP, energy consumption and employment rate, CI has remained unchanged for almost a century while other industries had almost totally revolutionized their way of working (NASFA et al., 2010). Between 1964-1999, a 0.48% steady decrease occurred in the labor productivity in the CI (Teicholz et al., 2001).

The CI is segmented into four distinctive sectors as residential, commercial, industrial, and heavy construction (National Research Council, 2009). A number of stakeholders having different terminologies and specialties take part in the successive construction process, including owners, contractors, designers, sub-contractors, etc. (Alzahrani and Emsley, 2013). Additionally, differentiation in construction partners eventually turns the CI into a multi-disciplinary industry (Fakhimi et al., 2016). Another major issue about the CI is complexity. Construction projects are inherently complex in terms of the characteristics of end-product (AIA, 2014; NIBS, 2017), one-time nature of the work (National Research Council, 2009), differentiated players (Choi et al., 2019; Fakhimi et al., 2016; Kent and Becerik-Gerber, 2010), contractual relations among parties involved (Ashcraft, 2014a). Furthermore, traditional form of contracting is another factor can lead to increase in inefficiency (Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011; Sun et al., 2015). As PDSs and related contractual arrangements decide the timely engagements of stakeholders and their interrelated relations, they have effect on project performance (El Asmar et al., 2013; Laurent and Leicht, 2019). Furthermore, the selection of PDSs has a vital role in achieving project success (Azhar et al., 2015). In the traditional form of delivery, also known as Design-Bid-Build (DBB), the owner first contracts with the designer, and then contracts with the general contractor after the completion of design (El Asmar et al., 2013). Contractual arrangements in DBB strongly limit the integration and collaboration of design and implementation teams by creating adversarial relationships among critical parties (Azhar et al., 2015; Baiden et al., 2006; Zhang et al., 2013). DBB can create a mistrusted and reduced teamwork environment which can result in inefficiency because of the increased change orders and disputes (AIA, 2007; Mesa et al., 2016). High level of segmentation, interdisciplinary nature of the industry, increased complexity, and traditional form of contracting are perceived as among the main reasons to common problems encountered in the CI (Baiden et al., 2006; Fakhimi et al., 2016; Lahdenperä, 2012; Sive and Hays, 2009). Traditional contracting differs from other problems as it depends on the owner’s preference (NASFA et al., 2010). Emerging tools, strategies and roles, however, are forcing cultural and business change in the CI and creating significant developments in the fields of sustainability by reducing waste in time, material use and labor activity (NASFA et al., 2010). The size and primitiveness of the industry also increases the impact of the improvements to be made. In the US, labor coordination and material application produce waste between 25% to 50% (National Research Council, 2009); the cost of the deficiency in interoperability is nearly $15.6 billion annually (Gallaher et al., 2004); whereas solving disputes and claims during construction projects cost between $4to12 billion annually (Federal Facilities Council, 2007). It is necessary to examine the team and process related problems and their causes in order to reduce the waste rate and make the CI more sustainable.

2.1.1 Team related problems

The formation and effective functioning of teams can play a major role in the implementation of the projects. In the CI, project teams consists of people with distinctive specialties and terminologies from various companies (Azmy, 2012). While forming an effective team is crucial for obtaining desired outcomes, the CI is not successful in bringing people together to work on achieving mutual goals without conflicting interests because of the widespread application of traditional delivery forms (Baiden et al., 2006). It is difficult to talk about a project team working towards the common goals of the project in DBB as the teams involved in the project have to act in their interests due to contractual structure (Ghassemi and Becerik-Gerber, 2011). Segregation of design and construction causes fragmentation in and consequently adversarial relationships among parties involved which can lead to non-transparent and mistrusted environments (Baiden et al., 2006). An antagonistic project environment can disrupt the unproblematic functioning of the team and reduces its effectiveness (Evbuomwan and Anumba, 1998). The operation of independent teams during the design and construction phase also causes needless design changes and increases the number of liability claims (Baiden et al., 2006). Furthermore, DBB can strongly limit the collaboration and coordination capabilities of the parties as the design is almost accomplished before the involvement of the people responsible for the construction (Hamzeh et al., 2019; Mesa et al., 2016). Increasing complexity of building systems and related technical requirements make collaboration obligatory, and this necessity can be seen as the reason for new delivery systems' evolution (Azhar et al., 2014). Consequently, the problems inherent in the CI can obstacle the accurate functioning of the teams, ultimately creating unfavorable effects in the project process.

2.1.2 Process related problems

Construction projects are complex and need multi-disciplinary participation at every stage of the whole process (Choi et al., 2019; Fakhimi et al., 2016). The interdisciplinary and complicated nature of the process has had many obstacles encountered over the years mainly due to disruption of team functioning (CURT, 2007). Segmented teams during the process can cause data losses and create an inconsistency with the intended design while increasing the number of design changes and reworks (Baiden et al., 2006; Yu et al., 2019). Design changes can be mainly caused by design errors and omissions made by designers having insufficient knowledge on construction and building codes or by the contractor due to contractor's effort to increase the profit margin using the loopholes in the contract (Alnuaimi et al., 2010). All deviations from the intended design and construction can lead to poor end quality and degradation in the project value (De Marco and Karzouna, 2018; Zhang et al., 2013). Furthermore, since the solution of all problems encountered in the process can require extra money and time, it can cause the project to deviate from the estimated schedule and cost (De Marco and Karzouna, 2018; Franz et al., 2017; Laurent and Leicht, 2019; Zhang et al., 2013).

Researchers have established variable relationships between common problems. For example, Baiden et al., (2006)'s study on team integration designates multi-disciplinary nature of the CI and excessive use of traditional contracts as the main reason for the nonfunctional team environment, which can cause high inefficiency and overruns in the estimated cost and schedule. Table 2.1 shows how the problems emerged in the process and their interrelationships. Using the data in Table 2.1, Figure 2.1 has been prepared to categorize the problems and to look at the relationship between each category.

Table 2.1 : Frequently faced main problems in the CI and their cause and effect relations according to literature review.

Common problems	Primary reason	Secondary reason	Result
Complexity	(Choi et al., 2019; Fakhimi et al., 2016)		
Multilateral industry	(Baiden et al., 2006; Fakhimi et al., 2016; Sive and Hays, 2009)		
Traditional contracting	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011; Sun et al., 2015)		
Adversarial relationship	(De Marco and Karzouna, 2018; Yu et al., 2019; Zhang et al., 2013)		(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; Zhang et al., 2013)
Fragmentation	(Baiden et al., 2006; Lahdenperä, 2012; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019)		
Contractual disputes	(De Marco and Karzouna, 2018)	(Zhang et al., 2013)	
Dis-integration	(Ghassemi and Becerik-Gerber, 2011)	(Lahdenperä, 2012)	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011; NASFA et al., 2010; Sive and Hays, 2009; Zhang et al., 2013)
Non-transparent relations		(Baiden et al., 2006)	
Mistrust environment	(De Marco and Karzouna, 2018)	(Baiden et al., 2006)	(Ghassemi and Becerik-Gerber, 2011)

Table 2.1 (continued): Frequently faced main problems in the CI and their cause and effect relations according to literature review.

Common problems	Primary reason	Secondary reason	Result
Ineffective teams	(Baiden et al., 2006; CURT, 2004)		
High inefficiency	(De Marco and Karzouna, 2018)		(Baiden et al., 2006; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; NASFA et al., 2010; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019; Zhang et al., 2013)
Low productivity	(De Marco and Karzouna, 2018)		(Fakhimi et al., 2016; NASFA et al., 2010; Yu et al., 2019)
Cost overruns	(Zhang et al., 2013)		(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; NASFA et al., 2010)
Schedule overruns	(Zhang et al., 2013)		(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019)
Poor end quality	(Zhang et al., 2013)		(De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019)
Degraded project value			(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016)
Inconsistency between design and construction			(Yu et al., 2019)
Over-reworks			(Yu et al., 2019)
Errors			(NASFA et al., 2010; Yu et al., 2019)
Omissions	(Baiden et al., 2006)		(NASFA et al., 2010)
Waste			(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011)
Excessive liability claims			(Baiden et al., 2006)
Data losses			(Baiden et al., 2006)
Excessive design changes			(Baiden et al., 2006)

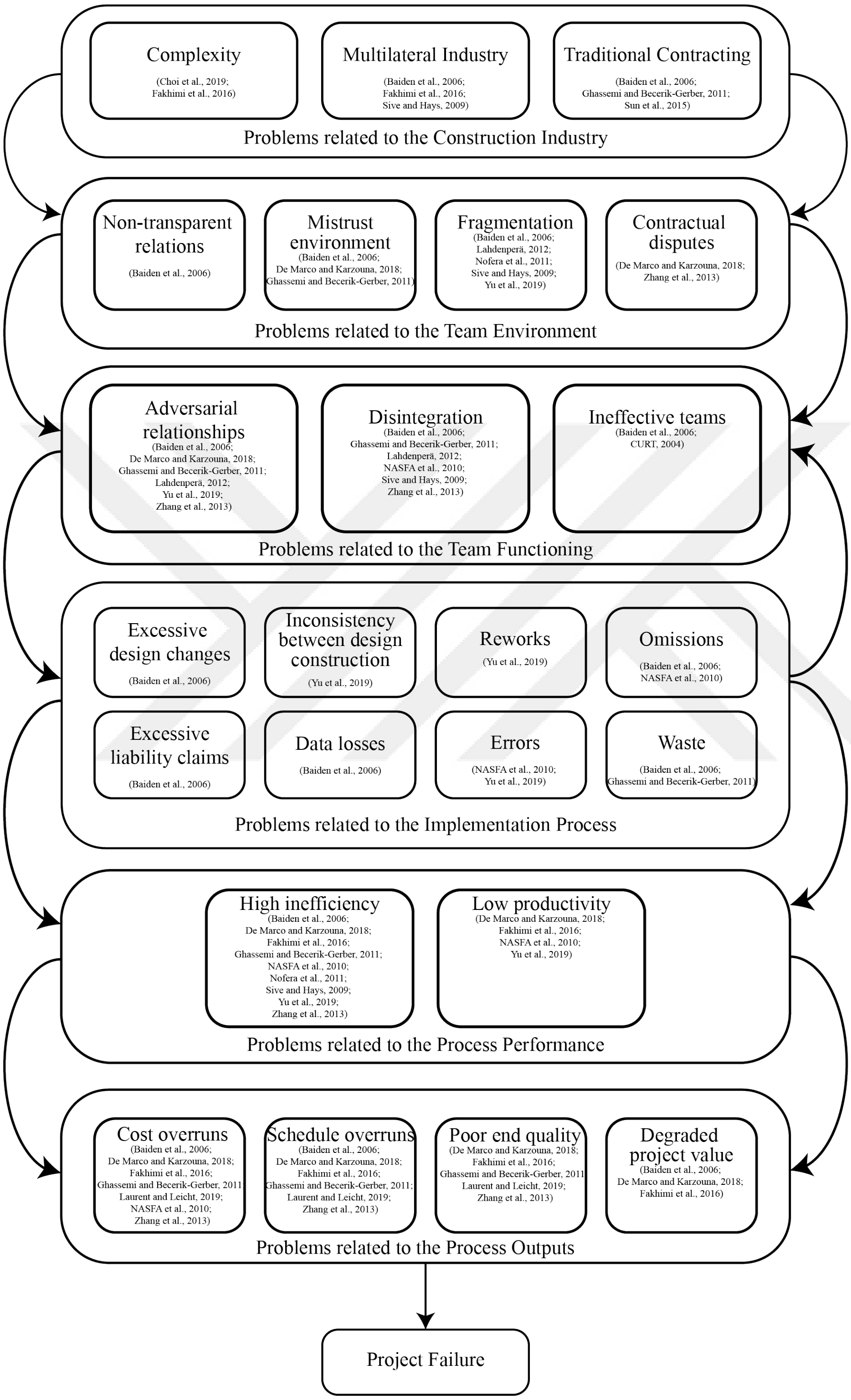

Figure 2.1 : Categorization of common problems and their interrelations.

2.2 The Emergence of IPD

In the late 20th and early 21st centuries, a growing interest in more integrated PDSs and teams has appeared in the CM literature mainly due to the perception of nonintegrated teams as the cause of inefficiency in the CI (CURT, 2004; Evbuomwan and Anumba, 1998; Koppinen and Lahdenperä, 2004; Matthews and Howell, 2005). In the same period, construction stakeholders had been in search for a new system to optimize their profits (Fakhimi et al., 2016; Matthews and Howell, 2005). In 2007, AIA responded to this search of both academia and industry by formulating the IPD (AIA, 2007). Two different roadmaps can be drawn for the IPD where one of them is structured by the required enhancements in collaboration and the transformation of DBB, CMAR to DB and finally IPD (El Asmar et al., 2013) whereas the other roadmap is originated from relational contracting arrangements, Project Partnering, Project Alliancing and IPD (Lahdenperä, 2012).

2.2.1 Evolution of Project Delivery Systems

The traditional way of PDS in the CI is DBB. Its baseline can be considered as the 1850s with the specialization of professions (e.g., architecture, civil engineering) (Ahmed and El-Sayegh, 2021). DBB is still the most widely used PDS globally (McGraw Hill Construction, 2014). Advantages of DBB are derived from its wide application creating familiarity and understanding of process among stakeholders (CMAA, 2012). The scope of work and risks in bidding process are well defined as the design is fully completed in DBB (Koppinen and Lahdenperä, 2004).

In the DBB, where the building process follows a linear path with no overlapping activities (Kubba, 2012), the process starts with the owner's or the client's brief and continues respectively by designer's architectural design, engineer's structural design, quantity surveyor's cost estimates and general contractor's execution of building (Evbuomwan and Anumba, 1998). Coordination and management of the whole process are under the responsibility of the owner or his/her representatives and gives the owner significant control over design (CMAA, 2012; Koppinen and Lahdenperä, 2004). Since bidding is made after the accomplishment of the design, the process can generally take a long time and leads to no design input from other stakeholders (Evbuomwan and Anumba, 1998). Furthermore, the separation of major stakeholders can increase the quantity of change orders and claims (Ahmed and El-Sayegh, 2021).

DBB, with limited alterations, has turned into the system called as CMAR (Construction Manager at Risk) in the 1960s (CMAA, 2012; Kent and Becerik-Gerber, 2010). Construction manager's roles as both coordinator during design and contractor during construction can reduce the adverse impacts of separation (Kubba, 2012). The percentage of the design completed before the participation of the construction manager is between 50% to 90% (CMAA, 2012). Early involvement of construction manager can contribute to the integration of the team, accuracy of cost and schedule (Syed Zuber et al., 2018). CMAR can shorten the process enabling overlappings of some part of the design and construction processes (CMAA, 2012). Although some degree of integration is achieved in CMAR, the owner's signing two different contracts with the parties can leave the designer and construction manager in adversarial relations (Syed Zuber et al., 2018). For example, if the contract is based on the fixed price principle, hostile relations might appear the owner and the construction manager (CMAA, 2012).

Master builder technique in ancient times is generally associated with the DB (Design-Build) as one single person or one entity was responsible for the design and accomplishment of the construction (Sell and Wilking, 2008). The increasing trend of project teams' integration led to the initial implementation of DB due to the package offerings from some contractors in the 1960s (Boudjabeur, 1997; Rowlinson, 1988). The rising complexity of buildings, demand for more integrated teams and automation of some construction activities led stakeholders to seek alternative PDSs (Ahmed and El-Sayegh, 2021). Publishment of the first DB contract by the Joint Contracts Tribunal enabled DB to be accepted as a procurement method in 1981 (Boudjabeur, 1997). Other milestones for the DB are the publishment of the AIA DB contract in 1985 and the foundation of the Design-Build Institute of America (DBIA) in 1993 (Sell and Wilking, 2008). In DB, the owner establishes the scope of the work, general framework of design, and desired end result before the tender phase (Koppinen and Lahdenperä, 2004). The percentage of the design completed before the contractor's involvement in DB is lower than in DBB and CMAR (El Asmar et al., 2013). Although team's collaboration level has increased from DBB to DB, traditional contracts have not been able to resolve the conflicting interests of the parties without relational arrangements (El Asmar et al., 2013; Lahdenperä, 2012).

RPDA (Relational Project Delivery Arrangements) starts with the implementation of PP (Project Partnering) in the CI (Lahdenperä, 2012). PP is a contractual arrangement between two parties for a limited time or project basis with the advancement in communication and collaboration skills to achieve the shared goals (Black et al., 2000). PP implementation initially started with the adoption of traditional contracting with the addition of another agreement ensuring partnering (Lahdenperä, 2012). Even if relational contracting takes part in PP, it lacks joint liability and provision for the early involvement of sub-contractor (Lahdenperä, 2012).

While the PP was applied extensively in UK and USA, the PA (Project Alliancing) was used in the Australian CI (Lahdenperä, 2012). PA differs from the PP in terms of the establihment of the team and its collaboration level (Walker et al., 2002). Furthermore, PA encourages the project team to behave as a virtual company through the integration of the individual's success of all parties into the project's outcome (Sakal, 2005). Unlike PP, multiple stakeholders selected by their level of expertise and ability can establish an alliance through multiparty contracts in PA (Hauck et al., 2004). PA focuses on best-value projects rather than low-cost solutions (Walker et al., 2002). PA's risk and reward sharing culture aligns the objectives of the parties involved in collaborative decision-making (Lahdenperä, 2012).

As the CI realizes the integration of team and process as an improvement in the project performance through the elimination of its chronic problems, PDSs have become more and more integrated (Franz et al., 2017). Demand for integration and more effective processes united with technological advancements led to the formation of another PDS called as the IPD (Ahmed and El-Sayegh, 2021; AIA, 2007). Figure 2.2 illustrates the two different paths to the formation of IPD. The first path leading to the IPD from the traditional contracting arrangements (e.g., DBB, DB and CMAR) derive from the demand for integration (El Asmar et al., 2013) whereas the other route to the IPD from PP and PA originates from the use of multi-party agreements (Lahdenperä, 2012). The main common features of both of these directions are the necessity of stakeholders' early involvement and the intensified design process (El Asmar et al., 2013; Lahdenperä, 2012).

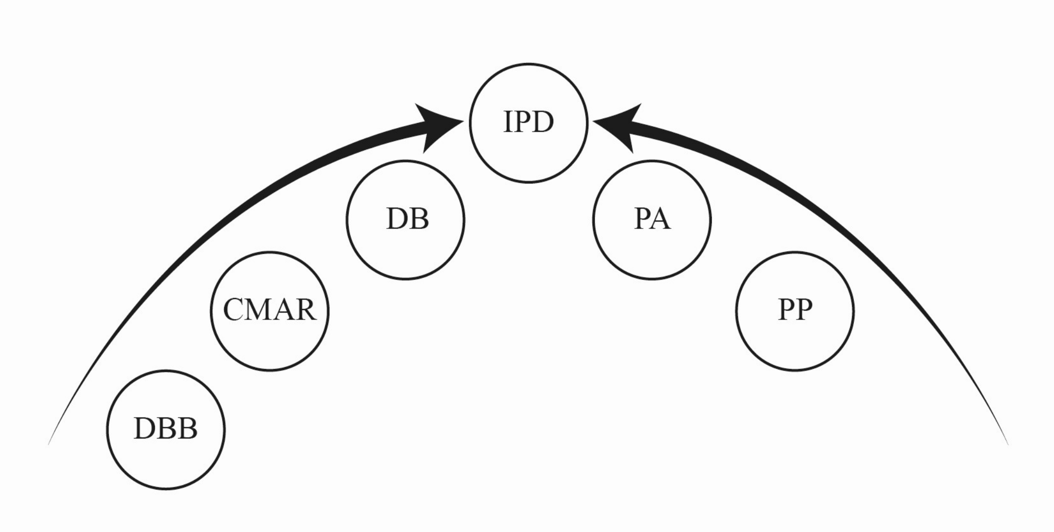

Figure 2.2 : The road to IPD from traditional and relational contracting (Adapted from El Asmar et al., 2013 and Lahdenperä, 2012).

2.2.2 Drivers for the IPD adoption

Main drivers for IPD can be listed as market and stakeholders' demands for more specific and trustworthy PDSs, technological advancements in the CI and their effects on the work environment, and sustainability pressure which requires multidisciplinary collaboration (Sive and Hays, 2009). Four reports prepared by CURT (Construction Users Roundtable) (2004 and 2006), NIST (National Institute of Standards and Technology) and NRC (National Research Council) (2009) have drawn attention to the situation in the CI and urged the CI to find more efficient and integrated work practice (CURT, 2004, 2006; Gallaher et al., 2004; NRC, 2009). Meanwhile, the owners dissatisfied with the established systems started to seek alternative methods to deliver high-performance projects to meet schedule, cost and quality expectations (AIA, 2007). The same motivations led many CI companies (e.g., Arup) to develop in-house solutions to integrate project teams (Uihlein, 2016). Architecture firms, contractors and sub-contractors in the CI, having frustrations with traditional delivery, also initiated a more integrated approach to get rid of problems (e.g., extensive change orders, liability claims and data losses) caused by lack of proper coordination and communication (Nofera et al., 2011; Sive and Hays, 2009). Advancements in the field of ICT like BIM are other drivers for IPD (Azhar et al., 2015; Sive and Hays, 2009). BIM is a revolutionary tool to optimize construction practices and the interest for the use and adoptation of BIM the CI is increasing (Chang et al., 2017; Kent and Becerik-

Gerber, 2010). The proper use of BIM and maximization of its potential over the process necessitate an appropriate procurement method that allows multi-disciplinary work environment at the earliest stage of the project (NASFA et al., 2010). Various dimensions of BIM from 3D to 7D with their application areas (e.g., clash detection, energy analysis, lifecycle and space management) can directly affect economic, environmental and social pillars of sustainability (Sertyesilisik et al., 2021). Sustainability as well as BIM can enable team collaboration to get benefit from the expertise of different stakeholders in terms of material selection, cost and process optimization, and reduction in waste, omissions and defects (Jones, 2014). Furthermore, the team can collectively define project goals in IPD and can designate sustainability features as a goal by importing rating criteria like LEED® (AIA, 2007). As sustainability issues and the use of BIM become important for the CI, the rise in the use of an integrated approach is inevitable.

2.2.3 Barriers against the IPD adoption

Construction professionals can encounter with some difficulties while moving from an environment that limits collaboration to practices that incentivize cooperation and integration (NASFA et al., 2010). Since the IPD is a relatively new system and differs from existing PDSs, barriers occur at two different stages while adopting IPD first and implementing it, respectively (Rodrigues and Lindhard, 2021). Barriers can be classified under the four categories (i.e., legal, cultural, financial and technological categories) (Ghassemi and Becerik-Gerber, 2011). The fundamental legal concerns for adopting IPD are liability, insurance and risk allocation issues that significantly differ from traditional arrangements (Ghassemi and Becerik-Gerber, 2011). Especially in public works, regulations strictly limit participants' integration and risk-sharing capabilities by promoting the use of DBB (Azhar et al., 2014). Joint liability and responsibility contradict widespread insurance policies, which designate each party as responsible for their actions (Sive and Hays, 2009).

Implementation and adoption of most IPD principles necessitate a cultural shift in the CI (AIA, 2007). As the owner is the responsible party for the PDS selection, the change in the owner's mindset can prepare the appropriate environment for the widespread adoption of IPD (NASFA et al., 2010). McGraw Hill Construction report (2014) predicted a cultural change in the CI with a decrease in the use of DBB and an increase in the use of more integrated delivery approaches. predicted a cultural change in the CI with respect to a decrease in the use of DBB and an increase in the use of more integrated delivery approaches. Activities (e.g., IPD training) can be implemented to create a trust-based and collaborative environment at the earlier phase of the project in order to overcome cultural barriers (Ghassemi and Becerik-Gerber, 2011). IPD brings a new approach to stakeholders' financial relations. Financial transparency and risk-sharing features of IPD can create a financial barrier because some stakeholders can perceive this environment as abusive and adversarial, especially when incentives are tied up with cost and schedule targets (AIA, 2010).

Technological advancements are actively used in the IPD process to settle more collaborative teamwork (Azhar et al., 2014). Interoperability, liability and legal ownership concerns related to BIM can be seen as technological barriers of IPD (Azhar et al., 2014; Ghassemi and Becerik-Gerber, 2011).

2.3 IPD Characteristics and Implementation

IPD is a PDS that uses relational multi-party contracting to transform separated teams into a virtual organization acting in the project's interests (Matthews and Howell, 2005). IPD creates a collaborative environment with the integration of specialized stakeholders and their systems, business structures and applications into the process to optimize project outcomes, increase project value, reduce waste and maximize efficiency (AIA, 2007). A project, which adopts some of the IPD features without using a multi-party contract (El Asmar et al., 2013), is called as IPD-ish by implementing some IPD features and the use of recent tools (e.g., BIM) that necessitate collaboration (NASFA et al., 2010; Sive and Hays, 2009). Adopted principles in IPD-ish projects can be the particular degree of pain and gain sharing, co-location, early involvement of subcontractors and contractual arrangements encouraging more collaboration (NASFA et al., 2010). In the literature, IPD definitions consist of critical characteristics (e.g., early involvement of key participants, shared risk and reward, multi-party contract, collaborative decision-making, liability waivers among key participants and collectively defined project goals) that IPD incentives to revolutionize the CI (AIA, 2010). Azhar et al. (2014) examined these characteristics under two categories as collaboration-related and contract-related characteristics. Furthermore, there are some principles that leverage the success of IPD adoption and implementation, including mutual respect and trust, joint innovation, intensified design, co-location, fiscal transparency, open communication, BIM and lean principles (AIA, 2010).

2.3.1 Collaboration-related characteristics of IPD

IPD and its promises on project success rely on the high-efficiency collaboration among key parties via incorporating them into the process as early as possible (AIA, 2007). CURT (2004)'s report emphasized the importance of early integration of stakeholders to process and illustrated the cost impact of the intensified design process with the help of the "MacLeamy Curve". Early involvement of all parties ensures that the design is built on solid foundations by evaluating alternatives more accurately, enhancing the constructability, and increasing the reliability of cost and schedule estimations (NASFA et al., 2010). Integration of design and construction teams can also shorten the construction phase with an earlier start of prefabrication studies and procurement for long-lead items (Azhar et al., 2015; NASFA et al., 2010). Early involvement can support reduction in the quantity of change orders that cause deviation from the estimated budget and schedule (Piroozfar et al., 2019). The owners can get advantage of early integration by clarifying the aims and objectives of the project in the earliest stage with the help of the IPD team and collaboration throughout the project (Azhar et al., 2014). Jointly developed goals can create an innovative and performance-based working environment through alignment of the desired project outputs with independent parties' objectives (AIA, 2007). As all parties, with distinctive areas of specialization, commonly develop the targets, the collaborative process can make the targets more achievable and increase the commitment level of each party to achieve project goals (Ashcraft, 2014b). Adding value to project, accomplishment of the project on time or ahead of schedule while sustaining the quality criterion can be listed as shared goals that the team is incentivized to achieve (Mesa et al., 2016). Unlike the traditional method in which the owner is responsible for decision-making, the decision-making process in IPD is collaborative (AIA, 2007). As the parties share risk and profit, they need to participate in the decision-making process and accept the developed decisions (Ashcraft, 2014b). The sides of the multi-party contract select representatives to form the governing board, which is responsible for making unanimous decisions by considering the project's best interest (AIA, 2007). Subcontractors can also be in the process to advise the team on their area of expertise besides the owner, designer and contractor (Azhar et al., 2015). Executing the decision-making process collaboratively strengthen the trust-based environment by fostering innovation, ensuring benefits from various area of expertise to the project and improving joint liability (NASFA et al., 2010).

2.3.2 Contract-related characteristics of IPD

In the CM literature, traditional contracts are seen as among the main reasons for the obstacles encountered in the CI as the contract defines the involvement time of the parties and their relationships (Azhar et al., 2015; Baiden et al., 2006; Zhang et al., 2013). IPD unites all participants through multi-party contracts to act in the best interest of the project as IPD can enable increase in the collaboration and coordination capabilities during the project life-cycle (Kent and Becerik-Gerber, 2010). The multi-party contracts necessitate extensive preparation, rigorous team building activities, and cautious discussions at the beginning of the project (AIA, 2007; De Marco and Karzouna, 2018). The preparation process can be costly but crucial for long-term vision and be shortened if the participants have prior work experience with each other (De Marco and Karzouna, 2018). As the selection process occurs before the accomplishment of design, participants qualification is at the core of selection criteria rather than the low-bidding process (Laurent and Leicht, 2019). The multi-party contract clearly defines each participant’s roles, responsibilities, accountabilities, interests, and relationships with others by eliminating fragmentation and conflicting interest issues (Azhar et al., 2015; Kent and Becerik-Gerber, 2010). The multi-party contract can leverage and catalyze the implementation of other characteristics of IPD (e.g., collaborative decision-making, risk and reward sharing, joint liability) (AIA, 2007). Therefore, the use of the multi-party contract becomes necessary for the implementation of pure-IPD and distinguishes pure-IPD from IPD-ish projects (NASFA et al., 2010). The multi-party contract focuses on the management aspects by defining how the project is executed and managed with use of tools like the Last Planner® System (Knapp et al., 2014). Several institutions prepared templates for multi-party contract for use in IPD including ConsensusDocs ® 300, AIA A295™, AIA C191™, AIA C195™, and CCDC-30 (AIA, 2008a, 2008b, 2009; CDCC, 2018; ConsensusDocs®, 2007). There are also custom-made agreements prepared by private organizations like Hanson Bridgett (Allison et al., 2018).

When project encounters adverse situations that may cause disagreement between team members, the multi-party contract can strengthen the team resilience through liability waivers among key participants (Fischer et al., 2017), as convenient application of liability waivers can ensure the internal resolution of disputes and the improved relationship between participants (Chang et al., 2017). The liability waivers principle limits the potential blaming culture in the project by holding the whole team responsible for errors and omissions until the end of the close-out phase (NASFA et al., 2010; Rodrigues and Lindhard, 2021), whereas after the close-out phase, participants are responsible for their deliveries during the warranty period (Rodrigues and Lindhard, 2021). CDCC-30 contract excludes the following claims in the waiver of liability (CDCC, 2018): claims arising from deliberate default by a party (CDCC, 2018); claims having a contractual, insurance, or warranty basis (CDCC, 2018); claims causing from any violations of trademark, licenses, or intellectual property rights (CDCC, 2018); claims by the party that is excluded from the multi-party contract (CDCC, 2018); claims for deficiencies in design and construction caused by unknown or unexplored situations during warranty phase (CDCC, 2018). As contractual disputes can damage the team environment (De Marco and Karzouna, 2018), joint liability can help establish an atmosphere of mutual trust and respect between the parties and increases communication capabilities by driving a solution-oriented approach (Azhar et al., 2015).

The final contract-related key characteristic of IPD is risk and reward sharing. In the C191™ contract, the risk-sharing concept is actually referring to joint liability (AIA, 2009). Furthermore, parties can share financial risk and reward by binding their entire profit or percentage of it to the project performance (Azhar et al., 2015; NASFA et al., 2010). If the project is completed within the estimated budget, parties retrieve the whole profit they put at risk in joint contingency pool (Mesa et al., 2016). Parties receive extra earnings in case of the project accomplishment under the estimated budget according to the compensation structure stated in the multi-party contract (Azhar et al., 2015). In the case of cost-overrun, the amount of overrun is met by the parties' profits (Pishdad-Bozorgi and Srivastava, 2018). Key stakeholders can take rewards by meeting project goals while bearing the risk of compensation for not meeting other criteria like schedule and quality (Azhar et al., 2014).

Apart from the key characteristics, there are some principles that leverage IPD implementation including financial transparency and incentives, internal dispute resolution, end-user involvement (AIA, 2010; Kent and Becerik-Gerber, 2010; NASFA et al., 2010). As the literature review shows, key characteristics of IPD (early involvement, collaborative decision-making and goal determination, multi-party contracts, joint liability, pain and gain sharing) have a direct impact on other characteristics associated with IPD (AIA, 2007). Table 2.2 shows which key characteristics affect the application of other characteristics associated with the IPD.

As IPD aims to reshape team dynamics in the CI, key characteristics directly influence the team environment and functioning (AIA, 2007; PMI, 2016). While multi-party contracts, risk and reward sharing, and joint liability can help elimination of traditional barriers between stakeholders contractually, other characteristics can encourage a fundamental cultural change in the work environment (Kent and Becerik-Gerber, 2010; NASFA et al., 2010). The positive effects on the team are reflected in the process outcomes, and early integration of the team can result in reduction in the quantity of deficiencies and changes in the implementation process (Ashcraft and Bridgett, 2014; Fischer et al., 2017). Table 2.3 indicates which IPD characteristics have a direct influence on common problems encountered in the CI according to literature review.

Table 2.2 : Key IPD characteristics' effects on each other and other principles.

Characteristics	Collaboration-related key characteristics			Contract-related key characteristics		
	Early involvement	Collectively defined goals	Collaborative decision-making	Multi-party contracts	Joint liability	Risk and reward sharing
Early involvement				(Laurent and Leicht, 2019)		
Collectively defined goals	(AIA, 2007; Azhar et al., 2014)		(Uihlein, 2016)	(AIA, 2007; Sive and Hays, 2009)		(Kent and Becerik-Gerber, 2010)
Collaborative decision-making	(AIA, 2007; Fischer et al., 2017)	(Uihlein, 2016)		(AIA, 2007; Sive and Hays, 2009)		
Multi-party contracts						
Joint liability	(AIA, 2010; El Asmar et al., 2013)		(Hamzeh et al., 2019)	(AIA, 2007)		
Risk and reward sharing	(AIA, 2010; El Asmar et al., 2013)	(Mesa et al., 2016)		(Ghassemi and Becerik-Gerber, 2011; NASFA et al., 2010)	(NASFA et al., 2010)	
Fiscal transparency				(Laurent and Leicht, 2019)		
Intensified design	(Azhar et al., 2015; NASFA et al., 2010)	(NASFA et al., 2010)		(De Marco and Karzouna, 2018)		

Table 2.2 (continued): Key IPD characteristics' effects on each other and other principles.

Characteristics	Collaboration-related key characteristics			Contract-related key characteristics		
	Early involvement	Collectively defined goals	Collaborative decision-making	Multi-party contracts	Joint liability	Risk and reward sharing
Financial incentives				(NASFA et al., 2010)	(Kent and Becerik-Gerber, 2010)	(Kent and Becerik-Gerber, 2010)
Early goal definition	(AIA, 2007; Piroozfar et al., 2019; Scott et al., 2013)			(Sive and Hays, 2009)		
Internal dispute resolution				(Sive and Hays, 2009)	(AIA, 2014)	
Shared contingency pool		(Mesa et al., 2016)				
Regular meetings			(AIA, 2007)			
Goals-owner's desired outcomes alignment			(Azhar et al., 2014)			

Table 2.3 : Key IPD characteristics' effects on frequently faced problems in the CI.

Team and process related problems	Collaboration-related key characteristics			Contract-related key characteristics		
	Early involvement	Collectively defined goals	Collaborative decision-making	Multi-party contracts	Joint liability	Risk and reward sharing
Adversarial relationship	(AIA, 2007; Fischer et al., 2017)			(Kent and Becerik-Gerber, 2010; PMI, 2016)	(AIA, 2014)	(Hamzeh et al., 2019)
Fragmentation	(Kent and Becerik-Gerber, 2010; Piroozfar et al., 2019)			(PMI, 2016; Sive and Hays, 2009)	(AIA, 2014)	(Fischer et al., 2017)
Contractual disputes			(Hamzeh et al., 2019)	(Fischer et al., 2017; NASFA et al., 2010)		
Dis-integration	(Ghassemi and Becerik-Gerber, 2011)		(Hamzeh et al., 2019)	(AIA, 2007; Forbes and Ahmed, 2010)	(Azhar et al., 2015)	(NASFA et al., 2010)
Non-transparent relations				(AIA, 2007)		
Mistrust environment			(Ghassemi and Becerik-Gerber, 2011)	(AIA, 2007; De Marco and Karzouna, 2018)	(Azhar et al., 2015)	
Ineffective teams	(Kent and Becerik-Gerber, 2010; Piroozfar et al., 2019)					
High inefficiency	(El Asmar et al., 2013; Kent and Becerik-Gerber, 2010)		(Knapp et al., 2014)	(Forbes and Ahmed, 2010; Knapp et al., 2014)		

Table 2.3 (continued): Key IPD characteristics' effects on frequently faced problems in the CI.

Team and process related problems	Collaboration-related key characteristics			Contract-related key characteristics		
	Early involvement	Collectively defined goals	Collaborative decision-making	Multi-party contracts	Joint liability	Risk and reward sharing
Low productivity	(Ghassemi and Becerik-Gerber, 2011)	(Piroozfar et al., 2019)			(Piroozfar et al., 2019)	(Piroozfar et al., 2019)
Cost overruns	(El Asmar et al., 2013; Fischer et al., 2017; Ghassemi and Becerik-Gerber, 2011; NASFA et al., 2010)	(AIA, 2007; Azhar et al., 2015)	(Knapp et al., 2014)	(Forbes and Ahmed, 2010)		(Azhar et al., 2015; Fischer et al., 2017)
Schedule overruns	(NASFA et al., 2010)	(AIA, 2007; Azhar et al., 2015; Mesa et al., 2016)		(Forbes and Ahmed, 2010)		(Azhar et al., 2015; Fischer et al., 2017)
Poor end quality		(AIA, 2007; Azhar et al., 2015; Mesa et al., 2016)	(Knapp et al., 2014)	(Forbes and Ahmed, 2010; Knapp et al., 2014)		
Inconsistency between design and construction	(Fischer et al., 2017; NASFA et al., 2010)			(Ghassemi and Becerik-Gerber, 2011)		
Over-reworks	(Ashcraft, 2014b)					
Errors	(Ashcraft, 2014b)					
Omissions	(Ashcraft, 2014b)					
Waste	(Ashcraft, 2014b; Zhang et al., 2013)			(AIA, 2007)		
Excessive liability claims	(Azhar et al., 2015)			(Fischer et al., 2017)	(Azhar et al., 2015)	(Azhar et al., 2015; Fischer et al., 2017)
Data losses	(Ghassemi and Becerik-Gerber, 2011)					
Excessive design changes	(Kent and Becerik-Gerber, 2010; NASFA et al., 2010; Piroozfar et al., 2019)				(AIA, 2014)	(Fischer et al., 2017)

2.3.3 IPD team establishment

The CI's inability to establish an effective team is perceived among the main reasons for many problems that the CI is faced (Baiden et al., 2006). IPD's main characteristics are established to increase teamwork efficiency by both leveraging the collaboration capabilities and preparing necessary legal arrangements contractually (AIA, 2007). Team integration necessitates assembling individual targets, demands, practices and cultures into a single body operating collaboratively with the aligned processes and knowledge (Baiden and Price, 2011; Choi et al., 2019). Integrated teams can diminish the traditional boundaries between individuals to work on mutual outcomes and objectives by promoting easy and free information sharing (Baiden and Price, 2011). Empirical results show that the cost and schedule performance of the projects executed by integrated teams are higher than those not having integrated units (Molenaar et al., 2014). According to AIA (2007), successful team establishment in IPD can be done by implementing the following stages (AIA, 2007):

- Determination of the key roles as early as possible,
- Qualification based selection of team members,
- Addition of third parties for the project's best interests,
- Definition of goals and objectives collectively,
- Designation of administrative and work structures best fit to IPD,
- Establishment of arrangements to clearly define the responsibilities and liabilities of participants.

In IPD, key stakeholders' representatives form a Core Group which is responsible for not only execution but also guidance and management of the project (Fischer et al., 2017; Knapp et al., 2014). The multi-party contracts define the Core Group and allow the addition of other parties' representatives (ConsensusDocs LLC, 2016). Team size is crucial for effective process and decision-making (Fischer et al., 2017). While teams having more than 10 members are more likely to improve alternatives and less likely to create a collaborative environment, teams less than 5 members lack diversified skills and knowledge (Fischer et al., 2017; Knapp et al., 2014; Robbins, 2003). Therefore, keeping the team size between 5 and 9 is desirable for utilizing different expertises and working collaboratively (Robbins and Judge, 2014). If the task is excessively enormous for handling effectively, the task ought to be divided into subtasks (Fischer et al., 2017).

As construction projects have a broad scope, IPD forms subteams compositions consisting of PET (Project Executive Team), PMT (Project Management Team) and PIT (Project Implementation Team) to make the process more manageable (AIA, 2009; Allison et al., 2018; NASFA et al., 2010), where PET, also called as SMT (Senior Management Team), consists of executives from each stakeholder signing the multi-party contract and is responsible for dispute resolution and supervising the PMT (AIA, 2009; Allison et al., 2018) whereas PMT acts as an intermediary between PET and PITs by managing the project and making daily decisions unanimously (AIA, 2010). PITs can be comprised of any member of involved parties to perform specific jobs within the limited time given by PMT (Allison et al., 2018). As these teams play a crucial role in achieving targeted project outcomes by making decisions related to the project, all parties need to pay particular attention to the selection process of team members, especially in PMT (NASFA et al., 2010).

2.4 BIM Adoption and Implementation in IPD

The opinion about a model that contains all of the information related to construction dated to studies about parametric modeling in the late 1970s and early 1980s, and BIM came into existence and started to use in the CI in the mid-2000s (Azhar et al., 2012). BIM's definitions and uses vary from profession to profession because of its comprehensive and widely distributed applications (Aranda-Mena et al., 2009). BIM can be perceived as a software application, or it can mean either a process development for the creation and documentation of building-related information or a new approach that requires changes in policies, contracts, and relationships amongst construction actors (Aranda-Mena et al., 2009). BIM's dimensions from 3D to 7D have emerged with the addition of new capabilities to the model in the fields of visualization, schedule, cost, sustainability analysis, and operation-related applications, respectively (Barnes, 2014; Deutsch, 2011). BIM offers different application areas for each dimension as following: BIM's dimensions from 3D to 7D have emerged with the addition of new capabilities to the model in the fields of visualization, schedule, cost, sustainability analysis, and operation-related applications, respectively (Barnes, 2014; Deutsch, 2011). BIM offers different application areas for each dimension as follows (Barnes, 2014; Eynon, 2016): clash detection, advanced visualization and prefabrication in 3D (Barnes, 2014; Eynon, 2016); schedule planning, management and visualisation in 4D (Barnes, 2014; Eynon, 2016); cost and quantity estimations in 5D (Barnes, 2014; Eynon, 2016); energy and life-cycle analysis in 6D (Barnes, 2014; Eynon, 2016); and facility management applications in 7D (Barnes, 2014; Eynon, 2016).

BIM is an effective driver for using the integrated approach (Sive and Hays, 2009; Sun et al., 2015). BIM can enable the multi-disciplinary team to work and collaborate on the virtual model by combining their individual ideas, knowledge and capabilities (Sun et al., 2015). IPD prepares an appropriate working environment for BIM by removing different stakeholders' contractual and communication barriers (Piroozfar et al., 2019). There are specific applications of BIM (e.g., data and visual accuracy, quantity take-offs, multi-user integration, energy and sustainability analysis, and reporting) which can reinforce the implementation of IPD's key characteristics (Azhar et al., 2014). Since IPD and BIM are systems and tools that cannot be adopted and implemented indissociably, BIM's barriers also appear in the IPD process (Ghassemi and Becerik-Gerber, 2011). BIM's obstacles can be examined under three categories including, process, people, and tools (Fakhimi et al., 2016). IPD's contractual and collaboration related characteristics are highly influential for overcoming some barriers of BIM like adverse work environment, risk allocation, liability concerns, and ineffective communication (Azhar et al., 2012 as cited by Fakhimi et al., 2016).

2.5 IPD and Project Success

Project success is not a simple term referencing the acceptance of the project with the achievement of the targeted schedule, budget, and quality (de Wit, 1988). Each organization involved to project may define and measure success in the scope of their business plan, and sometimes these definitions can be incompatible with each other (de Wit, 1988; T. A. Nguyen and Chovichien, 2013). IPD aims for a behavioral change in the construction teams by aligning individual success to project success with the achievement of collectively defined goals as stated in the incentive and compensation structure of the multi-party contract (AIA, 2007; NASFA et al., 2010). CSF lists can help the adoption of new systems and tools by clarifying what is best for the project (Antwi-Afari et al., 2018). Whang et al. (2019) examined the relative importance of 60 IPD-related factors, and the result showed that the following factors have a direct impact on the IPD projects' success: implementation of multi-party contract, team creation and management, early involvement, and the use of BIM (Whang et al., 2019). As Whang et al. (2019)'s study reveals the importance of implementing key characteristics, adopting BIM, and establishing teams, Tables 2.4, 2.5 and 2.6 have been prepared to emphasise each factors' effect on project success and adoption in current practices of the CI.

Table 2.4 : BIM-related factors.

BIM-related factors	References
Developing customized IPD business process involving BIM technology	(Whang et al., 2019)
Organizational structure to support BIM	(Won and Lee, 2010)
Communication of BIM objectives	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)
Standardized work procedures for BIM	(Won and Lee, 2010)
Allocation of budget toward BIM	(Badrinath and Hsieh, 2019)
Owners' satisfaction with BIM projects	(Won and Lee, 2010)
Early understanding of O&M-stage BIM uses	(Badrinath and Hsieh, 2019)
Owners' interest/request for BIM	(Won and Lee, 2010)
Documented BEP	(Badrinath and Hsieh, 2019)
General perception of BIM	(Amuda-Yusuf, 2018; Ugwu and Kumaraswamy, 2007)
Number of partners who have experienced BIM projects	(Won and Lee, 2010)
Incentive programs for using BIM	(Won and Lee, 2010)
BIM competence of in-house team	(Amuda-Yusuf, 2018; Morlhon et al., 2014; Singh et al., 2011)
BIM/FM integration	(Badrinath and Hsieh, 2019)
Use of BIM as a visual aid	(Yu et al., 2019)
Use of BIM for design and documentation	(Yu et al., 2019)
Use of BIM for performance improvement	(Yu et al., 2019)

Table 2.5 : IPD-related factors.

IPD-related factors	References
Early involvement of key participants	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)
Regular meetings	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)
Collectively defined project goals	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; Azhar et al., 2014, 2015; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)
Selection of decision making body	(AIA, 2007; Azhar et al., 2014; Whang et al., 2019)
Establishing project's information specification	(AIA, 2007; Lahdenperä, 2012)
Establishing the communication protocol	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)
Software choice	(AIA, 2007; Amuda-Yusuf, 2018; Ugwu and Kumaraswamy, 2007)
How develop, access and use the model	(AIA, 2007)
Information sharing protocols	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)
BIM Protocol	(AIA, 2007)
Collaborative contracting arrangements	(AIA, 2007)
Internal dispute resolution	(AIA, 2007; Hamzeh et al., 2019; Kog and Loh, 2012; Lahdenperä, 2012; Toor and Ogunlana, 2009)
End users' involvement	(Amuda-Yusuf, 2018; Fortune and White, 2006; Lam et al., 2008; Ugwu and Kumaraswamy, 2007)
Identification of project metric	(AIA, 2007; Won and Lee, 2010)
Joint Liability	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
Accountability	(AIA, 2007)
Financial incentives	(AIA, 2007; Chang et al., 2017; Kog and Loh, 2012; Yu et al., 2019)
Financial transparency	(AIA, 2007; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
Formal dispute resolution	(AIA, 2007)
Decision structures	(AIA, 2007; Whang et al., 2019)
Shared contingency pool	(AIA, 2007; Mesa et al., 2016)
Identification of time to measure to project goals	(AIA, 2007; Azhar et al., 2014)
Facilitated negotiations	(AIA, 2007)

Table 2.1 (continued) : IPD-related factors.

IPD-related factors	References
Binding resolution	(AIA, 2007)
Organizational and business structure best suited to IPD	(AIA, 2007; Ashcraft, 2014a; Hamzeh et al., 2019)
Shared financial risk and reward	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2014, 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Yu et al., 2019)
Collaborative decision-making	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)
Key participants equality	(AIA, 2007; Lahdenperä, 2012; Mesa et al., 2019)
Intensified design	(AIA, 2007; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019)
Multiparty Contract	(AIA, 2007; Azhar et al., 2014, 2015; Chang et al., 2017; Lahdenperä, 2012; Matthews and Howell, 2005; Mesa et al., 2019; Piroozfar et al., 2019; Sun et al., 2015; Yu et al., 2019)
Established process for handling change orders	(Hamzeh et al., 2019; Yu et al., 2019)
Goals-owner's desired outcomes alignment	(Azhar et al., 2014; Yu et al., 2019)
Efforts in reducing waste in time	(Yu et al., 2019)
Collaborative activity duration estimation	(Yu et al., 2019)
Careful contract review	(Yu et al., 2019)
Proper organization setting before design	(Yu et al., 2019)
Early goal definition	(Azhar et al., 2014; Piroozfar et al., 2019; Yu et al., 2019)
Integrated project insurance	(Chang et al., 2017)

Table 2.6 : IPD team-related factors.

Team-related factors	References
Team selection	(AIA, 2007; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009)
Team involvement	(AIA, 2007)
Team formation	(AIA, 2007; Chang et al., 2017; Piroozfar et al., 2019; Whang et al., 2019)
Team integration	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)
Commitment of team	(AIA, 2007)
Continuity of values	(AIA, 2007)
Continuity of team	(AIA, 2007)
Competencies of team	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; Nguyen et al., 2004; Toor and Ogunlana, 2009)
Subteams composition depending on purposes	(Yu et al., 2019)
Empowerment of team members	(Yu et al., 2019)
Good communication atmosphere	(Hamzeh et al., 2019; Yu et al., 2019)

3. RESEARCH METHODS

This study aims to investigate the IPD characteristics' adoption in current practices of the CI and their impacts on process and team related problems of the industry while creating an IPD specific CSFs' preliminary list to measure the effect of IPD, IPD-team and BIM on project success (Table 1.1). To achieve this aim, the objectives of this study are as follows:

- Objective 1: To determine the process and team related problems of the CI and examine their occurrence in construction projects.
- Objective 2: To determine the adoption of IPD, BIM and IPD team characteristics in construction projects.
- Objective 3: To determine IPD related CSFs and to examine their importance for project success in IPD projects.
- Objective 4: To determine BIM related CSFs in IPD projects and to examine their importance for project success in IPD projects.
- Objective 5: To determine and rank IPD team related CSFs in IPD projects.

First of all, in-depth literature has been carried out to determine the common problems in the CI (Table 2.1). These problems were evaluated under three primary and six subcategories (Figure 2.1). Articles, guides, and reports were reviewed to specify IPD, IPD team and BIM characteristics. Moreover, factor lists covering key stakeholders' roles and responsibilities in IPD were prepared using the AIA's IPD guide as the basis (AIA, 2007). Prepared lists were used to conduct an online questionnaire survey, interviews and the Delphi method to achieve the research objectives and provided in the Appendix A. Figure 3.1 shows the flowchart diagram of the study and the use of prepared lists in research methods in detail. The approval to conduct the study covering all research methods was granted from the Istanbul Technical University's Ethics Committee for Social and Human Sciences Human Studies.

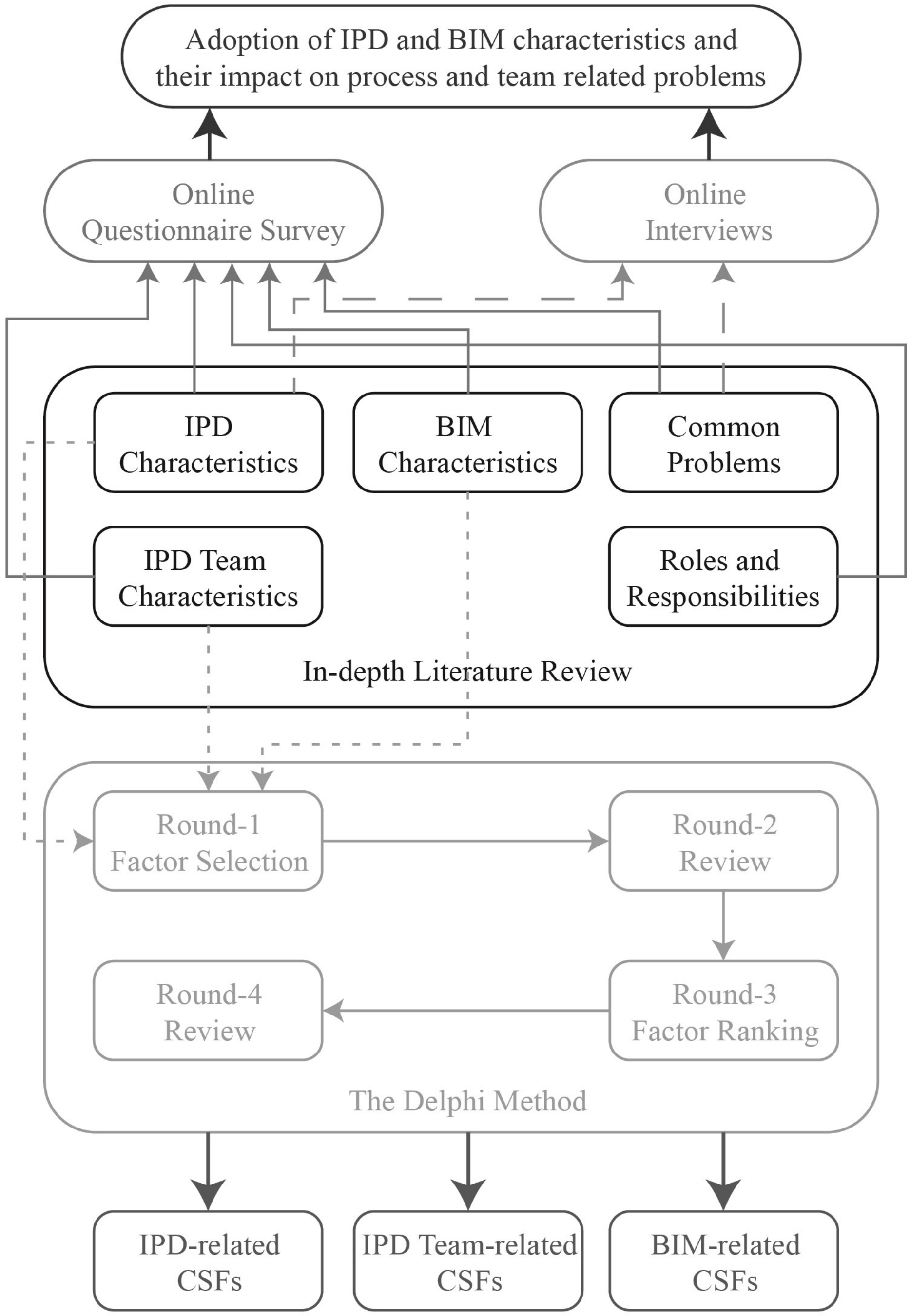

Figure 3.1 : Flowchart diagram of research methods and targeted aims.

3.1 Online Questionnaire Survey

Within the scope of the first two objectives, an online questionnaire survey was conducted with professionals and academics having experience in or researches on IPD and BIM. It was aimed to conduct the study anonymously, without asking for any personal information from the participants. Participation in the online questionnaire survey was voluntary, and participants could leave the study at any time they wanted. The survey has been sent to 110 people and 31 people responded.

The questionnaire consisted of two pages, on the first page the participants' professional experiences were asked. On the second page, there were questions in compliance with the objectives. The online questionnaire and the references of the factors in the online questionnaire have been provided in the Appendix B and C. In the first three questions on the first page, the participants were asked about their construction, IPD, and BIM experiences, respectively. The fourth question was about which stakeholders the participants have worked for in the CI. Table 3.1 shows the distribution of stakeholders in the questionnaire survey sample. In the fifth question, the sub-teams of the participants in IPD and BIM-based projects were examined. In the sixth question, participants were asked to specify which dimension(s) of BIM has (have) been used in the project they were involved. Table 3.2 shows the frequency of BIM dimensions. The second section of the questionnaire consisted of seven questions. In question 1, participants were asked to indicate the level of frequency of listed 22 problems they have encountered in the CI with respect to their frequency at the 7-point Likert scale (Vagias, 2006). The successive three questions were about ranking the priority of IPD, BIM and IPD-team characteristics with respect to their priority at the 7-point Likert scale (Vagias, 2006). The last three questions were about ranking the priority of the roles and responsibilities of key stakeholders.

The Independent- Sample T Test has been applied in order to examine the difference in the mean values for encountering team and process related problems between questionnaire survey participants who use BIM 3D only and participants who use more than one dimension.

Table 3.1 : Stakeholder distribution of the questionnaire survey sample.

Stakeholders	Responses		Percent of Cases
	Frequency	Percent	
Owner	10	16,90%	34,50%
Designer	4	6,80%	13,80%
Design Consultant	20	33,90%	69,00%
Prime Constructor	14	23,70%	48,30%
Trade Constructor	5	8,50%	17,20%
Suppliers	3	5,10%	10,30%
Agencies	3	5,10%	10,30%
Total	59	100,00%	203,40%

Table 3.2 : Percentages of BIM dimensions use in the questionnaire survey sample.

BIM dimensions	Responses		Percent of Cases
	Frequency	Percent	
3D	24	36,90%	82,80%
4D	21	32,30%	72,40%
5D	12	18,50%	41,40%
6D	1	1,50%	3,40%
7D	7	10,80%	24,10%
Total	65	100,00%	224,10%

3.2 Online Interviews

Online interviews have been conducted to investigate the change in common problems of the industry, and to evaluate the adoption of IPD characteristics' in current practices. First, the participants were asked to assess the changes in the frequency of encountering the problems mentioned in the literature during their professional/academic experience. After that, the participants were requested to indicate both which IPD characteristics they adopted in current construction practices and perceived drivers for and barriers against the integrated approach. Finally, the participants' opinions about the changes they expect in the CI in the upcoming period were taken. The online interviews questions have been provided in the Appendix D.

Online interviews have been performed with 15 participants and took approximately 25 minutes. Table 3.3 shows the qualifications of the participants.

Table 3.3 : Interviewed professionals.

Experience in the industry (in years)	Experience with integrated practices (in years)	Stakeholders worked on behalf of
5	2	The owner, prime designer
33	5	The owner, prime designer
30	4	The owner, prime designer, prime constructor
25	3	The owner, prime designer, prime constructor, trade constructor and suppliers, agencies
5	5	The owner, prime designer, prime constructor
7	4	Prime designer, prime constructor
15	5	Prime designer (Academic)
8	3	The owner, prime constructor
25	6	Prime designer (Academic)
33	12	Prime designer

Table 3.3 (continued) : Interviewed professionals

Experience in the industry (in years)	Experience with integrated practices (in years)	Stakeholders worked on behalf of
7	7	Prime designer, consultants, suppliers, agencies
9	7	Prime designer
7	4	Consultants
17	12	Prime constructor, consultants
12	10	Prime constructor, consultants

3.3 The Delphi Method

The Delphi method consists of a series of comprehensive survey rounds combined with a structured feedback cycle to collect the most reliable unanimity from experts' opinions (Dalkey and Helmer, 1963). Hallowell and Gambatese (2010) examined the compatibility of the Delphi method in CM literature, and revealed that some industry features like multidisciplinary nature and dynamic work environment make the Delphi method very useful. There is no generally accepted limitation in the number of participant (Hallowell and Gambatese, 2010; Skulmoski et al., 2007). The number of panelists may vary between three and hundreds (Skulmoski et al., 2007). Hallowell and Gambatese (2010) suggested that minimum of eight experts are enough for conducting the Delphi survey.

In this study, the simultaneous 3 group Delphi Surveys were conducted on three different sub-topics, namely: IPD-related factors, BIM-related factors, IPD team-related factors. Participants were asked to choose the sub-topics according to their expertise and knowledge. 3 different Delphi groups, for IPD-related factors, BIM-related factors, IPD team-related factors respectively, were conducted through 4 rounds. Characteristics of the conducted Delphi Method and applied techniques to minimize bias are shown in Table 3.4. Methods to minimize bias are taken from the study of Hallowell and Gambatese (2010).

Table 3.4 : Delphi Method characteristics and applied techniques to minimize bias in the study.

Characteristics and methods (Hallowell and Gambatese, 2010)	Application in the study
Participants’ qualifications	Construction professionals having more than five years of experience with IPD or BIM Academicians having IPD related publications
Number of participants	21 in total At least 8 for each sub-topic
Number of rounds	4
Validation rounds	2 and 4
Contrast effect	Factor orders are randomized in round 3
Primacy effect	Factors are arranged differently for each participant in round 3
Dominance	Anonymous feedbacks

The first round of the 3 groups of the Delphi study: IPD, BIM and IPD team related factors extracted from the literature were sent to the selected 66 experts and 21 people returned. In this round, participants were asked to select crucial factors for project success. Total numbers of IPD, BIM, and IPD team-related factors were 38, 17 and 11, respectively. The selection range for sub-topics was between 15 and 20 in IPD-related factors and 5 to 10 in BIM and IPD team-related factors. The first round of the Delphi study was conducted with 3 different groups of experts (professionals/academics). The number of participants for 3 groups of Delphi Survey (i.e. IPD, BIM and IPD-team related factors) were 8, 15, and 8, respectively. Figure 3.2, Figure 3.3 and Figure 3.4 show the distribution of professional and/or academic experiences of first round participants for each group.

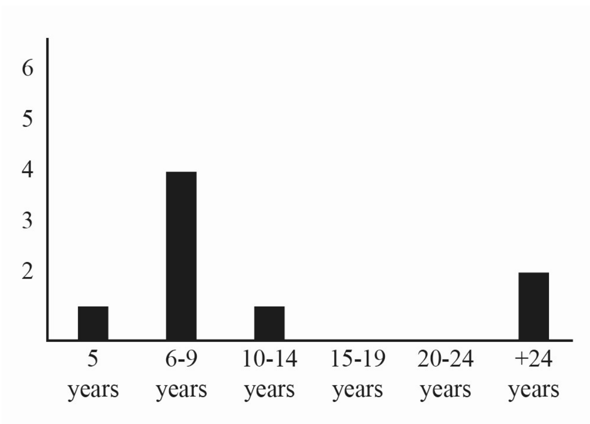

Figure 3.2 : Professional/academic experiences of the Delphi round 1 participants (IPD-related factors).

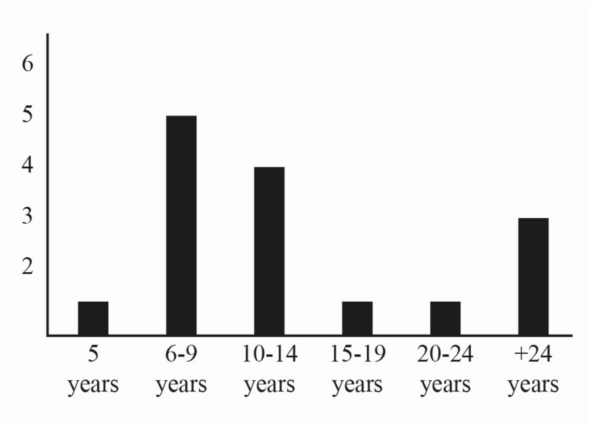

Figure 3.3 : Professional/academic experiences of the Delphi round 1 participants (BIM-related factors).

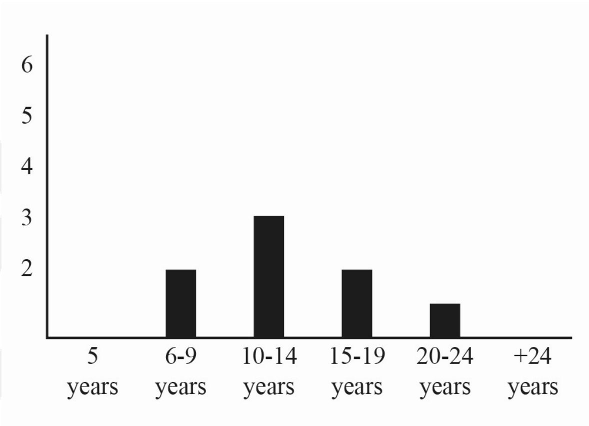

Figure 3.4 : Professional/academic experiences of the Delphi round 1 participants (IPD Team-related factors).

The second round of the 3 group Delphi study: After the completion of the first round, the results were combined and ranked according to participants' selections. The second round questionnaires were prepared for each participant, indicating their answers and the percentage of participants who chose each factor. The forms were sent to the participants and asked to evaluate their answers and whether or not they wanted to change them.

The third round of the 3 group Delphi study: The results of second round were combined and ranked according to participants' selections. The third round questionnaires for each group were prepared with the factors selected by half or more of the participants in the previous round. Participants were asked to evaluate the impact of each factor on project success at the 7-point Likert scale of importance.

The fourth round of the 3 group Delphi study: Participants were evaluated their rankings in third round by reviewing the mean and SD (standard deviation) of each factor.

Determination of the preliminary CSFs list: Following the fourth round of the 3 groups Delphi study results were obtained, factors were ranked based on their mean scores. In order to increase the reliability of the study, some factors were removed from the list. After that, 5,5 out of 7 has been determined as a cut-off point for identifying CSFs in the CSFs preliminary list. Moreover, CSFs identified through the Delphi method were further examined based on the questionnaire survey findings. The Independent- Sample T Test has been applied to reveal any significant difference between the mean values of CSFs' adoption status based on the participants' IPD experience.

4. RESULTS

4.1 Data Obtained Through Questionnaire Survey

In this part of the dissertation, statistical results of the questionnaire survey are provided. Reliability Analysis (Cronbach's Alpha) of each section are presented in Table 4.1. Cronbach's Alpha value of 6 sections is greater than 0,9 with an excellent reliability level, and the α value of BIM-related characteristics is between 0,8 and 0,9. This α value corresponds to good reliability level (Hair et al., 2020).

Table 4.1 : Reliability statistics of each section.

Sections	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Common problems	0,944	0,946	22
IPD-related characteristics	0,940	0,94	19
Team-related characteristics	0,922	0,924	9
BIM-related characteristics	0,859	0,866	8
Roles and responsibilities of the owner	0,945	0,948	16
Roles and responsibilities of the prime designer and design consultants	0,934	0,935	22
Roles and responsibilities of the prime constructor and subcontractor	0,915	0,914	14

In the first section, the participants evaluated the frequency of encountering common problems in the CI on a 7-point Likert scale. Problems were ranked based on their mean score (Table 4.2). If the mean scores were equal, the problem with the smaller SD was ranked first.

Table 4.2 : Means and SDs of common problems.

Rank	Common problems	Mean	Std. Deviation	N	References
1	Disintegration	5,06	1,750	31	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; NASFA et al., 2010; Sive and Hays, 2009; Zhang et al., 2013)
2	Schedule overruns	5,06	1,750	31	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)
3	Over-reworks	4,84	1,614	31	(Yu et al., 2019)
4	Cost overruns	4,71	1,553	31	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; NASFA et al., 2010; Zhang et al., 2013)
5	Excessive design changes	4,65	1,854	31	(Baiden et al., 2006)
6	Omissions	4,42	1,361	31	(Baiden et al., 2006; NASFA et al., 2010)
7	Errors	4,39	1,308	31	(NASFA et al., 2010; Yu et al., 2019)
8	Waste	4,19	1,701	31	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011)
9	Adversarial relationship	4,13	1,432	31	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; Yu et al., 2019; Zhang et al., 2013)
10	Inconsistency between design and actual work	4,13	1,586	31	(Yu et al., 2019)
11	Low productivity	4,06	1,482	31	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; NASFA et al., 2010; Yu et al., 2019)
12	Ineffective teams	3,97	1,354	31	(Baiden et al., 2006; CURT, 2004)
13	Contractual disputes	3,94	1,315	31	(De Marco and Karzouna, 2018; Zhang et al., 2013)
14	Data losses	3,94	1,931	31	(Baiden et al., 2006)
15	High inefficiency	3,90	1,700	31	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; NASFA et al., 2010; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019; Zhang et al., 2013)
16	Fragmentation	3,68	1,194	31	(Baiden et al., 2006; Lahdenperä, 2012; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019)
17	Degraded project value	3,65	1,561	31	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016)
18	Mistrust environment	3,65	1,704	31	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011)
19	Poor end quality	3,52	1,546	31	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)
20	Excessive liability claims	3,32	1,492	31	(Baiden et al., 2006)
21	Non-transparent relations	3,10	1,777	31	(Baiden et al., 2006)

In the following three sections, the participants evaluated the priority of IPD, BIM and IPD team related characteristics' adoption in the current practices on a 7-point Likert scale. Characteristics were ranked based on their mean score. If the mean scores were equal, the characteristic with the smaller SD was ranked first. Table 4.3, 4.4 and 4.5 shows the results of related sections, respectively.

Table 4.3 : Means and SDs of IPD-related characteristics.

Rank	IPD-related characteristics.	Mean	Std. Deviation	N	References
1	Information sharing protocols	5,68	1,137	31	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)
2	BIM Protocol	5,55	1,338	31	(AIA, 2007)
3	Collectively defined project goals	5,52	1,503	31	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; N. Azhar et al., 2015, 2014; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)
4	Software choice	5,42	1,478	31	(AIA, 2007; Amuda-Yusuf, 2018; Ugwu and Kumaraswamy, 2007)
5	How develop, access, and use the model	5,35	1,427	31	(AIA, 2007)
6	Proper organization setting before design	5,32	1,301	31	(Yu et al., 2019)
7	Collaborative decision-making	5,32	1,536	31	(AIA, 2007; Ashcraft, 2014b; N. Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)
8	Establishing project's information specification	5,29	1,510	31	(AIA, 2007; Lahdenperä, 2012)
9	Establishing the communication protocol	5,16	1,508	31	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)
10	Collaborative contracting arrangements	5,10	1,326	31	(AIA, 2007)
11	Goals-owner's desired outcomes alignment	5,10	1,375	31	(N. Azhar et al., 2014; Yu et al., 2019)
12	Early involvement of participants	5,03	1,958	31	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; N. Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)
13	Established process for handling change orders	5,00	1,366	31	(Hamzeh et al., 2019; Yu et al., 2019)
14	Joint Liability	5,00	1,414	31	(AIA, 2007; Ashcraft, 2014b; N. Azhar et al., 2015; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
15	Accountability	4,97	1,426	31	(AIA, 2007)
16	Financial transparency	4,97	1,560	31	(AIA, 2007; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
17	Regular meetings	4,87	1,522	31	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)
18	Shared financial risk and reward	4,77	1,586	31	(AIA, 2007; Ashcraft, 2014b; N. Azhar et al., 2014, 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Yu et al., 2019)
19	Financial incentives	4,52	1,503	31	(AIA, 2007; Chang et al., 2017; Kog and Loh, 2012; Yu et al., 2019)

Table 4.4 : Means and SDs of BIM-related characteristics.

Rank	BIM-related characteristics	Mean	Std. Deviation	N	References
1	Documented BEP	6,32	0,979	31	(Badrinath and Hsieh, 2019)
2	Use of BIM for design and documentation	6,06	0,772	31	(Yu et al., 2019)
3	Organizational structure to support BIM	6,06	0,892	31	(Won and Lee, 2010)
4	Standardized work procedures for BIM	5,97	1,016	31	(Won and Lee, 2010)
5	Communication of BIM objectives	5,71	1,039	31	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)
6	BIM competence of in-house team	5,61	1,145	31	(Amuda-Yusuf, 2018; Morlhon et al., 2014; Singh et al., 2011)
7	Allocation of budget toward BIM	5,45	1,261	31	(Badrinath and Hsieh, 2019)
8	Number of subcontractors who have experienced BIM projects	5,13	1,284	31	(Won and Lee, 2010)

Table 4.5 : Means and SDs of team-related characteristics.

Rank	Team-related characteristics	Mean	Std. Deviation	N	References
1	Good communication atmosphere	6,10	1,076	31	(Hamzeh et al., 2019; Yu et al., 2019)
2	Team collaboration	5,97	1,197	31	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)
3	Commitment of team	5,97	1,140	31	(AIA, 2007)
4	Team involvement	5,84	1,344	31	(AIA, 2007)
5	Empowerment of team members	5,81	1,167	31	(Yu et al., 2019)
6	Continuity of values	5,61	1,334	31	(AIA, 2007)
7	Sub-teams compositions	5,55	1,312	31	(Yu et al., 2019)
8	Continuity of team	5,42	1,177	31	(AIA, 2007)
9	Competencies of team	5,42	1,385	31	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; L. D. Nguyen et al., 2004; Toor and Ogunlana, 2009)

In the last three sections, the participants evaluated the priority of roles and responsibilities of the stakeholders mentioned in the IPD guide (AIA, 2007) in the current practices on a 7-point Likert scale. Roles and responsibilities were ranked based on their mean score. If the mean scores were equal, the factor with the smaller SD was ranked first. Table 4.6, 4.7 and 4.8 shows the results of related sections, respectively.

Table 4.6 : Means and SDs of roles and responsibilities of the owner in IPD process.

Rank	Roles and responsibilities of the owner	Mean	Std. Deviation	N	References
1	Clear definitions of scope of services	6,06	1,237	31	(AIA,2007;Nguyen et al.,2004;Sanvido et al.,1992;Whang et al.,2019)
2	Owner's approval of design	6,00	0,931	31	(AIA,2007)
3	Clear definitions of teams' tasks and responsibilities	5,94	1,031	31	(Azhar et al.,2014; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Whang et al., 2019)
4	Clarity of owner's requirements	5,68	1,400	31	(Lam et al.,2008)
5	Owner's contractual obligations	5,68	1,249	31	(AIA,2007)
6	Evaluating and influencing design options	5,61	0,955	31	(AIA,2007; Hamzeh et al.,2019)
7	Clear definition and understanding of users' requirements	5,61	1,334	31	(Amuda- Yusuf, 2018; Morlhon et al., 2014; Ugwu and Kumaraswamy, 2007)
8	Continual monitoring of project with respect to project goals and metrics related to performance	5,58	1,432	31	(AIA,2007)
9	Owner's internal review and decision process	5,48	1,208	31	(AIA,2007)
10	Providing site data	5,48	1,458	31	(AIA,2007)
11	Early owner participation	5,45	1,480	31	(Yu et al.,2019)
12	Suitability between project initial objective and final product	5,45	1,362	31	(Nguyen and Chovichien, 2013)
13	Final user reviews and approvals	5,42	1,649	31	(AIA,2007)
14	Defining and controlling the relation between project and business case	5,29	0,902	31	(AIA,2007)
15	Effective change management	5,23	1,283	31	(Fortune and White, 2006; Toor and Ogunlana, 2009)
16	Negotiations with jurisdiction providing permits	5,16	1,267	31	(AIA,2007)

Table 4.7 : Means and SDs of roles and responsibilities of the prime designer and design consultants in IPD process.

Rank	Roles and responsibilities of the prime designer and design consultants	Mean	Std. Deviation	N	References
1	Coordination of RFI and submittal responses from all design consultants	5,77	1,175	31	(AIA,2007)
2	Regulatory requirements for the building (i.e.: fire/life safety plan)	5,74	1,154	31	(AIA,2007)
3	Identification of project and system requirements	5,71	1,006	31	(AIA,2007)
4	Specification finalization	5,71	1,039	31	(AIA,2007)
5	Completeness of model for architecturally related design intent for construction	5,65	0,950	31	(AIA,2007)

Table 4.7 (continued) : Means and SDs of roles and responsibilities of the prime designer and design consultants in IPD process.

Rank	Roles and responsibilities of the prime designer and design consultants	Mean	Std. Deviation	N	References
6	Ensuring coordination to selection of major building systems and performance requirements	5,65	1,305	31	(AIA,2007)
7	Identification of unique conditions in criteria design	5,61	0,919	31	(AIA,2007)
8	Locating major pieces of equipment and routing in the project	5,61	1,174	31	(AIA,2007)
9	Using the BIM for life cycle benefit	5,61	1,256	31	(AIA,2007)
10	BIM Model updates during construction	5,58	1,285	31	(AIA,2007)
11	Designer's response to RFI's	5,58	1,409	31	(AIA,2007)
12	3D detailing	5,55	1,060	31	(Badrinath and Hsieh, 2019)
13	Providing descriptive information for fabrication and construction of architecturally related scope	5,48	1,262	31	(AIA,2007)
14	Interoperability of BIM with agencies to ensure code compliance	5,48	1,262	31	(AIA,2007)
15	Design schedule (Accuracy)	5,48	1,411	31	(AIA,2007)
16	Selection of major building systems	5,42	1,089	31	(AIA,2007)
17	Alignment of space program with project goals	5,39	1,308	31	(AIA,2007)
18	Integrity of the design intent and pre-fabrication studies	5,26	1,154	31	(AIA,2007)
19	Effective consultation with key stakeholders	5,26	1,437	31	(AIA,2007; Khang and Moe, 2008)
20	Variety of design options	5,23	1,257	31	(AIA, 2007; Fischer et al., 2017; Forbes and Ahmed, 2010; Hamzeh et al.,2019)
21	Accurate identification of sustainable design outcomes	5,13	1,384	31	(AIA,2007)
22	Construction Contract Administration	5,10	1,578	31	(AIA,2007)

Table 4.8 : Means and SDs of roles and responsibilities of the the prime constructor and subcontractors in IPD process.

Rank	Roles and responsibilities of the prime constructor and subcontractor	Mean	Std. Deviation	N	References
1	Compatibility with the design and work of other trades	6,06	0,772	31	(AIA, 2007)
2	Meeting schedule goal	5,97	0,875	31	(Sanvido et al., 1992; Shenhar et al., 2001)
3	Cost estimation	5,87	1,088	31	(Badrinath and Hsieh, 2019)
4	Shop drawings/ model	5,81	1,078	31	(AIA, 2007)
5	Trade contractors' coordination during construction	5,71	1,006	31	(AIA, 2007)
6	Constructability program	5,71	1,071	31	(AIA, 2007; Badrinath and Hsieh, 2019; Kog and Loh, 2012)

Table 4.8 (continued) : Means and SDs of roles and responsibilities of the the prime constructor and subcontractors in IPD process.

Rank	Roles and responsibilities of the prime constructor and subcontractor	Mean	Std. Deviation	N	References
7	Coordination of building systems	5,71	1,189	31	(AIA, 2007)
8	Completeness of BIM and specifications for applicable scope of work	5,68	1,107	31	(AIA, 2007)
9	Trade contractors' participation in coordination and conflict resolution	5,68	1,137	31	(AIA, 2007)
10	Construction Schedule (Accuracy)	5,65	1,018	31	(AIA, 2007)
11	Trade contractors' contribution to model	5,61	0,989	31	(AIA, 2007)
12	Identification of long lead items	5,42	1,259	31	(AIA, 2007)
13	Synchronized model for fabrication or installation purposes	5,42	1,409	31	(AIA, 2007)
14	Prefabrication opportunities	4,97	1,110	31	(AIA, 2007)

An Independent-Samples T test was applied to analyze whether any significant difference exists between the answers of participants who use BIM 3D only and participants who use more than one dimension. The results of the normality test unveiled that the data used for conducting the T test are normally distributed as the values gathered for Kurtosis and Skewness, for all items (i.e., team and process related problems) fulfil the proposed level of -1,5 to +1,5 (Tabachnick and Fidell, 2013). Table A.8 and Table A.9 show the results of the normality test and the Independent-Samples T test. A bivariate correlation analysis was made to examine the relationship between common problems and other characteristics. The chosen method for this analysis was Spearman's correlation as the collected data were in an ordinal scale (nonmetric) and Spearman's correlation assigns two values to variables for measuring the effect of each variable on another (Ling et al., 2020). The strength of the correlation is calculated by the p value and if p value is less than 0,05, there is a significant correlation between variables (Ling et al., 2020). Linear relationship between variables is calculated by the r value, ranging between -1 and 1 (Ling et al., 2020). Table A.10 and A.11 show the significant correlation coefficients of examined factors.

4.2 Data Obtained Through Interviews

In this part of the study, the results of the structured interviews are provided. Respondents' similar answers are grouped under each question. 17 topics were discussed with the interview participants. The change in the encountering common problems, the use of main IPD characteristics, driver for and barriers against the IPD adoption and implementation were the main topics for interviews.

Topic 1: Problems encountered more frequently and less frequently than before:

- Less frequently encountered problems
  - Over-reworks (12 participants)
  - Contractual disputes (8 participants)
  - Degraded project value (8 participants)
  - Fragmentation (6 participants)
  - Poor end quality (6 participants)
  - Excessive liability claims (6 participants)
  - Mistrust environment (5 participants)
  - Non-transparent relations (5 participants)
  - Cost overruns (5 participants)
  - Schedule overruns (5 participants)
  - Excessive design changes (5 participants)
  - Data losses (5 participants)
  - High inefficiency (4 participants)
  - Low productivity (4 participants)
  - Adversarial relationships (4 participants)
  - Dis-integration (4 participants)
  - Waste (4 participants)
  - Ineffective teams (3 participants)
- More frequently encountered problems

    - Cost overruns (8 participants)
    - Schedule overruns (8 participants)
    - Waste (8 participants)
    - Poor end quality (6 participants)
    - Dis-integration (6 participants)
    - Ineffective teams (5 participants)
    - Excessive design changes (5 participants)
    - High inefficiency (4 participants)
    - Low productivity (4 participants)
    - Adversarial relationships (4 participants)
    - Excessive liability claims (4 participants)
    - Data losses (3 participants)

Topic 2: Changes in the roles and responsibilities of stakeholders in construction projects over time:

- Prime constructors' input to design (7 participants)
- Continuous involvement of the owner (6 participants)
- Designers' more active involvement in construction process (5 participants)
- No change (5 participants)
- Design consultants' integration to design process (4 participants)
- Subcontractors' input to design (3 participants)
- Changes caused by the global pandemic (2 participants)

Topic 3: Changes in the involvement time of stakeholders to the project:

- Early involvement of prime constructor (7 participants)
- No change (5 participants)
- Early involvement of subcontractors (3 participants)
- End users' involvement (2 participants)

- Agencies' involvement (1 participant)

Topic 4: Changes in the use of contracts:

- Multi-party contracts between key stakeholders (5 participants)
- Optimized traditional contracts (5 participants)
- Traditional contracts (3 participants)
- Multi-party contracts with subcontactors (2 participants)

Topic 5: Changes in the project environment in terms of mutual respect and trust:

- Adverse changes (7 participants)
- Positive changes (5 participants)
- No change (3 participants)

Topic 6: Changes in the project environment in terms of collaboration and decision-making:

- More collaborative (12 participants)
- No change (3 participants)
- Collaborative decision-making (10 participants)
- Decision-making process under the responsibility of the owner (5 participants)

Topic 7: Changes in the project environment in terms of defining project goals:

- Jointly developed goals (12 participants)
- Defining project goals under the responsibility of the owner (3 participants)

Topic 8: Changes in the project environment in terms of communication:

- Open communication (12 participants)
    - Technological advancements (12 participants)
    - The use of BIM (9 participants)
    - Early involvement (5 participants)
- No change (3 participants)

Topic 9: Changes in the planning phase:

- Intensified and collaborative design (9 participants)
- No change (6 participants)

Topic 10: Risk sharing and incentive compensation in contract:

- Reward sharing (5 participants)
- Risk and reward sharing (5 participants)
- Traditional structures (3 participants)

Topic 11: Dispute resolution:

- Internal dispute resolution by IPD team (5 participants)
- Internal dispute resolution by the owner (4 participants)
- Negotiation, formal dispute resolution in case of disagreement (3 participants)

Topic 12: Transparency of financial calculations:

- Transparent, open-book calculations (5 participants)
- Some degree of transparency during cost estimation (3 participants)
- Non-transparent relations (3 participants)

Topic 13: Key stakeholders' equality:

- No change (10 participants)
- More equal conditions (5 participants)

Topic 14: Drivers for the adoption and implementation of integrated approaches:

- Technological advancements (8 participants)
- Achieving high efficiency teamwork (7 participants)
- The adoption of BIM (6 participants)
- More accurate schedule and cost estimation (6 participants)
- Contractual structures to support BIM implementation (4 participants)
- Minimizing risks (2 participants)
- Necessary legal arrangements (1 participants)

Topic 15: Barriers against the adoption and implementation of integrated approaches:

- Legal concerns (11 participants)
- Extra cost in first adoption period (8 participants)
- Resistance to change (7 participants)
- Lack of IPD experience (7 participants)
- Multi-disciplinary industry (6 participants)
- Communication problems (4 participants)

Topic 16: Expected changes in the CI:

- More technological integration (13 participants)
- Increase in the use of BIM (10 participants)
- Increase in the adoption of integrated practices (8 participants)
- Changes in the regulations to support BIM and integration (7 participants)
- Changes in the scope of construction works due to global pandemic (4 participants)
- Changes in the construction companies' corporate identity (1 participant)

Topic 17: Recommendations about the study:

- The impact of the country's economic situation on stakeholder relations can be evaluated. (1 participant)
- The role and effectiveness of stakeholders in the industry may differ from country to country. (1 participant)
- A distinction can be made between public and private owners. (1 participant)
- Some subcontractors may be involved in the process early, depending on their importance in the project. Subcontractors can be categorized according to their specialty. (1 participant)
- The type and size of the projects can be included in the scope of the research. (1 participant)

4.3 Data Obtained Through the Delphi Surveys

This section includes the data obtained through 4 rounds of the 3 group Delphi survey. The results have been presented based on their related rounds and groups.

4.3.1 IPD-related factors

The results of 4 round of the Delphi study about IPD-related CSFs have been presented in this section.

Delphi round 1: The participants were asked to select the factors that have an impact on the project success. Table 4.9 shows the results of the Delphi round 1.

Delphi round 2: The participants were given the right to make changes in their choices after reviewing the results of the first round. Table 4.9 shows the percent of the participants who choose specific items in the Delphi round 1 and 2.

Table 4.9 : Delphi round 1 and 2 results of IPD-related factors.

IPD-related factors	Selection percentage of participants (%) in Delphi round 1	Selection percentage of participants (%) in Delphi round 2	References
Early involvement of key participants	75	87,5	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)
BIM Protocol	75	87,5	(AIA, 2007)
Collectively defined project goals	75	75	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; Azhar et al., 2015, 2014; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)
Collaborative decision-making	75	75	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)
Regular meetings	62,5	75	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)
Establishing project's information specification	62,5	62,5	(AIA, 2007; Lahdenperä, 2012)
Establishing the communication protocol	62,5	62,5	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)
Software choice	62,5	62,5	(AIA, 2007; Amuda-Yusuf, 2018; Ugwu and Kumaraswamy, 2007)
How develop, access, and use the model	62,5	62,5	(AIA, 2007)
Information sharing protocols	62,5	62,5	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)
Financial transparency	62,5	62,5	(AIA, 2007; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)

Table 4.9 (continued): Delphi round 1 and 2 results of IPD-related factors.

IPD-related factors	Selection percentage of participants (%) in Delphi round 1	Selection percentage of participants (%) in Delphi round 2	References
Goals-owner's desired outcomes alignment	62,5	62,5	(Azhar et al., 2014; Yu et al., 2019)
Shared financial risk and reward	50	62,5	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2014, 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Yu et al., 2019)
Proper organization setting before design	50	62,5	(Yu et al., 2019)
Collaborative contracting arrangements	50	50	(AIA, 2007)
Joint Liability	50	50	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
Accountability	50	50	(AIA, 2007)
Financial incentives	50	50	(AIA, 2007; Chang et al., 2017; Kog and Loh, 2012; Yu et al., 2019)
Established process for handling change orders	50	50	(Hamzeh et al., 2019; Yu et al., 2019)
Selection of decision making body	37,5	37,5	(AIA, 2007; Azhar et al., 2014; Whang et al., 2019)
Internal dispute resolution	37,5	37,5	(AIA, 2007; Hamzeh et al., 2019; Kog and Loh, 2012; Lahdenperä, 2012; Toor and Ogunlana, 2009)
End users' involvement	37,5	37,5	(Amuda-Yusuf, 2018; Fortune and White, 2006; Lam et al., 2008; Ugwu and Kumaraswamy, 2007)
Identification of time to measure to project goals	37,5	37,5	(AIA, 2007; Azhar et al., 2014)
Organizational and business structure best suited to IPD	37,5	37,5	(AIA, 2007; Ashcraft, 2014a; Hamzeh et al., 2019)
Key participants' equality	37,5	37,5	(AIA, 2007; Lahdenperä, 2012; Mesa et al., 2019)
Efforts in reducing waste in time	37,5	37,5	(Yu et al., 2019)
Early goal definition	37,5	37,5	(Azhar et al., 2014; Piroozfar et al., 2019; Yu et al., 2019)
Integrated project insurance	37,5	37,5	(Chang et al., 2017)
Contingency funds	37,5	25	(AIA, 2007; Mesa et al., 2016)
Careful contract review	37,5	25	(Yu et al., 2019)
Identification of project metric	25	25	(AIA, 2007; Won and Lee, 2010)
Decision structures	25	25	(AIA, 2007; Whang et al., 2019)
Multiparty Contract	25	25	(AIA, 2007; Azhar et al., 2014, 2015; Chang et al., 2017; Lahdenperä, 2012; Matthews and Howell, 2005; Mesa et al., 2019; Piroozfar et al., 2019; Sun et al., 2015; Yu et al., 2019)
Collaborative activity duration estimation	25	25	(Yu et al., 2019)
Intensified design	12,5	12,5	(AIA, 2007; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019)
Formal dispute resolution	0	0	(AIA, 2007)
Facilitated negotiations	0	0	(AIA, 2007)
Binding resolution	0	0	(AIA, 2007)

Delphi round 3: A new list of factors was prepared with the factors selected by half or more of the participants in the Delphi round 2. Participants were asked to evaluate the impact of each factor on project success on a 7-point Likert scale of importance. Factor orders were randomized for each participant to minimize bias. Table 4.10 shows the means and SDs of the IPD-related factors. Factors were ranked according to their mean score. If the mean scores were equal, the factor with the smaller SD was ranked first.

Delphi round 4: In this round, participants were evaluated their rankings in third round by reviewing the mean and SDs of each factor. After the results were collected, Reliability Analysis were applied to a set of factors. In order to increase the α value above 0,9, 5 factors were removed from the set (Table 4.11). The α value of the remaining factors is 0,904. This α value indicates an excellent reliability level (Hair et al., 2020).

Table 4.10 : Delphi 3 results of IPD-related factors.

Rank	IPD-related factors	Mean	Std. Deviations	N	References
1	Early involvement of key participants	6,63	0,52	8,00	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)
2	Collectively defined project goals	6,63	0,52	8,00	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; Azhar et al., 2015, 2014; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)
3	Accountability	6,25	0,89	8,00	(AIA, 2007)
4	Collaborative decision-making	6,00	0,76	8,00	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)
5	BIM Protocol	6,00	0,93	8,00	(AIA, 2007)
6	Regular meetings	6,00	0,93	8,00	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)
7	Information sharing protocols	6,00	1,07	8,00	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)
8	Proper organization setting before design	5,88	1,13	8,00	(Yu et al., 2019)
9	Shared financial risk and reward	5,75	1,49	8,00	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2014, 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Yu et al., 2019)
10	Goals-owner’s desired outcomes alignment	5,63	0,92	8,00	(Azhar et al., 2014; Yu et al., 2019)
11	Establishing the communication protocol	5,63	1,41	8,00	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)

Table 4.10 (continued) : Delphi 3 results of IPD-related factors.

Rank	IPD-related factors	Mean	Std. Deviations	N	References
12	Established process for handling change orders	5,38	1,06	8,00	(Hamzeh et al., 2019; Yu et al., 2019)
13	Collaborative contracting arrangements	5,38	1,19	8,00	(Yu et al., 2019)
14	Establishing project's information specification	5,38	1,51	8,00	(AIA, 2007; Lahdenperä, 2012)
15	How develop, access, and use the model	5,13	0,99	8,00	(AIA, 2007)
16	Financial incentives	4,63	0,52	8,00	(AIA, 2007; Chang et al., 2017; Kog and Loh, 2012; Yu et al., 2019)
17	Financial transparency	4,63	1,30	8,00	(AIA, 2007; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
18	Joint Liability	4,25	1,04	8,00	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
19	Software choice	3,75	1,49	8,00	(AIA, 2007; Amuda-Yusuf, 2018; Ugwu and Kumaraswamy, 2007)

Table 4.11 : Delphi 4 results of IPD-related factors.

Rank	IPD-related factors	Mean	Std. Deviations	N	References
1	Early involvement of key participants	6,63	0,518	8	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)
2	Collectively defined project goals	6,63	0,518	8	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; Azhar et al., 2015, 2014; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)
3	Accountability	6,25	0,886	8	(AIA, 2007)
4	Collaborative decision-making	6,00	0,756	8	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)
5	BIM Protocol	6,00	0,926	8	(AIA, 2007)
6	Regular meetings	6,00	0,926	8	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)
7	Information sharing protocols	6,00	1,069	8	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)
8	Proper organization setting before design	5,88	1,126	8	(Yu et al., 2019)
9	Establishing the communication protocol	5,63	1,408	8	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)
10	Established process for handling change orders	5,38	1,061	8	(Hamzeh et al., 2019; Yu et al., 2019)
11	Establishing project's information specification	5,38	1,506	8	(AIA, 2007; Lahdenperä, 2012)

Table 4.11 (continued) : Delphi 4 results of IPD-related factors.

Rank	IPD-related factors	Mean	Std. Deviations	N	References
12	How develop, access, and use the model	5,00	0,926	8	(AIA, 2007)
13	Joint Liability	4,00	1,069	8	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
14	Software choice	3,50	1,512	8	(AIA, 2007; Amuda-Yusuf, 2018; Ugwu and Kumaraswamy, 2007)

4.3.2 BIM-related factors

The results of 4 round of the Delphi study about BIM-related CSFs have been presented in this section.

Delphi round 1: The participants were asked to select the factors that have an impact on the project success. Table 4.12 shows the results of the Delphi round 1.

Delphi round 2: The participants were given the right to make changes in their choices after reviewing the results of the first round. Table 4.12 shows the percent of the participants who choose specific items in the Delphi round 1 and 2.

Table 4.12 : Delphi round 1 and 2 results of BIM-related factors.

BIM-related factors	Selection percentage of participants (%) in Delphi round 1	Selection percentage of participants (%) in Delphi round 2	References
Documented BEP	80,0	80,0	(Badrinath and Hsieh, 2019)
Organizational structure to support BIM	73,3	80,0	(Won and Lee, 2010)
Standardized work procedures for BIM	73,3	73,3	(Won and Lee, 2010)
Number of subcontractors who have experienced BIM projects	66,7	66,7	(Won and Lee, 2010)
BIM competence of in-house team	66,7	66,7	(Amuda-Yusuf, 2018; Morlhon et al., 2014; Singh et al., 2011)
Communication of BIM objectives	53,3	60,0	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)
Use of BIM for design and documentation	53,3	53,3	(Yu et al., 2019)
Allocation of budget toward BIM	46,7	53,3	(Badrinath and Hsieh, 2019)
BIM/FM integration	40,0	40,0	(Badrinath and Hsieh, 2019)
Use of BIM for performance improvement	40,0	40,0	(Yu et al., 2019)
Developing customized IPD business process involving BIM technology	33,3	33,3	(Whang et al., 2019)
Owners' interest/request for BIM	26,7	33,3	(Won and Lee, 2010)
Use of BIM as a visual aid	26,7	26,7	(Yu et al., 2019)
Owners' satisfaction with BIM projects	20,0	26,7	(Won and Lee, 2010)
Early understanding of O&M-stage BIM uses	20,0	26,7	(Badrinath and Hsieh, 2019)
Incentive programs for using BIM	20,0	20,0	(Won and Lee, 2010)
General perception of BIM as improving productivity	13,3	20,0	(Amuda-Yusuf, 2018; Ugwu and Kumaraswamy, 2007)

Delphi round 3: A new list of factors was prepared with the factors selected by half or more of the participants in the Delphi round 2. Participants were asked to evaluate the impact of each factor on project success on a 7-point Likert scale of importance. Factor orders were randomized for each participant to minimize bias. Table 4.13 shows the means and SDs of the BIM-related factors. Factors were ranked according to their mean score. If the mean scores were equal, the factor with the smaller SD was ranked first.

Table 4.13 : Delphi round 3 results of BIM-related factors.

Rank	BIM-related factors	Mean	Std. Deviations	N	References
1	Documented BEP	6,50	0,756	8	(Badrinath and Hsieh, 2019)
2	Organizational structure to support BIM	6,38	0,744	8	(Won and Lee, 2010)
3	BIM competence of in-house team	6,13	0,835	8	(Amuda-Yusuf, 2018; Morlhon et al., 2014; Singh et al., 2011)
4	Allocation of budget toward BIM	6,00	0,756	8	(Badrinath and Hsieh, 2019)
5	Communication of BIM objectives	5,88	0,835	8	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)
6	Standardized work procedures for BIM	5,63	0,518	8	(Won and Lee, 2010)
7	Number of subcontractors/partners who have experienced BIM projects	4,88	0,835	8	(Won and Lee, 2010)
8	Use of BIM for design and documentation	4,88	0,991	8	(Yu et al., 2019)

Delphi round 4: Participants were evaluated their rankings in third round by reviewing the mean and SDs of each factor. After the results were collected, Reliability Analysis were applied to a set of factors. In order to increase the α value above 0,8, 2 factors were removed from the set (Table 4.14). The α value of the remaining factors is 0,812, which indicates an good reliability level (Hair et al., 2020).

Table 4.14 : Delphi round 4 results of BIM-related factors.

Rank	BIM-related factors	Mean	Std. Deviations	N	References
1	Documented BEP	6,75	0,463	8	(Badrinath and Hsieh, 2019)
2	Organizational structure to support BIM	6,38	0,744	8	(Won and Lee, 2010)
3	Communication of BIM objectives	5,88	0,835	8	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)
4	Standardized work procedures for BIM	5,63	0,518	8	(Won and Lee, 2010)
5	Number of subcontractors who have experienced BIM projects	4,88	0,835	8	(Won and Lee, 2010)
6	Use of BIM for design and documentation	4,75	0,886	8	(Yu et al., 2019)

4.3.3 Team-related factors

The results of 4 round of the Delphi study about IPD Team-related CSFs have been presented in this section.

Delphi round 1: The participants were asked to select the factors that have an impact on the project success. Table 4.15 shows the results of the Delphi round 1.

Delphi round 2: The participants were given the right to make changes in their choices after reviewing the results of the first round. Table 4.15 shows the percent of the participants who choose specific items in the Delphi round 1 and 2.

Table 4.15 : Delphi round 1 and 2 results of team-related factors.

Team-related factors	Selection percentage of participants (%) in Delphi round 1	Selection percentage of participants (%) in Delphi round 2	References
Competencies of team	100	100	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; Nguyen et al., 2004; Toor and Ogunlana, 2009)
Team involvement	75	87,5	(AIA, 2007)
Team collaboration/ integration	75	87,5	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)
Empowerment of team members	75	75	(Yu et al., 2019)
Good communication atmosphere	75	75	(Hamzeh et al., 2019; Yu et al., 2019)
Commitment of team	62,5	75	(AIA, 2007)
Continuity of values	62,5	62,5	(AIA, 2007)
Continuity of team	50	50	(AIA, 2007)
Subteams composition depending on purposes	50	50	(Yu et al., 2019)
Team selection	37,5	37,5	(AIA, 2007; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009)
Team formation/ organization	25	25	(AIA, 2007; Chang et al., 2017; Piroozfar et al., 2019; Whang et al., 2019)

Delphi round 3: A new list of factors was prepared with the factors selected by half or more of the participants in the Delphi round 2. Participants were asked to evaluate the impact of each factor on project success on a 7-point Likert scale of importance. Factor orders were randomized for each participant to minimize bias. Table 4.16 shows the means and SDs of the team-related factors. Factors were ranked according to their mean score. If the mean scores were equal, the factor with the smaller SD was ranked first.

Table 4.16 : Delphi round 3 results of team-related factors.

Rank	Team-related factors	Mean	Std. Deviations	N	References
1	Team collaboration/ integration	6,63	0,744	8	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)
2	Competencies of team	6,38	0,518	8	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; Nguyen et al., 2004; Toor and Ogunlana, 2009)
3	Good communication atmosphere	6,13	0,835	8	(Hamzeh et al., 2019; Yu et al., 2019)
4	Team involvement	5,75	1,035	8	(AIA, 2007)
5	Commitment of team	5,75	1,165	8	(AIA, 2007)
6	Empowerment of team members	5,50	1,195	8	(Yu et al., 2019)
7	Subteams composition depending on purposes	4,88	0,991	8	(Yu et al., 2019)
8	Continuity of team	4,88	1,126	8	(AIA, 2007)
9	Continuity of values	4,75	0,707	8	(AIA, 2007)

Delphi round 4: Participants were evaluated their rankings in third round by reviewing the mean and SDs of each factor. After the results were collected, Reliability Analysis were applied to a set of factors. In order to increase the α value above 0,8, 2 factors were removed from the set (Table 4.17). The α value of the remaining factors is 0,822. This α value indicates an good reliability level (Hair et al., 2020).

Table 4.17 : Delphi round 4 results of team-related factors.

Rank	Team-related factors	Mean	Std. Deviations	N	References
1	Team collaboration/ integration	6,63	0,744	8	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)
2	Competencies of team	6,38	0,518	8	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; Nguyen et al., 2004; Toor and Ogunlana, 2009)
3	Good communication atmosphere	6,13	0,835	8	(Hamzeh et al., 2019; Yu et al., 2019)
4	Team involvement	5,75	1,035	8	(AIA, 2007)
5	Empowerment of team members	5,50	1,195	8	(Yu et al., 2019)
6	Sub-teams composition depending on purposes	4,88	0,991	8	(Yu et al., 2019)
7	Continuity of team	4,75	1,035	8	(AIA, 2007)

After the completion of all subtopics, the cutoff point was identified as 5,5. Factors having mean scores over 5,5 were considered as CSFs and listed in Table 4.18.

Table 4.18 : The preliminary CSFs list in the implementation of IPD.

Rank	CSFs	Mean	Std. Deviations	N	References
1	Documented BEP	6,75	0,463	8	(Badrinath and Hsieh, 2019)
2	Early involvement of key participants	6,63	0,518	8	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)
3	Collectively defined project goals	6,63	0,518	8	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; Azhar et al., 2015, 2014; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)
4	Team collaboration/ integration	6,63	0,744	8	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)
5	Competencies of team	6,38	0,518	8	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; Nguyen et al., 2004; Toor and Ogunlana, 2009)
6	Organizational structure to support BIM	6,38	0,744	8	(Won and Lee, 2010)
7	Accountability	6,25	0,886	8	(AIA, 2007)
8	Good communication atmosphere	6,13	0,835	8	(Hamzeh et al., 2019; Yu et al., 2019)
9	Collaborative decision-making	6,00	0,756	8	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)
10	BIM Protocol	6,00	0,926	8	(AIA, 2007)
11	Regular meetings	6,00	0,926	8	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)
12	Information sharing protocols	6,00	1,069	8	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)
13	Communication of BIM objectives	5,88	0,835	8	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)
14	Proper organization setting before design	5,88	1,126	8	(Yu et al., 2019)
15	Team involvement	5,75	1,035	8	(AIA, 2007)
16	Standardized work procedures for BIM	5,63	0,518	8	(Won and Lee, 2010)
17	Establishing the communication protocol	5,63	1,408	8	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)
18	Empowerment of team members	5,50	1,195	8	(Yu et al., 2019)

In order to associate the results of the Delphi method and the questionnaire survey, the priority of the factors in the CSFs preliminary list has been examined with the Independent-Samples T test based on the IPD experiences of participants. The results of the normality test unveiled that the data used for conducting the T test are normally distributed as the values gathered for both Kurtosis and Skewness, for all items (identified CSFs) except the 'information sharing protocols', 'documented BIM execution plan' and 'good communication atmosphere' items fulfil the proposed level of -1,5 to +1,5 (Tabachnick and Fidell, 2013). Table 4.19 and 4.20 show the result of the tests.

Table 4.19 : The normality test results of the identified CSFs.

Identified CSFs	References	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Skewness		Kurtosis	
		Statistic	Std. Error	Lower Bound	Upper Bound					Statistics	Std. Error	Statistics	Std. Error
Early involvement of participants	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)	5,03	0,352	4,31	5,75	5,15	6	3,832	1,958	-0,96	0,421	-0,207	0,821
Regular meetings	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)	4,87	0,273	4,31	5,43	4,91	5	2,316	1,522	-0,374	0,421	-0,623	0,821
Collectively defined project goals	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; Azhar et al., 2015, 2014; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)	5,52	0,27	4,96	6,07	5,63	6	2,258	1,503	-0,978	0,421	0,236	0,821
Establishing the communication protocol	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)	5,16	0,271	4,61	5,71	5,23	5	2,273	1,508	-0,667	0,421	-0,08	0,821
Information sharing protocols	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)	5,68	0,204	5,26	6,09	5,77	6	1,292	1,137	-1,199	0,421	2,274	0,821
BIM Protocol	(AIA, 2007)	5,55	0,24	5,06	6,04	5,61	6	1,789	1,338	-0,512	0,421	-0,847	0,821
Accountability	(AIA, 2007)	4,97	0,256	4,44	5,49	5,06	5	2,032	1,426	-1,047	0,421	1,306	0,821
Collaborative decision-making	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)	5,32	0,276	4,76	5,89	5,45	6	2,359	1,536	-0,998	0,421	0,922	0,821
Proper organization setting before design	(Yu et al., 2019)	5,32	0,234	4,85	5,8	5,39	5	1,692	1,301	-0,359	0,421	-0,047	0,821
Team involvement	(AIA, 2007)	5,84	0,241	5,35	6,33	5,97	6	1,806	1,344	-1,36	0,421	1,451	0,821
Team integration	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)	5,97	0,215	5,53	6,41	6,08	6	1,432	1,197	-1,182	0,421	0,713	0,821
Competencies of team	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; Nguyen et al., 2004; Toor and Ogunlana, 2009)	5,42	0,249	4,91	5,93	5,52	6	1,918	1,385	-1,149	0,421	0,936	0,821
Empowerment of team members	(Yu et al., 2019)	5,81	0,21	5,38	6,23	5,9	6	1,361	1,167	-1,078	0,421	0,533	0,821
Good communication atmosphere	(Hamzeh et al., 2019; Yu et al., 2019)	6,1	0,193	5,7	6,49	6,2	6	1,157	1,076	-1,406	0,421	1,544	0,821
Documented BIM execution plan	(Badrinath and Hsieh, 2019)	6,32	0,176	5,96	6,68	6,45	7	0,959	0,979	-1,854	0,421	3,792	0,821
Organizational structure to support BIM	(Won and Lee, 2010)	6,06	0,16	5,74	6,39	6,13	6	0,796	0,892	-0,734	0,421	-0,033	0,821

Table 4.19 (continued) : The normality test results of the identified CSFs.

Identified CSFs	References	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Skewness		Kurtosis	
		Statistic	Std. Error	Lower Bound	Upper Bound					Statistics	Std. Error	Statistics	Std. Error
Standardized work procedures for BIM	(Won and Lee, 2010)	5,97	0,182	5,6	6,34	6,02	6	1,032	1,016	-0,544	0,421	-0,851	0,821
Communication of BIM objectives	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)	5,71	0,187	5,33	6,09	5,77	6	1,08	1,039	-0,509	0,421	0,022	0,821

Table 4.20 : The Independent-Sample T Test results of the identified CSFs based on the IPD experiences of questionnaire survey participants.

Identified CSFs	References		Levene's Test for Equality of Variances		t-test for Equality of Means						
			F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
										Lower	Upper
Early involvement of participants	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)	EVA*	0,001	0,972	-0,816	29	0,421	-0,58	0,71	-2,033	0,873
		EVNA**			-0,818	28,149	0,42	-0,58	0,709	-2,031	0,871
Regular meetings	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)	EVA*	0,817	0,373	0,9	29	0,376	0,496	0,551	-0,631	1,623
		EVNA**			0,912	28,893	0,369	0,496	0,543	-0,616	1,607
Collectively defined project goals	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; Azhar et al., 2015, 2014; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)	EVA*	0,205	0,654	-0,053	29	0,958	-0,029	0,552	-1,157	1,099
		EVNA**			-0,053	26,71	0,958	-0,029	0,557	-1,172	1,113
Establishing the communication protocol	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)	EVA*	1,297	0,264	-0,297	29	0,769	-0,164	0,553	-1,294	0,966
		EVNA**			-0,288	23,335	0,776	-0,164	0,57	-1,341	1,013
BIM Protocol	(AIA, 2007)	EVA*	4,362	0,046	-1,429	29	0,164	-0,723	0,506	-1,757	0,312
		EVNA**			-1,354	19,35	0,191	-0,723	0,534	-1,838	0,393
Accountability	(AIA, 2007)	EVA*	0,921	0,345	-1,568	29	0,128	-0,849	0,541	-1,956	0,258
		EVNA**			-1,511	22,106	0,145	-0,849	0,562	-2,014	0,316

Table 4.20 (continued) : The Independent-Sample T Test results of the identified CSFs based on the IPD experiences of questionnaire survey participants.

Identified CSFs	References		Levene's Test for Equality of Variances		t-test for Equality of Means						
			F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
										Lower	Upper
Collaborative decision-making	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)	EVA*	0,089	0,768	-0,415	29	0,681	-0,197	0,476	-1,171	0,776
		EVNA**			-0,412	27,038	0,684	-0,197	0,479	-1,181	0,786
Proper organization setting before design	(Yu et al., 2019)	EVA*	0,232	0,633	0,068	29	0,946	0,034	0,493	-0,975	1,043
		EVNA**			0,069	28,982	0,945	0,034	0,485	-0,958	1,025
Team involvement	(AIA, 2007)	EVA*	1,191	0,284	0,134	29	0,894	0,059	0,439	-0,839	0,957
		EVNA**			0,136	28,944	0,893	0,059	0,432	-0,826	0,943
Team integration	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)	EVA*	0,104	0,749	-1,283	29	0,21	-0,634	0,495	-1,646	0,377
		EVNA**			-1,262	25,626	0,218	-0,634	0,503	-1,669	0,4
Competencies of team	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; Nguyen et al., 2004; Toor and Ogunlana, 2009)	EVA*	2,482	0,126	-1,345	29	0,189	-0,559	0,416	-1,409	0,291
		EVNA**			-1,303	23,028	0,206	-0,559	0,429	-1,446	0,329
Empowerment of team members	(Yu et al., 2019)	EVA*	0,436	0,514	-0,448	29	0,657	-0,176	0,393	-0,981	0,628
		EVNA**			-0,437	24,054	0,666	-0,176	0,404	-1,01	0,657
Organizational structure to support BIM	(Won and Lee, 2010)	EVA*	0,56	0,46	1,067	29	0,295	0,399	0,374	-0,366	1,164
		EVNA**			1,074	28,495	0,292	0,399	0,372	-0,361	1,16
Standardized work procedures for BIM	(Won and Lee, 2010)	EVA*	0,001	0,972	-0,816	29	0,421	-0,58	0,71	-2,033	0,873
		EVNA**			-0,818	28,149	0,42	-0,58	0,709	-2,031	0,871
Communication of BIM objectives	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)	EVA*	0,817	0,373	0,9	29	0,376	0,496	0,551	-0,631	1,623
		EVNA**			0,912	28,893	0,369	0,496	0,543	-0,616	1,607

*EVA= Equal variances assumed

*EVNA= Equal variances not assumed

5. DISCUSSION

In this chapter, findings of the questionnaire survey, interviews, and the Delphi method were discussed and compared with the literature review in compliance with the objectives of the study.

5.1 IPD Adoption

IPD has emerged from the CI's search for a PDS that would foster collaboration, add value to the project, and provide a contractual basis for advanced tools (AIA, 2007). IPD can be implemented in its pure form with the use of multi-party contracts, or some features of IPD can be adopted to achieve some degree of collaboration and positive outcomes (NASFA et al., 2010). The findings of the questionnaire survey revealed that the adoption rates of collaboration-related characteristics (with ranks 3rd ,7th , and 12th where 'collectively defined project goals' (AIA, 2007) was in the 3rd rank, 'collaborative decision-making'(AIA, 2007) was in the 7th and 'early involvement of participants' in the 12th (AIA, 2007)) are more than contractual ones (10th , 14th and 18th where 'collaborative contracting arrangements' (AIA, 2007) was in the 10th, 'Joint Liability' (AIA, 2007) was in the 14th and 'shared financial risk and reward' (AIA, 2007) was in the 18th), according to Table 4.3.

IPD reshapes the team dynamics to overcome team-related problems (e.g., fragmentation and antagonistic relationships), which are seen as the leading causes of the long-lasting problems of the CI (Lahdenperä, 2012; Laurent and Leicht, 2019). Although the findings of the questionnaire survey did not show any significant correlation between IPD characteristics and team-related problems (Table A.9), team-related problems were listed as the least faced ones (Table 4.2). On the other hand, 'disintegration' (Ghassemi and Becerik-Gerber, 2011) was ranked as the most frequently encountered problems (Table 4.2). The reason for this situation may be that although the teams are encouraged to work more collaboratively, the necessary contractual arrangements have not been widely provided and implemented as survey and interviews findings revealed.

The study found out that ineffective teams are significantly correlated with all problems except the ‘data losses’ (Baiden et al., 2006), ‘excessive design changes’ (Baiden et al., 2006) and ‘excessive liability claims’ (Baiden et al., 2006) (Table A.8). Molenaar et al. (2014) demonstrated that integrated and united teams could reduce the schedule and cost growth with more effective practices. Likewise, the findings of the questionnaire survey revealed a significant correlation of ‘ineffective teams’ with ‘cost and budget overruns’ and ‘poor end quality’ with r values 0,692, 0,594, and 0,627, respectively. Furthermore, advanced and preserved commitment of team with proper management techniques can increase the effectiveness of teamwork (Baiden and Price, 2011).

There is a significant correlation (r = 0,831) between cost and schedule overruns (Table 4.9). Moreover, 53% of interview participants stated that these overruns occur more frequently than before. Early involvement of prime constructors and subcontractors can create cost savings and reduce the quantity of changes that can cause delays in the construction phase (El Asmar et al., 2013; Ghassemi and Becerik-Gerber, 2011; Kent and Becerik-Gerber, 2010). Although ‘early involvement’ is the highest-ranked IPD-related CSF according to the Delphi method, its adoption rate tends to have not reached high levels. Limited focus on integrating stakeholders as early as possible can prevent the desired project performance outcomes.

BIM can be perceived as the main driver for IPD adoption as stated by 40% of interview participants (AIA, 2007). While IPD necessitates a tool to increase collaboration capabilities of team, BIM requires a PDS that enable the collaboration of various disciplines (Piroozfar et al., 2019). After the obligations in some countries to use BIM in public projects, the BIM adoption rate has increased globally (Ullah et al., 2019). As there is a win-win relationship between BIM and IPD, the increase in BIM adoption can end up with the wide application of more integrated approaches. Likewise, the questionnaire survey findings emphasized the importance of organizational structure and standardized work procedures to implement BIM more effectively. Mesa et al. (2016) compared the organizational structures of DBB, CMAR, DB and IPD, and uncovered that organizational structure in IPD has a positive impact on all supply chain relationship factors such as effective communication, trust-based environment, and efficient team working.

The questionnaire survey findings revealed that the priority of the stakeholders in the IPD process is to determine the topics related to BIM and to include them within the scope of the contract (Table 4.3). These topics were about information sharing protocols, BIM protocol, software selection, and how the model would be developed, accessed and used in the process. The BIM protocol is crucial for the BIM process to proceed smoothly and should be included in the agreements of all stakeholders to make them contractually obligatory (Eynon, 2016). BIM Protocol prepared by AIA assigns the responsibilities of the parties, ownership and coordination issues, and agreed level of detail on each building component (AIA, 2008c). IPD contract prepared by AIA has provisions to incorporate BIM Protocol (AIA, 2008a). Therefore, it can be concluded that IPD contracts can facilitate the correct implementation of BIM protocols.

5.2 IPD Implementation and CSFs

The effect of IPD-related factors on project success was examined by the Delphi study. A total of 9 IPD-related CSFs were identified (Table 4.18). The identified CSFs are 'early involvement of key participants' (AIA, 2007; Lahdenperä, 2012; Ugwu and Kumaraswamy, 2007; Whang et al., 2019), 'collectively defined project goals' (AIA, 2007; Aksorn and Hadikusumo, 2008; Lahdenperä, 2012; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019), 'accountability' (AIA, 2007), 'collaborative decision-making' (AIA, 2007; Azhar et al., 2015; Fischer et al., 2017; Lahdenperä, 2012; Yu et al., 2019), 'BIM Protocol' (AIA, 2007), 'Regular meetings' (AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019), 'information sharing protocols' (AIA, 2007; Chang et al., 2017; Won and Lee, 2010), 'proper organization setting before design' (Yu et al., 2019), and 'establishing the communication protocol' (AIA, 2007; Lahdenperä, 2012; Yu et al., 2019).

'Early involvement' and 'collectively defined project goals' were ranked as the essential IPD-related CSFs for project success. These two factors were among collaboration-related key characteristics of IPD with collaborative decision-making (Azhar et al., 2014), which was classified as the 4th IPD-related CSF (with a mean score of 6 out of 7). These results are in compliance with the report prepared by NASFA, COAA, APPA, AGC, and AIA, which indicated that early collaboration principles of IPD have a direct impact on project success (NASFA et al., 2010). Early involvement can maximize the impact of different expertise on design development where decisions have the ability to influence project outcomes significantly (AIA, 2007). As complexity of projects and variety of comprehensive technological tools rise, the need to bring specialized parties together is also increasing (Azhar et al., 2015). Furthermore, 'early' and 'collectively' concepts of IPD are crucial for sustainability as sustainability requires inter-disciplinary teamwork for both creating a number of design options and evaluating them to enhance the environmental performance of buildings (Nofera et al., 2011; Sive and Hays, 2009). Furthermore, lean practices can promote early collaboration to minimize waste in time spent due to reworks and construction waste caused by design errors (Fakhimi et al., 2016).

'Early involvement' and 'collectively defined goals' were ranked as equal-weighted CSFs, and interrelated factors as team members must come together before the design is finalized to set targets collectively (Azhar et al., 2014). Jointly developed goals align parties' individual interests and tie their perception of success to project success (Mesa et al., 2016). The collaborative environment with the alignment of interests encourages the team to develop innovative and value-added solutions (AIA, 2007).

Other interrelated factors are 'joint accountability' and 'decision-making' which were listed as the 3rd and 4th CSFs according to Allison et al. (2018). PMT is responsible for making important decisions with unanimity, and is held accountable for them (Allison et al., 2018). Joint decision-making protocol and accountability are identified in the process design which is crucial for multi-party contracts (AIA, 2007).

'BIM protocol' is a standard form of document attached to the contract and specifies the details of model development and parties' responsibilities (Eynon, 2016). Implementation of BIM protocol can eliminate the model ownership and organization issues seen as barriers to BIM adoption (Fakhimi et al., 2016). Information-sharing protocols can be part of BIM protocol or be prepared and applied to projects not implementing BIM Protocol. According to the Delphi method results, the mean scores of BIM Protocol, regular meetings, and information-sharing protocols were calculated as equal.

The collaborative and trust-based environment established in the IPD process can be maintained by the regular meetings among PMT members (AIA, 2007). According to the Delphi method results, 'regular meetings' were ranked as the 6th IPD-related CSFs with a mean score of 6 out of 7. Yu et al. (2019) listed 'regular meetings' in the communication-related CSFs and indicated their favorable effects on schedule and cost performance, and reduction in defects, and change orders. Furthermore, 'regular meetings' are crucial in the BIM coordination process by allowing the team to discuss model-related issues and sharing the resources (NIBS, 2017).

The 'proper organization setting before design', the 8th IPD-related CSF, emphasizes the necessary team-building activities and careful discussions to assemble an efficient team at the earliest possible stage (De Marco and Karzouna, 2018). Yu et al. (2019) categorized it among planning-related CSFs and revealed its significant impact on the reduced change orders, defects, and schedule growth.

Based on the Delphi method results, the 'communication protocol' was ranked as the 9th CSF. PMT develops the communication protocol to catalyze communication and enables data exchange freely (AIA, 2009). In the development of the communication protocol, the team identifies the usage, management, and transaction of the information through collective meetings (AIA, 2007).

To summarize, the IPD-related factors of CSFs preliminary lists revealed the superior impact of collaboration-related factors, administrative BIM factors, and factors facilitating team-building on project success.

5.3 BIM Implementation CSFs for IPD

The BIM-related factors affecting the project success was examined by the Delphi study. A total of 4 BIM-related CSFs were identified (Table 4.18), which are 'documented BEP' (Badrinath and Hsieh, 2019), 'organizational structure to support BIM' (Won and Lee, 2010), 'communication of BIM objectives' (Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014), 'standardized work procedures for BIM' (Won and Lee, 2010)

'BEP' (BIM Execution Plan) was ranked as the most important BIM-related CSF. In BIM process, the owner prepares the Employer's Information Requirements (EIR) before the selection of team members (Ashworth et al., 2019). Draft BEPs stating how to execute the specified items in the EIR are produced and delivered by potential bidders to the owner (Beetz, 2018). After the selection and integration of key stakeholders, project teams finalize the BEP collaboratively as defining the responsibilities of each party (Ashworth et al., 2019). Badrinath and Hsieh (2019) had listed the BEP as administrative BIM-related CSF while investigating the operational factors contributing to project success in BIM projects.

According to the Delphi method results, the ‘proper organizational structure for BIM’ was selected as the 2nd BIM-related CSF with a mean score of 6,38 out of 7. The BIM process faces some collaboration-related barriers in the traditional PDSs (Azhar et al., 2012). Moreover, different disciplines need to come together in the early stages of the project to create a comprehensive and functional BIM (Fakhimi et al., 2016). NASFA et al. (2010) highlighted the mutual relationship between BIM and IPD, noting the impact of transparency of the collaborative decision-making process on the BIM application.

The other BIM-related CSF is the ‘communication of BIM objectives’. The communication of BIM objectives refers to the team activities to embrace different techniques used by parties involved and harmonize them for the interest of the project (Amuda-Yusuf, 2018). Eynon (2016) determined three successive steps for aligning BIM objectives effectively as follows, understanding the individual interests of each stakeholder and developing alternatives to optimize them, producing collaborative outputs as acting in the best interest of the integrated team, determining the road map to achieve long-term objectives. Therefore, it can be concluded that collective efforts to define project goals in IPD can embrace the communication of the BIM objectives.

Based on the Delphi method results, the ‘standardized work procedures for BIM’ with a mean score of 5,63 is another BIM-related CSF in the CSFs preliminary list and indicates the necessity for identification of roles and responsibilities of each party to operate the BIM process smoothly. Won and Lee (2010) identified standardized work procedures and organizational structure as CSFs for the BIM adoption.

BIM has different dimensions from 3D to 7D, and the use of these dimensions directly impacts the project process and outputs (Eynon, 2016). Comparison of the mean values of common problems illustrated that the mean values of the participants whose projects are used more than one dimension of BIM is lower for each problem except ‘cost overruns’ in which two groups have the same mean value. Table 5.1 shows the mean values of two groups for each problem and the difference in the mean values. Moreover, Table 5.1 illustrates the significant difference in 4 problems having Sig value less than 0,05, which are ‘adversarial relationships’, ‘degraded project value’, ‘data losses’ and ‘excessive liability claims’ based on the use of multiple BIM dimensions.

Table 5.1 : Mean differences of common problems and summary of the Independent-Sample T Test related to BIM dimensions.

Common problems	References	Team	Process	Mean	Only 3D BIM	More dimensions	Difference	t	df	Sig.
Degraded project value	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016)		●	3,65	4,71	3,33	1,38	2,185	29	0,037
Data losses	(Baiden et al., 2006)		●	3,94	5,00	3,63	1,37	2,163	15,337	0,047
Adversarial relationship	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; Yu et al., 2019; Zhang et al., 2013)	●		4,13	5,14	3,83	1,31	2,272	29	0,031
Excessive liability claims	(Baiden et al., 2006)		●	3,32	4,29	3,04	1,25	2,041	29	0,05
Dis-integration	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; NASFA et al., 2010; Sive and Hays, 2009; Zhang et al., 2013)	●		5,06	6,00	4,79	1,21			
Over-reworks	(Yu et al., 2019)		●	4,84	5,71	4,58	1,13			
Omissions/ defects	(Baiden et al., 2006; NASFA et al., 2010)		●	4,42	5,29	4,17	1,12			
High inefficiency	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; NASFA et al., 2010; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019; Zhang et al., 2013)		●	3,90	4,71	3,67	1,04			
Excessive design changes	(Baiden et al., 2006)		●	4,65	5,43	4,42	1,01			
Non-transparent relations	(Baiden et al., 2006)	●		3,10	3,86	2,88	0,98			
Schedule overruns	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)		●	5,06	5,71	4,88	0,83			
Contractual disputes	(De Marco and Karzouna, 2018; Zhang et al., 2013)	●		3,94	4,57	3,75	0,82			
Incompatibility between design and actual work	(Yu et al., 2019)		●	4,13	4,71	3,96	0,75			
Low productivity	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; NASFA et al., 2010; Yu et al., 2019)		●	4,06	4,57	3,92	0,65			
Mistrust environment	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011)	●		3,65	4,00	3,54	0,46			
Poor end quality	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)		●	3,52	3,86	3,42	0,44			

Table 5.1 (continued) : Mean differences of common problems and summary of the Independent-Sample T Test related to BIM dimensions.

Common problems	References	Team	Process	Mean	Only 3D BIM	More dimensions	Difference	t	df	Sig.
Fragmentation	(Baiden et al., 2006; Lahdenperä, 2012; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019)	●		3,68	4,00	3,58	0,42			
Errors	(NASFA et al., 2010; Yu et al., 2019)		●	4,39	4,71	4,29	0,42			
Waste	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011)		●	4,19	4,43	4,13	0,30			
Ineffective teams	(Baiden et al., 2006; CURT, 2004)	●		3,97	4,14	3,92	0,22			
Cost overruns	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; NASFA et al., 2010; Zhang et al., 2013)		●	4,71	4,71	4,71	0,00			

To sum up, the BIM-related factors of the CSFs preliminary list have a significant relationship with fundamental IPD principles. These associations confirm the integrity of IPD and BIM, which is frequently mentioned in the literature (AIA, 2007; NASFA et al., 2010). The study reveals that administrative BIM characteristics like BEP and BIM protocol are more critical than organizational and operational BIM characteristics in IPD projects.

5.4 IPD Team Characteristics and CSFs

The effect of team-related factors on project success was examined by the delphi study. A total of 5 team-related CSFs were identified (Table 4.18). Identified CSFs are ‘team integration’ (AIA, 2007; Ashcraft, 2011; Won and Lee, 2010), ‘competencies of team’ (Aksorn and Hadikusumo, 2008; Nguyen et al., 2004; Toor and Ogunlana, 2009) ‘good communication atmosphere’ (Hamzeh et al., 2019; Yu et al., 2019), and ‘team involvement’ (AIA, 2007), and ‘empowerment of team members’(Yu et al., 2019), respectively.

The ‘team integration’ was identified to be the most crucial team-related CSF. Team integration in construction projects can be defined as the harmonization of different systems, tools, and behaviors to achieve an efficient working environment (Baiden et al., 2006). The need for an effective integration in the CI has been emphasized by various reports and has been the leading cause of the emergence of IPD (CURT, 2004; CURT, 2006). Baiden et al. (2006) have listed the main features of fully integrated teams as following: alignment of objectives and actions in the common interests; elimination of traditional barriers; ability to make more precise calculations by utilizing collaboration; flexibility in the composition to adapt to the changes; co-location capabilities; incentives for free exchange of information; equality of participants; and joint accountability (Baiden et al., 2006). Therefore, considering the characteristics of integrated teams, the reason for its impact on project success can be understood. Moreover, Choi et al. (2019) compared the level of integration in IPD and CMAR, and revealed the significant correlation between the higher level of collaboration in IPD and the owner satisfaction. Likewise, Baiden and Price (2011) uncovered the direct impact of team integration on team effectiveness with the help of 9 case studies. Along with the IPD, team integration is also crucial for the BIM process (IFMA, 2013). The integrated team in BIM can achieve a decrease in total cost, and an increase in end-quality of the product and effectiveness of life-cycle management (ACIF and APCC, 2014).

Based on the Delphi survey results, the 2nd team-related CSF is the 'team competency' with a mean score of 6,38 out of 7. The 'team competency' was listed as a CSF in various studies (e.g.,Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; Nguyen et al., 2004; Toor and Ogunlana, 2009). Team competency can be defined as assigning the right people capable of performing a specific task mentally and physically (Aksorn and Hadikusumo, 2008). As smooth functioning of the team is at the center of IPD, the team's competency plays a crucial role in achieving defined goals, and therefore project success (Ashcraft, 2014b). In the IPD process, these three sets of competencies can be distributed according to the responsibilities of the sub-teams. Firstly, PET can be responsible for policy-related competencies as it includes guidance and supervision of the BIM process. Secondly, process set, including the leadership and management capabilities, can be assigned to PMT. Finally, the technology set can be given to PIT, which is responsible for the project implementation.

The 3rd team-related CSF, according to the Delphi study, is the 'good communication atmosphere', which refers to direct and open communication between stakeholders in a mutual trust and respect-based environment (Yu et al., 2019). Open communication is essential for the implementation of other CSFs like 'team integration', 'early involvement', 'jointly developed goals', 'joint accountability' and 'collaborative decision-making', and can be enhanced by the 'regular meetings' (Nofera et al., 2011).

Moreover, BIM can improve the communication capabilities of the team with its collaborative and visual features (Ghassemi and Becerik-Gerber, 2011).

According to the Delphi study results, the 4th team-related CSF is ‘team involvement’ with a mean score of 5,75 out of 7. It refers to the team’s presence in the critical decisions made and plans prepared regarding the project (Nofera et al., 2011). Moreover, the team can also involve the goal definition process (Ashcraft, 2011), and the preparation process of multi-party contracts (De Marco and Karzouna, 2018).

Based on the Delphi survey results, the 5th team-related CSF is the ‘empowerment of team members’ with a mean score of 5,50 out of 7. IPD team compromises different members from each stakeholder (Ashcraft, 2011). The success of IPD relies heavily on the empowered members who take the responsibility of ownership and leadership of the works in their scope (Fischer et al., 2017; Yu et al., 2019).

Table 5.2 shows the factors in the CSFs preliminary list in the implementation of IPD.

Table 5.2 : Comparison of determined CSFs with existing literature.

Rank	CSFs	(Yu et al., 2019)	(Won et al., 2013)	(Whang et al., 2019)	(Badrinath and Hsieh, 2019)	(Amuda-Yusuf, 2018)	(Brennan, 2011)
1	Documented BEP				●		
2	Early involvement of key participants			●			
3	Collectively defined project goals	●					
4	Team collaboration/ integration						●
5	Competencies of team					●	●
6	Organizational structure to support BIM		●	●	●		
7	Accountability						
8	Good communication atmosphere	●				●	●
9	Collaborative decision-making			●			
10	BIM Protocol					●	
11	Regular meetings	●			●		
12	Information sharing protocols		●				
13	Communication of BIM objectives					●	
14	Proper organization setting before design	●					
15	Team involvement			●			
16	Standardized work procedures for BIM		●				
17	Establishing the communication protocol	●					
18	Empowerment of team members	●		●			

The Independent- Sample T Test, which investigated the adoption status of identified CSFs according to the questionnaire survey participants’ IPD experiences, showed that Sig values of all CSFs are greater than 0,05 (Table 4.20). Therefore, no significant difference exists in identified CSFs based on the participants’ IPD experiences. Factors in Table 5.3 were arranged and aligned based on the difference in the mean scores of the two groups. Moreover, mean scores of contractual IPD characteristics are more outstanding in the more experienced participants. The adoption status of overall BIM-related factors except 'information sharing protocols' are either equal between two groups or greater in the less experienced participants.

Table 5.3 : Mean differences of the identified CSFs related to IPD experience of the questionnaire survey participants.

Factor lists	References	IPD	BIM	Team	CCF score	Mean	Less than 3 years	Equal or more than 3 years	Difference
Accountability	(AIA, 2007)	Contractual			6,25	5,32	4,86	5,71	-0,85
Information sharing protocols	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)		Administrative		6,00	4,97	4,57	5,29	-0,72
Team integration	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)			Team-functioning	6,63	5,42	5,07	5,71	-0,64
Establishing the communication protocol	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)	Contractual			5,63	5,55	5,21	5,82	-0,61
Early involvement of key participants	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)	Collaborative			6,63	5,03	4,71	5,29	-0,58
Empowerment of team members	(Yu et al., 2019)			Team-building	5,50	5,81	5,50	6,06	-0,56
Proper organization setting before design	(Yu et al., 2019)	Managerial			5,88	5,32	5,21	5,41	-0,20
Good communication atmosphere	(Hamzeh et al., 2019; Yu et al., 2019)			Team-building	6,13	6,10	6,00	6,18	-0,18
Collaborative decision-making	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)	Collaborative			6,00	5,16	5,07	5,24	-0,17
BIM Protocol	(AIA, 2007)		Administrative		6,00	5,52	5,50	5,53	-0,03
Competencies of team	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; Nguyen et al., 2004; Toor and Ogunlana, 2009)			Team-building	6,38	5,84	5,86	5,82	0,04

Table 5.3 (continued): Mean differences of the identified CSFs related to IPD experience of the questionnaire survey participants.

Factor lists	References	IPD	BIM	Team	CCF score	Mean	Less than 3 years	Equal or more than 3 years	Difference
Standardized work procedures for BIM	(Won and Lee, 2010)		Organizational		5,63	5,97	6,00	5,94	0,06
Team involvement	(AIA, 2007)			Team-functioning	5,75	5,97	6,00	5,94	0,06
Organizational structure to support BIM	(Won and Lee, 2010)		Organizational		6,38	6,32	6,43	6,24	0,19
Communication of BIM objectives	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)		Administrative		5,88	5,71	5,93	5,53	0,40
Documented BEP	(Badrinath and Hsieh, 2019)		Administrative		6,75	6,06	6,29	5,88	0,41
Regular meetings	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)			Team-building	6,00	5,68	5,93	5,47	0,46
Collectively defined project goals	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; Azhar et al., 2015, 2014; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)	Collaborative			6,63	4,87	5,14	4,65	0,49

6. CONCLUSIONS AND RECOMMENDATIONS

This dissertation aimed to explore the adoption level of IPD characteristics in the present work practices of the CI and their influence on the process and team-related problems of the CI while preparing a CSFs' preliminary list covering the IPD, BIM, and IPD-team related factors (Table 1.1). To achieve these aims and objectives, firstly in-depth literature has been carried out to determine the common problems in the CI, and identify the characteristics of IPD, BIM, and IPD-team. Identified lists were used to conduct the online questionnaire survey and online interviews within the scope of objectives 1 and 2. To achieve the 3rd , 4th and 5th objectives, the 4 round of three group Delphi surveys were conducted with IPD and BIM experts and/or academics having publications and/or experience on related topics. This section includes the conclusions and recommendations made from the results of literature review, online questionnaire survey, interviews and the Delphi surveys.

6.1 Practical and Theoretical Applications

The main findings obtained from the online questionnaire survey, online interviews, and the Delphi surveys are summarized in the following sub-sections in line with the research objectives.

A total of 66 factors related to IPD, BIM, and IPD-team were examined through 4 rounds and 3 groups of the Delphi study. 30 factors chosen by less than half of the participants were eliminated at the end of the 2nd round for each group. A total of 9 factors were removed from the sets to increase the reliability of each group. Then, as the mean values of 9 factors of the remaining 27 were under 5,5, they were also extracted from the preliminary CSFs list. Table 6.1 shows the categorization of the factors and their removal process from the CSFs preliminary list.through the Delphi study.

In order to examine the relationship between each CSF, a general framework for IPD and BIM implementation has been developed based on the findings of the literature review, questionnaire survey, interviews and the Delphi method. BIM-related factors are grouped under two categories as administrative and organizational. IPD-related factors are classified as collaborative and contractual characteristics. Team-related factors are categorized as team-building and team-funtioning. Figure 6.1 shows the interrelations between each category.

The classification system used in Table 6.1 and Figure 6.1 in IPD and BIM-related factors were derived from the studies of Azhar et al. (2014) and Badrinath and Hsieh (2019), respectively. Team-related factors were classified according to the careful examination of the factors.

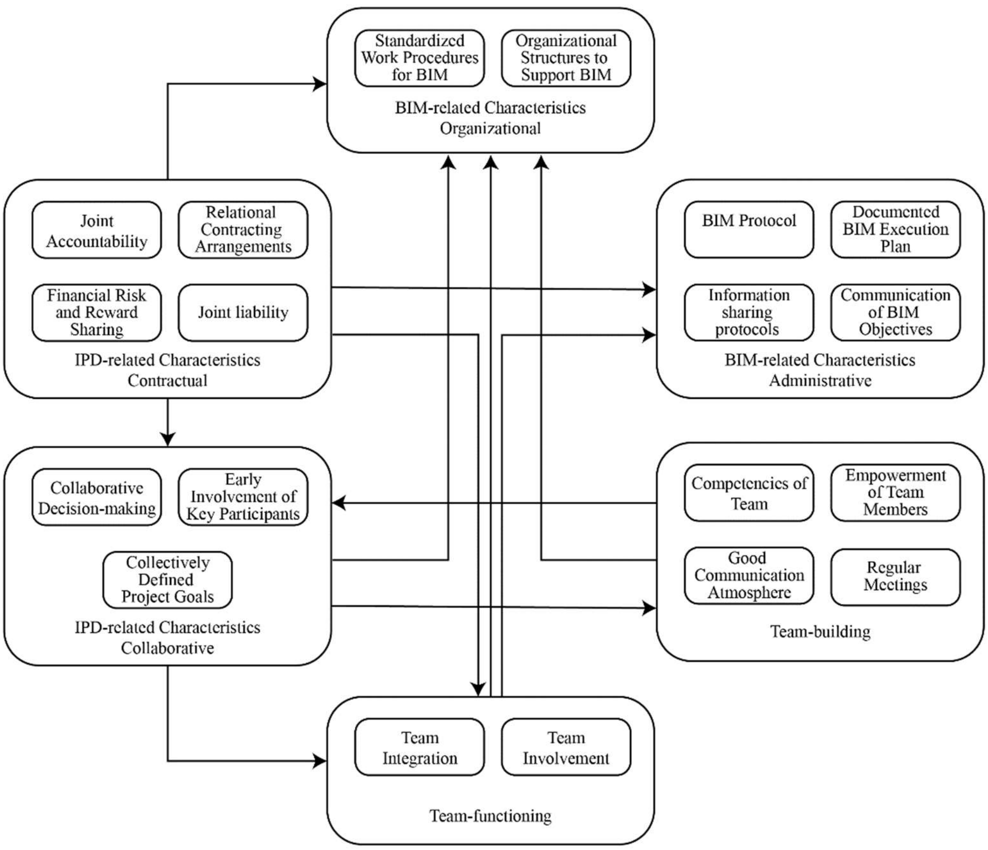

Figure 6.1 : General framework for BIM and IPD implementation.

Table 6.1 : Classification of each factor and their evaluation through the Delphi study.

Factor lists	IPD (Azhar et al., 2014)	BIM (Badrinath and Hsieh, 2019)	Team	Factor reduction in the Delphi round 1-2	Reliability Analysis	Factor ranking in the Delphi round 3-4	CSFs preliminary list	References
Early involvement of key participants	Collaborative						○	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)
Collectively defined project goals	Collaborative						○	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; Azhar et al., 2014, 2015; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)
Collaborative decision-making	Collaborative						○	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)
Establishing the communication protocol	Contractual						○	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)
Accountability	Contractual						○	(AIA, 2007)
Proper organization setting before design	Managerial						○	(Yu et al., 2019)
Communication of BIM objectives		Administrative					○	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)
Documented BEP		Administrative					○	(Badrinath and Hsieh, 2019)
Information sharing protocols		Administrative					○	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)
BIM Protocol		Administrative					○	(AIA, 2007)
Organizational structure to support BIM		Organizational					○	(Won and Lee, 2010)
Standardized work procedures for BIM		Organizational					○	(Won and Lee, 2010)
Competencies of team			Team-building				○	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; Nguyen et al., 2004; Toor and Ogunlana, 2009)
Empowerment of team members			Team-building				○	(Yu et al., 2019)
Good communication atmosphere			Team-building				○	(Hamzeh et al., 2019; Yu et al., 2019)
Regular meetings			Team-building				○	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)
Team involvement			Team-functioning				○	(AIA, 2007)

Table 6.1 (continued): Classification of each factor and their evaluation through the Delphi study.

Factor lists	IPD (Azhar et al., 2014)	BIM (Badrinath and Hsieh, 2019)	Team	Factor reduction in the Delphi round 1-2	Reliability Analysis	Factor ranking in the Delphi round 3-4	CSFs preliminary list	References
Team integration			Team-functioning				○	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)
Establishing project's information specification	Contractual					●		(AIA, 2007; Lahdenperä, 2012)
Joint Liability	Contractual					●		(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
Established process for handling change orders	Managerial					●		(Hamzeh et al., 2019; Yu et al., 2019)
Number of partners who have experienced BIM projects		Competency				●		(Won and Lee, 2010)
Use of BIM for design and documentation		Operational				●		(Yu et al., 2019)
Software choice		Operational				●		(AIA, 2007; Amuda-Yusuf, 2018; Ugwu and Kumaraswamy, 2007)
How develop, access and use the model		Operational				●		(AIA, 2007)
Subteams composition depending on purposes			Team-building			●		(Yu et al., 2019)
Continuity of team			Team-functioning			●		(AIA, 2007)
Collaborative contracting arrangements	Contractual				●			(AIA, 2007)
Shared financial risk and reward	Contractual				●			(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2014, 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Yu et al., 2019)
Financial incentives	Financial				●			(AIA, 2007; Chang et al., 2017; Kog and Loh, 2012; Yu et al., 2019)
Financial transparency	Financial				●			(AIA, 2007; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
Goals-owner's desired outcomes alignment	Managerial				●			(Azhar et al., 2014; Yu et al., 2019)

Table 6.1 (continued): Classification of each factor and their evaluation through the Delphi study.

Factor lists	IPD (Azhar et al., 2014)	BIM (Badrinath and Hsieh, 2019)	Team	Factor reduction in the Delphi round 1-2	Reliability Analysis	Factor ranking in the Delphi round 3-4	CSFs preliminary list	References
BIM competence of in-house team		Competency			●			(Amuda-Yusuf, 2018; Morlhon et al., 2014; Singh et al., 2011)
Allocation of budget toward BIM		Managerial			●			(Badrinath and Hsieh, 2019)
Commitment of team			Team-functioning		●			(AIA, 2007)
Continuity of values			Team-functioning		●			(AIA, 2007)
Selection of decision making body	Collaborative			●				(AIA, 2007; Azhar et al., 2014; Whang et al., 2019)
Internal dispute resolution	Collaborative			●				(AIA, 2007; Hamzeh et al., 2019; Kog and Loh, 2012; Lahdenperä, 2012; Toor and Ogunlana, 2009)
End users' involvement	Collaborative			●				(Amuda-Yusuf, 2018; Fortune and White, 2006; Lam et al., 2008; Ugwu and Kumaraswamy, 2007)
Facilitated negotiations	Collaborative			●				(AIA, 2007)
Key participants equality	Collaborative			●				(AIA, 2007; Lahdenperä, 2012; Mesa et al., 2019)
Intensified design	Collaborative			●				(AIA, 2007; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019)
Efforts in reducing waste in time	Collaborative			●				(Yu et al., 2019)
Collaborative activity duration estimation	Collaborative			●				(Yu et al., 2019)
Early goal definition	Collaborative			●				(Azhar et al., 2014; Piroozfar et al., 2019; Yu et al., 2019)
Binding resolution	Contractual			●				(AIA, 2007)
Multiparty Contract	Contractual			●				(AIA, 2007; Azhar et al., 2014, 2015; Chang et al., 2017; Lahdenperä, 2012; Matthews and Howell, 2005; Mesa et al., 2019; Piroozfar et al., 2019; Sun et al., 2015; Yu et al., 2019)
Careful contract review	Contractual			●				(Yu et al., 2019)
Shared contingency pool	Financial			●				(AIA, 2007; Mesa et al., 2016)
Formal dispute resolution	Legal			●				(AIA, 2007)
Integrated project insurance	Legal			●				(Chang et al., 2017)
Identification of project metric	Managerial			●				(AIA, 2007; Won and Lee, 2010)
Decision structures	Managerial			●				(AIA, 2007; Whang et al., 2019)
Identification of time to measure to project goals	Managerial			●				(AIA, 2007; Azhar et al., 2014)
Organizational and business structure best suited to IPD	Managerial			●				(AIA, 2007; Ashcraft, 2014a; Hamzeh et al., 2019)

Table 6.1 (continued): Classification of each factor and their evaluation through the Delphi study.

Factor lists	IPD (Azhar et al., 2014)	BIM (Badrinath and Hsieh, 2019)	Team	Factor reduction in the Delphi round 1-2	Reliability Analysis	Factor ranking in the Delphi round 3-4	CSFs preliminary list	References
Owners' satisfaction with BIM projects		Managerial		●				(Won and Lee, 2010)
Owners' interest/request for BIM		Managerial		●				(Won and Lee, 2010)
General perception of BIM		Managerial		●				(Amuda-Yusuf, 2018; Ugwu and Kumaraswamy, 2007)
Incentive programs for using BIM		Managerial		●				(Won and Lee, 2010)
Early understanding of O&M-stage BIM uses		Operational		●				(Badrinath and Hsieh, 2019)
BIM/FM integration		Operational		●				(Badrinath and Hsieh, 2019)
Use of BIM as a visual aid		Operational		●				(Yu et al., 2019)
Use of BIM for performance improvement		Operational		●				(Yu et al., 2019)
Developing customized IPD business process involving BIM technology		Organizational		●				(Whang et al., 2019)
Team selection			Formation	●				(AIA, 2007; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009)
Team formation			Formation	●				(AIA, 2007; Chang et al., 2017; Piroozfar et al., 2019; Whang et al., 2019)

○ indicates the factors in the CSFs preliminary list.
● indicates the removal process of the relevant factor through the Delphi survey.

6.1.1 IPD Adoption

Even if an increase in the adoption of collaboration-related IPD characteristics (Azhar et al., 2015), jointly developed goals, joint decision-making, and early involvement has been observed, contractual characteristics' adoption remained low, which are multi-party contracts, shared risks and rewards, and joint liability (Azhar et al., 2015). Team collaboration alone could not acquire the projected outcomes of IPD without relational contracts and a contractually incentivized team to integrate (NASFA et al., 2010). This situation can explain the lower frequency of encountering team-related problems than process-related problems. Therefore, necessary contractual arrangements need to be made if improvements in the team environment are desired to be spread throughout the process.

As the early involvement principle of IPD aims to bring construction expertise to the design process (AIA, 2007), relatively low-level adoption of early involvement can be another reason for ongoing process-related problems.

The results of questionnaire survey, interviews and the Delphi method confirmed the mutual relationship between the adoption of BIM and IPD characteristics as mentioned in Azhar et al. (2015)'s study. The relationship between BIM and IPD is further examined under the following relevant factors:

- Early involvement can increase the collaboration capabilities of the IPD team, and advance the BIM model with the contractor and subcontractor input in terms of constructibility, and more accurate 4D, 5D, 6D, and 7D applications, including cost and schedule estimation and sustainability analysis.
- Early integration in the IPD process can enhance the preparation process of the administrative BIM documents like BIM Protocol and BEP with the help of the collaborative and multidisciplinary team (ACIF and APCC, 2014). Furthermore, these agreements can be brought under the scope of the multi-party contracts so that the stakeholders must comply with these documents contractually.
- While the team is collectively defining and developing the project goals in IPD (Hamzeh et al., 2019), the BIM objectives of the parties can be shared and aligned with the overall objectives and project goals in this process.

- IPD provides the necessary communication, collaboration, and contractual environment for the development of BIM without traditional barriers that exist between the stakeholders preventing the easy share of information and knowledge (Sun, 2013).
- The visualization capabilities of the BIM can enhance good communication atmosphere in the IPD (Nofera et al., 2011).
- BIM's differentiated competency areas (Succar et al., 2013) can be handled and operated by the sub-teams compositions of the IPD, which are PET, PMT, and PIT.

As the findings of the Delphi method illustrated the importance of IPD related characteristics on project success, their adoption situation remained low compared to BIM and IPD team characteristics. Table 6.2 shows the comparison of findings of the Delphi method, online questionnaire survey and interviews based on the determined CSFs.

Table 6.2 : Comparison of the results of the research methods based on the determined factors.

Rank	Factors	References	CSF scores	Survey scores	Findings of interviews
1	Documented BEP	(Badrinath and Hsieh, 2019)	6,75	6,32	-
2	Early involvement of key participants	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)	6,63	5,03	Early involvement of prime constructor (46 %) Early involvement of subcontractors (20 %)
3	Collectively defined project goals	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; Azhar et al., 2015, 2014; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)	6,63	5,52	Jointly developed goals (80%) Owners' responsibility (20%)
4	Team collaboration/ integration	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)	6,63	5,97	More collaborative than before (80%)
5	Competencies of team	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; Nguyen et al., 2004; Toor and Ogunlana, 2009)	6,38	5,42	-
6	Organizational structure to support BIM	(Won and Lee, 2010)	6,38	6,06	Listed as a driver for IPD (40%)
7	Joint accountability	(AIA, 2007)	6,25	4,97	-

Table 6.2 (continued) : Comparison of the results of the research methods based on the determined factors.

Rank	Factors	References	CSF scores	Survey scores	Findings of interviews
8	Good communication atmosphere	(Hamzeh et al., 2019; Yu et al., 2019)	6,13	6,10	Open communication (80%) due to technological advancements (%80), BIM (%60), and (early involvement (%33)
9	Collaborative decision-making	(AIA, 2007; Ashcraft, 2014b; Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)	6,00	5,32	Collaborative (66%) Owners' responsibility (33%)
10	BIM Protocol	(AIA, 2007)	6,00	5,55	-
11	Regular meetings	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)	6,00	4,87	-
12	Information sharing protocols	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)	6,00	5,68	-
13	Communication of BIM objectives	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)	5,88	5,71	-
14	Proper organization setting before design	(Yu et al., 2019)	5,88	5,32	Intensified and collaborative design (80%)
15	Team involvement	(AIA, 2007)	5,75	5,84	Prime constructors' input to design (46%) Continuous involvement of the owner (40%) Designers' more active involvement in construction process (33%) Design consultants' integration to design process (26%) Subcontractors' input to design (20%)
16	Standardized work procedures for BIM	(Won and Lee, 2010)	5,63	5,97	Listed as a driver for IPD (26%)
17	Establishing the communication protocol	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)	5,63	5,16	-
18	Empowerment of team members	(Yu et al., 2019)	5,50	5,81	-

6.1.2 IPD Implementation and CSFs

The CSFs preliminary list (Table 6.2) reveals the crucial influences of collaboration-related key characteristics of IPD on achieving project success. IPD related CSFs' effects on project success are further explained under the related factors as follows:

- ‘Early involvement of key participants’ facilitates the taking of important decisions related to design and execution in the early stages of the project and the implementation of these decisions throughout the process. Moreover, the parties can identify innovative and feasible work practices regarding the project with the utilization of different areas of expertise (Hall et al., 2014). ‘Early involvement of key participants’ can solve the fragmentation problem in the CI (Kent and Becerik-Gerber, 2010). Therefore, the problems caused by fragmentation, such as excessive design changes (Baiden et al., 2006) and re-works, causing deviations in the targeted time, cost and quality (Yu et al., 2019).
- ‘Collectively defined project goals’ and ‘collaborative decision-making’ can eliminate the problem of adversarial relationships between major stakeholders by aligning individual interests of the parties with the achievement of common goals and project success (AIA, 2007). Solving the problem of adversarial relations can increase the project efficiency by reducing the disruptions in the process like cost and schedule overruns (De Marco and Karzouna, 2018), which may arise from this problem.
- ‘Joint accountability’ and ‘collaborative decision-making’ incentive the team to collaboratively work on problems arising through the process rather than blaming the specific stakeholder (Fischer et al., 2017). Therefore, deficiencies and errors can be taken care of in a shorter time than the traditional process, without causing disputes and delays in the delivery of the project.
- ‘Regular meetings’ are fundamental for establishing the trust-based and open communication environment (Pishdad-Bozorgi, 2017). These meetings can enable stakeholders to understand each other's objectives and act according to the greater good.
- The pre-design process in IPD is more intensive than other PDSs (Mesa et al., 2019). ‘Proper organization setting before the design’ is needed to proceed team selection and team integration process smoothly. Careful negotiations (CMAA, 2012) and team-building activities (Jones, 2014) in this stage can eliminate the problems affecting the effectiveness of the team that may arise later.

6.1.3 BIM Implementation CSFs for IPD

The preliminary CSFs list (Table 6.2) reveals the importance of administrative and organizational BIM characteristics. These characteristics directly affect the success of BIM process. BIM related CSFs' effects on project success are further explained below under the related factors.

- 'BEP' is important for the implementation of BIM as it defines the execution of the owner's BIM requirements and the responsibility of each party during the BIM process (Joblot et al., 2019). Enhanced communication and collaboration provided by IPD can advance the BEP (ACIF and APCC, 2014). With the involvement of all major stakeholders in the BEP preparation process, parties can learn about each other's differentiated procedures, tools, and priorities. This situation can prevent possible disputes from arising when the prime constructor is later involved in the process.
- BIM can become dysfunctional in a structure that is not suitable for it. 'Organizational structure to support BIM' is crucial for the success of BIM projects (Won and Lee, 2010). In order to utilize BIM's multidimensional benefits, integration of different disciplines is required (Eynon, 2016). IPD prepares the necessary environment to foster BIM adoption and take advantage of all its dimensions.
- 'The BIM' protocol', like 'BEP', is of critical importance for the BIM process to be carried out by minimizing conflicts (ACIF and APCC, 2014).

As the Independent- Sample T Test results showed, adopting and implementing BIM with various dimensions can lower the frequency rate of encountering some common problems including 'adversarial relationships', 'degraded project value', 'data losses' and 'excessive liability claims'. Therefore, it is significant for CI companies to enhance their BIM usage to increase the efficiency of all processes.

6.1.4 IPD Team Characteristics and CSFs

The preliminary CSFs list (Table 6.2) reveals the effects of IPD team characteristics on project success. IPD team related CSFs' effects on project success are further explained under the related factors as follows:

- As the questionnaire survey results reveal, the problem of the CI's inability to form an integrated team continues. Integrated teams promote "no-blame culture" by aligning different objectives, collective accountability, and the free exchange of information (AIA, 2007). 'Team integration' can help the team to handle disputes and problems more efficiently with their flexible composition (Zhang et al., 2013). As different systems, tools, and behaviors are harmonized within the integrated team (Baiden and Price, 2011), they can become more capable of achieving desired outcomes.
- In the IPD process, representatives of the main stakeholders form the IPD team (Allison et al., 2018). As the Delphi survey results show, 'team competency' have a crucial role in project success. Therefore, companies must select the right people to represent them in the IPD team, and team skills should be taken into account as well as individual talents and capabilities in the selection of representatives. Moreover, 'empowerment of team members' (Yu et al., 2019) needs to be ensured by related stakeholders for the team members' ability to make decisions regarding the project and implement them efficiently.
- 'Good communication atmosphere' (Yu et al., 2019) is critical for almost all factors related to IPD, BIM, and IPD teams. If the communication atmosphere is good, the BIM and IPD process can smoothly proceed with continuous feedback from all parties. If there are factors that prevent effective communication, the whole process can encounter problems (Nofera et al., 2011). Therefore, establishing and preserving the communication capabilities of the team need to be targeted by all parties and incentivized by contracts.

For the aim of this study, initial list covering the frequently faced problems in the CI, and characteristics of IPD, BIM and IPD-team have been prepared. Findings obtained from the online questionnaire survey, interviews and the Delphi method can show the specific areas for enhancing project efficiency. The CSFs preliminary list can be used as a potential checklist for the IPD and BIM adoption. Moreover, the list can be used by construction professionals to evaluate their work practices. Since the CSFs preliminary list has been formed as a suggestion, changes, additions and/or removals can be made in this list according to the changing and developing conditions of the projects. Moreover, the research methods and findings of the study can be useful for academics interested in IPD, BIM, and project success. Future studies on this topic might focus on a specific country or region and/or the projects' type and size.

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APPENDICES

APPENDIX A

	Critical Success Factors	References
IPD Related Factors	Early involvement of key participants	(AIA California Council, 2007) (Ugwu & Kumaraswamy, 2007)(Amuda-Yusuf, 2018)(Whang, Park, & Kim, 2019)(Mesa, Molenaar, & Alarcón, 2019)(Azhar, Kang, & Ahmad, 2015)(Piroozfar et al., 2019)(Azhar et al., 2014)(Chang et al., 2017)(Ashcraft, 2014) (Hamzeh et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
	Regular meetings	(AIA California Council, 2007) (Toor and Ogunlana 2009)(Badrinath & Hsieh, 2019)(Yu et al., 2019)
	Collectively defined project goals	(AIA California Council, 2007) (Gudiene et al. 2014)(Hyväri 2006)(Toor and Ogunlana 2009)(Aksorn and Hadikusumo 2008)(Badrinath & Hsieh, 2019)(Mesa, Molenaar, & Alarcón, 2019)(Mesa, Molenaar, & Alarcón, 2016)(Azhar, Kang, & Ahmad, 2015)(Azhar et al., 2014)(Ashcraft, 2014) (Lahdenperä, 2012)(Hamzeh et al., 2019)(Uihlein, 2016)(Yu et al., 2019)
	Selection of decision making body	(AIA California Council, 2007) (Whang, Park, & Kim, 2019)(Azhar et al., 2014)
	Establishing project's information specification	(AIA California Council, 2007) (Lahdenperä, 2012)
	Establishing the communication protocol/Appropriate tools for communication	(AIA California Council, 2007) (Yu et al., 2019)(Lahdenperä, 2012)
	Software choice	(AIA California Council, 2007) (Ugwu & Kumaraswamy, 2007)(Bui, et al., 2016)(Amuda-Yusuf, 2018)
	How develop/ accessed/ used the model	(AIA California Council, 2007)
	Information sharing protocols	(AIA California Council, 2007) (Won & Lee, 2010)(Chang et al., 2017)
	BIM Protocol	(AIA California Council, 2007)
	Collaborative contracting arrangements	(AIA California Council, 2007)
	Internal dispute resolution	(AIA California Council, 2007) (Toor and Ogunlana 2009)(Kog and Loh 2012)(Hamzeh et al., 2019)(Lahdenperä, 2012)
	End users' involvement	(Fortune and White 2006) (Lam, Chan, and Chan 2008)(Ugwu & Kumaraswamy, 2007)(Bui, et al., 2016)(Amuda-Yusuf, 2018)
	Identification of project metric	(AIA California Council, 2007) (Won & Lee, 2010)
	Joint Liability (Liability Waivers among Key Participants)	(AIA California Council, 2007) (Mesa, Molenaar, & Alarcón, 2019)(Azhar, Kang, & Ahmad, 2015)(Yu et al., 2019)(Chang et al., 2017)(Ashcraft, 2014) (Lahdenperä, 2012)
	Accountability	(AIA California Council, 2007)
	Financial intencives	(AIA California Council, 2007) (Kog and Loh 2012)(Yu et al., 2019)(Chang et al., 2017)
	Stakeholders' open book calculations/ Fiscal transparency between key participants/ Financial transparency	(AIA California Council, 2007) (Mesa, Molenaar, & Alarcón, 2019)(Yu et al., 2019)(Chang et al., 2017)(Lahdenperä, 2012)
	Formal dispute resolution	(AIA California Council, 2007)
	Decision structures	(AIA California Council, 2007) (Whang, Park, & Kim, 2019)
	Target Outturn Cost??	(AIA California Council, 2007)
	Contingency funds/ shared contingency pool	(AIA California Council, 2007) (Mesa, Molenaar, & Alarcón, 2016)
	Identification of time to measure to project goals	(AIA California Council, 2007) (Azhar et al., 2014)
	Facilitated negotiations	(AIA California Council, 2007)
	Binding resolution	(AIA California Council, 2007)
	Organizational and business structure best suited to IPD	(AIA California Council, 2007) (Ashcraft, 2014b)(Hamzeh et al., 2019)
	Shared financial risk and reward/ pain and gain sharing	(Mesa, Molenaar, & Alarcón, 2019) (AIA California Council, 2007)(Azhar, Kang, & Ahmad, 2015)(Mesa, Molenaar, & Alarcón, 2016)(Yu et al., 2019)(Piroozfar et al., 2019)(Azhar et al., 2014)(Ashcraft, 2014) (Hamzeh et al., 2019)(Lahdenperä, 2012)
	Collaborative decision-making	(Mesa, Molenaar, & Alarcón, 2019) (Azhar, Kang, & Ahmad, 2015)(Yu et al., 2019)(Piroozfar et al., 2019)(Chang et al., 2017)(Ashcraft, 2014) (Hamzeh et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
	Key participants bound together as equals	(Mesa, Molenaar, & Alarcón, 2019) (Lahdenperä, 2012)
	Intensified design	(Mesa, Molenaar, & Alarcón, 2019) (Chang et al., 2017)(Piroozfar et al., 2019)(Lahdenperä, 2012)
	Multiparty Contract	(AIA California Council, 2007) (Azhar, Kang, & Ahmad, 2015)(Mesa, Molenaar, & Alarcón, 2019)(Sun et al., 2015)(Yu et al., 2019)(Piroozfar et al., 2019)(Azhar et al., 2014)(Chang et al., 2017)(Matthews & Howell, 2005)(Lahdenperä, 2012)
	Established process for handling change orders	(Yu et al., 2019) (Hamzeh et al., 2019)
	Goals-owner's desired outcomes alignment	(Yu et al., 2019) (Azhar et al., 2014)
	Efforts in reducing waste in time	(Yu et al., 2019)
	Collaborative activity duration estimation	(Yu et al., 2019)
	Careful contract review	(Yu et al., 2019)
	Proper organization setting before design	(Yu et al., 2019)
	Early goal definition	(Yu et al., 2019) (Piroozfar et al., 2019)(Azhar et al., 2014)
	Integrated project insurance	(Chang et al., 2017)

Figure A.1 : Comprehensive lists covering all processes and stakeholders 1.

BIM Related Factors	Developing customized IPD business process involving BIM technology	(Whang, Park, & Kim, 2019)
	Organizational structure to support BIM	(Won & Lee, 2010)
	Communication of BIM objectives	(Eadie, et al., 2013) (Morlhon, et al., 2014)(Amuda-Yusuf, 2018)
	Standardized work procedures for BIM	(Won & Lee, 2010)
	Allocation of budget toward BIM	(Badrinath & Hsieh, 2019)
	Clients' satisfaction with BIM projects	(Won & Lee, 2010)
	Early understanding of O&M-stage BIM uses	(Badrinath & Hsieh, 2019)
	Clients' interest/request for BIM	(Won & Lee, 2010)
	Documented BIM execution plan	(Badrinath & Hsieh, 2019)
	General perception of BIM as improving productivity	(Ugwu & Kumaraswamy, 2007) (Amuda-Yusuf, 2018)
	Number of subcontractors/partners who have experienced BIM projects	(Won & Lee, 2010)
	Incentive programs for using BIM	(Won & Lee, 2010)
	BIM competence of in-house team	(Singh, et al., 2011) (Morlhon, et al., 2014) (Amuda-Yusuf, 2018)
	BIM/FM integration	(Badrinath & Hsieh, 2019)
	Use of BIM as a visual aid	(Yu et al., 2019)
	Use of BIM for design and documentation	(Yu et al., 2019)
	Use of BIM for performance improvement	(Yu et al., 2019)
Team Related Factors	Team selection (OWNER)	(AIA California Council, 2007) (Toor and Ogunlana 2009)(Mesa, Molenaar, & Alarcón, 2016)(Lahdenperä, 2012)(Ghassemi & Becerik-Gerber, 2011)
	Team involvement	(AIA California Council, 2007)
	Team formation/ organization	(AIA California Council, 2007) (Whang, Park, & Kim, 2019)(Piroozfar et al., 2019)(Chang et al., 2017)(Abdirad & Dossick, 2019)
	Team collaboration/ integration	(AIA California Council, 2007) (Won & Lee, 2010)(Whang, Park, & Kim, 2019)(Abdirad & Pishdad-Bozorgi, 2014)Ashcraft, 2011O'Connor, 2009Franz and Leicht, 2017(Cleves and Dal Gallo, 2012)(Franz et al., 2017)(Sun et al., 2015)(Ashcraft, 2014) (Lahdenperä, 2012)(Hamzeh et al., 2019)
	Commitment of team	(AIA California Council, 2007)
	Continuity of values	(AIA California Council, 2007)
	Continuity of team	(AIA California Council, 2007)
	Competencies of team	(Toor and Ogunlana 2009) (Gudiene et al. 2014)(Aksorn and Hadikusumo 2008)(Kog and Loh 2012)(Nguyen, Ogunlana, and Lan 2004)
	Subteams composition depending on purposes	(Yu et al., 2019)
	Empowerment of team members	(Yu et al., 2019)
	Good communication atmosphere	(Yu et al., 2019) (Hamzeh et al., 2019)

Figure A.2 : Comprehensive lists covering all processes and stakeholders 2.

Outcomes	Conceptualization	Performance goals are developed by the team	(AIA California Council, 2007)
		Size	(AIA California Council, 2007)
		Sustainable or green criteria or goals	(AIA California Council, 2007)
		Economic performance based on the complete building life span including operation	(AIA California Council, 2007)
		Successful outcome metrics (e.g. cost, schedule, quality, etc.)	(AIA California Council, 2007)
		Cost structure is developed earlier and in greater detail	(AIA California Council, 2007)
		Costs may be linked to Building Information Model to enable rapid assessment of design decisions	(AIA California Council, 2007)
		Costs are detailed by system, providing an understanding of the cost range and importance of each system	(AIA California Council, 2007)
		Key parties assess areas where greatest improvements are possible	(AIA California Council, 2007)
		Initial benchmarking comparison is performed to assess project costs against market rates	(AIA California Council, 2007)
		Preliminary schedule is developed and linked to developing model	(AIA California Council, 2007)
		Communication methodologies and technologies are identified and key parameters agreed upon	(AIA California Council, 2007)
		Building Information Modeling platform(s)	(AIA California Council, 2007)
		Administration and maintenance of BIM(s)	(AIA California Council, 2007)
		Source of truth for all data	(AIA California Council, 2007)
		Interoperability criteria	(AIA California Council, 2007)
		Data transfer protocols	(AIA California Council, 2007)
		Level of detail development by phase	(AIA California Council, 2007)
		Development of tolerances	(AIA California Council, 2007)

Figure A.3 : Comprehensive lists covering all processes and stakeholders 3.

Outcomes	Criteria Design	The following aspects of the project are finalized, allowing the team to proceed with confidence to the next level of detail	(AIA California Council, 2007)
		Scope	(AIA California Council, 2007)
		Form, adjacencies and spatial relationships	(AIA California Council, 2007)
		Selection and initial design of major building systems (structure, skin, HVAC, etc.)	(AIA California Council, 2007)
		Cost estimate (at appropriate precision)	(AIA California Council, 2007)
		Schedule (at appropriate precision)	(AIA California Council, 2007)
		Agreement is reached on tolerances between trades to enable prefabrication.	(AIA California Council, 2007)
	Detailed Design	Building is fully and unambiguously defined, coordinated and validated	(AIA California Council, 2007)
		All major building systems are defined, including any furnishings, fixtures and equipment within the scope of the project	(AIA California Council, 2007)
		All building elements are fully engineered and coordinated. The team will have collaborated to resolve any inconsistencies, conflicts or constructability issues	(AIA California Council, 2007)
		Agreement is reached on tolerances between trades to ensure constructability and to enable as much prefabrication as possible	(AIA California Council, 2007)
		Quality levels are established	(AIA California Council, 2007)
		Prescriptive Specifications are completed based on prescribed and agreed systems	(AIA California Council, 2007)
		Cost is established to a high level of precision	(AIA California Council, 2007)
		Construction schedule is established to a high level of precision	(AIA California Council, 2007)
	Implementation Documents	Construction means and methods are finalized and documented	(AIA California Council, 2007)
		Construction schedule is finalized and agreed upon	(AIA California Council, 2007)
		Cost is finalized and agreed upon	(AIA California Council, 2007)
		Costs are tied to the model	(AIA California Council, 2007)
		The specifications are finalized, supplementing the model with narrative documentation of the design intent wherever necessary	(AIA California Council, 2007)
		Implementation Documents define and visualize the project for participants who aren't involved in the development of the model, providing	(AIA California Council, 2007)
		A "finance-able" project (a completed model that gives "the bank" sufficient detail to finance the project)	(AIA California Council, 2007)
		Bid documents for parties outside the integrated process	(AIA California Council, 2007)
		The "shop drawing" phase that in traditional phases occurs after Construction Documents will be largely completed during the Implementation Documents phase	(AIA California Council, 2007)
		Prefabrication of some systems can commence because the model is sufficiently fixed (object sizes and positions are frozen) to allow early purchasing and prefabrication to begin	(AIA California Council, 2007)

Figure A.4 : Comprehensive lists covering all processes and stakeholders 4.

Outcomes	Agency Review	All necessary permits and approvals	(AIA California Council, 2007)
	Buyout	Commitments are in place for all work, materials and equipment needed to complete the project	(AIA California Council, 2007)
	Construction	Substantial Completion of the project, characterized by:	(AIA California Council, 2007)
		Virtually no RFIs from major trades because prime constructor, key trade contractors and key vendors have been involved in developing the design intent and implementation	(AIA California Council, 2007)
		Less construction administration effort required because submittals for key scopes of work have already been integrated into the model and conflicts have been resolved virtually	(AIA California Council, 2007)
		Better understanding of design intent by all participants because the BIM provides effective visualization	(AIA California Council, 2007)
		More pre-fabrication resulting in:	(AIA California Council, 2007)
		Less waste because more assemblies are factory generated.	(AIA California Council, 2007)
		Fewer injuries because more work is being performed in a more controlled environment	(AIA California Council, 2007)
		A schedule tied to the model to allow visualization of crew coordination and deviations from planned sequences and durations	(AIA California Council, 2007)
		Some elements of current construction administration will remain similar to current practice	(AIA California Council, 2007)
		Quality control, inspection and testing will be relatively unchanged	(AIA California Council, 2007)
		Changes within the agreed project scope will be virtually eliminated, but owner-directed changes will need to be formally negotiated	(AIA California Council, 2007)
		Scheduling and progress will be periodically reviewed	(AIA California Council, 2007)
	Closeout	A complete building information model reflecting "as-built" conditions will be provided to the owner for long term use for building management, maintenance and operation. This model can also be used for:	(AIA California Council, 2007)
		Integration of building monitoring, control and security systems	(AIA California Council, 2007)
		Comparing actual performance of building and systems to planned performance	(AIA California Council, 2007)
		Referencing of warranty, operation and maintenance information	(AIA California Council, 2007)
		Traditional warranties will remain for installation quality and defective products.	(AIA California Council, 2007)

Figure A.5 : Comprehensive lists covering all processes and stakeholders 5.

Integrated Project Coordinator	Characteristics	Leadership skills	(Gudiene et al. 2014)
		Motivating skills	(Gudiene et al. 2014)
		Organizing skills	(Gudiene et al. 2014)
		Coordinating skills	(Gudiene et al. 2014) (Hyväri 2006)(Belassi and Tukel 1996)
		Interpersonal skills	(Ugwu & Kumaraswamy, 2007) (Bui, et al., 2016)(Amuda-Yusuf, 2018)
		Mutual respect and trust	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Hamzeh et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
		Willingness to collaborate	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Uihlein, 2016)
		Open communication	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
	Factors derived from roles and responsibilities	Realistic Schedule	(Fortune and White 2006) (Gudiene et al. 2014)
		Team's compliance with owner's requirements	(AIA California Council, 2007)
		Completeness of necessary project information	(AIA California Council, 2007)
		Facilitation, coordination, organization and direction of the integrated team	(AIA California Council, 2007)
		Coordination of overall project schedule	(AIA California Council, 2007)
		Coordinating and track integrated team's performance	(AIA California Council, 2007)
		Coordination of assignment related to responsibilities, actions and completion requirements	(AIA California Council, 2007)
		Coordination of alternative options for presentation to Owner	(AIA California Council, 2007)
		Ensuring compliance with project requirements	(AIA California Council, 2007)
		Performance checking of building systems	(AIA California Council, 2007)
		Completion of information for legal requirements of project	(AIA California Council, 2007)
		Coordination of team input and facilitating team buy-in for overall project schedule and budget	(AIA California Council, 2007)
		Coordination and management of the Agency Review process	(AIA California Council, 2007)

Figure A.6 : Comprehensive lists covering all processes and stakeholders 6.

Owner	Characteristics	Client's ability to brief	(Chan, Scott, and Chan 2004) (Lam, Chan, and Chan 2008)
		Owners competence	(Jha 2013)
		Client's ability to make decision/ Quick owner decision making	(Chan, Scott, and Chan 2004) (Lam, Chan, and Chan 2008)(Yu et al., 2019)
		Mutual respect and trust	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Hamzeh et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
		Willingness to collaborate	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Uihlein, 2016)
		Open communication	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
		Commitment to improvement	(Lahdenperä, 2012)
	Factors derived from roles and responsibilities	Clear definitions of teams' tasks and responsibilities	(Whang, Park, & Kim, 2019) (Badrinath & Hsieh, 2019)(Azhar et al., 2014)(Hamzeh et al., 2019)
		Clear definitions of scope of services	(AIA California Council, 2007) (Sanvido et al. 1992)(Nguyen, Ogunlana, and Lan 2004(Whang, Park, & Kim, 2019)
		Evaluating and influencing design options (OWNER)	(AIA California Council, 2007) (Hamzeh et al., 2019)
		Procurement method	(AIA California Council, 2007) (Gudiene et al. 2014)(Chan, Scott, and Chan 2004)
		Providing site data (topography, utility locations, soils condition, environmental impact studies and reports, Phase I mitigation reports)	(AIA California Council, 2007)
		Adequate funds/resources	(AIA California Council, 2007) (Nguyen, Ogunlana, and Lan 2004)(Hyväri 2006)(Kog and Loh 2012)
		Client’s emphasis on transfer of risk	(Lam, Chan, and Chan 2008)
		Risk attitude	(Gudiene et al. 2014)
		Risk identification and allocation/ risk sharing	(Kog and Loh 2012) (AIA California Council, 2007)(Whang, Park, & Kim, 2019)
		Implementation an effective safety program	(Chan, Scott, and Chan 2004)
		Risks addressed/assessed/managed	(Fortune and White 2006)
		Clear definition and understanding of users’ requirements	(Ugwu & Kumaraswamy, 2007) (Morlhon, et al., 2014)(Amuda-Yusuf, 2018)
		Owner's review and approval of criteria documents	(AIA California Council, 2007)
		Clarity of client’s requirements	(Lam, Chan, and Chan 2008)
		Effective change management	(Fortune and White 2006) (Toor and Ogunlana 2009)
		Suitability between project initial objective and final product	(Nguyen and Chovichien 2013)
		Owner's approval of design	(AIA California Council, 2007)
		Facilitating IPD teams response to modifications required by jurisdiction	(AIA California Council, 2007)
		Transition planning	(AIA California Council, 2007)
		User appeals process	(AIA California Council, 2007)
		Final user reviews and approvals	(AIA California Council, 2007)
		Major equipments' specifications	(AIA California Council, 2007)
		Defining and controlling the relation between project and business case	(AIA California Council, 2007)
		Coordination of financial requirements necessary to begin construction	(AIA California Council, 2007)
		Negotiations with jurisdiction providing permits	(AIA California Council, 2007)
		Permits and approvals	(AIA California Council, 2007)
		Identification of pre qualification requirements	(AIA California Council, 2007)
		Organizations requirements for outreach	(AIA California Council, 2007)
		Early owner participation	(Yu et al., 2019)
		Owner's participation in pre bid conferences	(AIA California Council, 2007)
		Owner’s contractual obligations	(AIA California Council, 2007)
		Owner’s internal review and decision process	(AIA California Council, 2007)
		Owner’s transition process to occupy and startup of completed project	(AIA California Council, 2007)
		Organizing equipment procurement and staging	(AIA California Council, 2007)
		Training of operation and maintenance personnel	(AIA California Council, 2007)
		Continual monitoring of project with respect to project goals and metrics related to performance	(AIA California Council, 2007)
		Complementation of jurisdictional requirements for occupancy and project completion	(AIA California Council, 2007)

Figure A.7 : Comprehensive lists covering all processes and stakeholders 7.

Prime Designer	Characteristics	Competencies of project designers	(Khang and Moe 2008)
		Mutual respect and trust	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Hamzeh et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
		Willingness to collaborate	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Uihlein, 2016)
		Open communication	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
	Factors derived from roles and responsibilities	Variety of design options	(AIA California Council, 2007) (Fischer et al., 2017)(Walker and Rowlinson, 2019)(Forbes and Ahmed, 2010)(Cleves and Gallo, 2012)(Hamzeh et al., 2019)
		Effective consultation with key stakeholders	(AIA California Council, 2007) (Khang and Moe 2008)
		Design schedule (Accuracy)	(AIA California Council, 2007)
		3D detailing	(Badrinath & Hsieh, 2019)
		Direct connection with quantity surveyor	(AIA California Council, 2007)
		Alignment of space program with project goals	(AIA California Council, 2007)
		Visualization	(AIA California Council, 2007)
		Accurate identification of sustainable design outcomes	(AIA California Council, 2007)
		Designer's response to RFI's	(AIA California Council, 2007)
		Construction Contract Administration	(AIA California Council, 2007)
		Coordination of RFI and submittal responses from all design consultants	(AIA California Council, 2007)
		BIM Model updates during construction	(AIA California Council, 2007)
		Conformance of the construction with design intent	(AIA California Council, 2007)
		Substantial and final completions documents	(AIA California Council, 2007)
		Effective change management	(AIA California Council, 2007) (Fortune and White 2006)(Toor and Ogunlana 2009)
		Form, adjacencies and spatial relationships of the project	(AIA California Council, 2007)
		Code compliance	(AIA California Council, 2007)
		Constructible detailing	(AIA California Council, 2007)
		Conformance of the user experience of building and project goals	(AIA California Council, 2007)
		Ensuring coordination to selection of major building systems and performance requirements	(AIA California Council, 2007)
		Outline or Performance Specification	(AIA California Council, 2007)
		Regulatory requirements for the building (i.e.: fire/life safety plan)	(AIA California Council, 2007)
		Sustainability targets and proposed systems	(AIA California Council, 2007)
		Completeness of model for architecturally related design intent for construction	(AIA California Council, 2007)
		Providing descriptive information for fabrication and construction of architecturally related scope	(AIA California Council, 2007)
		Specification finalization	(AIA California Council, 2007)
		Interfacing with agency representative to ensure code compliance of design is understood	(AIA California Council, 2007)
		Interoperability of BIM with agencies to ensure code compliance	(AIA California Council, 2007)
		Responding to questions from remaining trades bidding on the project	(AIA California Council, 2007)
		Integrity of the design intent and pre-fabrication studies	(AIA California Council, 2007)
		Using the BIM for life cycle benefit	(AIA California Council, 2007)
		Analyzing Post Occupancy Evaluation	(AIA California Council, 2007)
Design Consultants	Characteristics	Mutual respect and trust	(Mesa, Molenaar, & Alarcón, 2019)(Piroozfar et al., 2019)(Hamzeh et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
		Willingness to collaborate	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Uihlein, 2016)
		Open communication	(Mesa, Molenaar, & Alarcón, 2019)(Piroozfar et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
	Factors derived from roles and responsibilities	Identification of project and system requirements	(AIA California Council, 2007)
		Selection of major building systems	(AIA California Council, 2007)
		Setting performance requirements	(AIA California Council, 2007)
		Building systems' compliance with project performance goals	(AIA California Council, 2007)
		Identification of unique conditions in criteria design	(AIA California Council, 2007)
		Locating major pieces of equipment and routing in the project	(AIA California Council, 2007)
		System performance verification	(AIA California Council, 2007)

Figure A.8 : Comprehensive lists covering all processes and stakeholders 8.

Trade Constructor	Characteristics	Mutual respect and trust	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Hamzeh et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
		Willingness to collaborate	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Uihlein, 2016)
		Open communication	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
	Factors derived from roles and responsibilities	Accuracy of trade contractors' cost data	(AIA California Council, 2007)
		Accuracy of trade contractors' schedule data	(AIA California Council, 2007)
		Cost options	(AIA California Council, 2007)
		Compatibility with the design and work of other trades	(AIA California Council, 2007)
		Shop drawings/ model	(AIA California Council, 2007)
		Synchronized model for fabrication or installation purposes	(AIA California Council, 2007)
		Completeness of BIM and specifications for applicable scope of work	(AIA California Council, 2007)
		Trade contractors' contribution to model	(AIA California Council, 2007)
		Trade contractors' participation in coordination and conflict resolution	(AIA California Council, 2007)
		Trade contractors' coordination during construction	(AIA California Council, 2007)
		O&M informations by trade contractors	(AIA California Council, 2007)
Suppliers	Characteristics	Mutual respect and trust	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Hamzeh et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
		Willingness to collaborate	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Uihlein, 2016)
		Open communication	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
	Factors derived from roles and responsibilities	Identification of long lead items	(AIA California Council, 2007)
		Suppliers' specific cost data	(AIA California Council, 2007)
		Suppliers' life cycle and energy efficiency data	(AIA California Council, 2007)
		Product data sheets accuracy	(AIA California Council, 2007)
		Suppliers' cost and schedule data accuracy	(AIA California Council, 2007)
		Schedule of long lead items	(AIA California Council, 2007)
		Suppliers' contribution to model	(AIA California Council, 2007)
		Suppliers' participation in coordination and conflict resolution	(AIA California Council, 2007)
		Suppliers' coordination during construction	(AIA California Council, 2007)
		O&M informations by suppliers	(AIA California Council, 2007)

Figure A.9 : Comprehensive lists covering all processes and stakeholders 9.

Prime Constructor	Characteristics	Mutual respect and trust	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Hamzeh et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
		Willingness to collaborate	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Uihlein, 2016)
		Open communication	(Mesa, Molenaar, & Alarcón, 2019) (Piroozfar et al., 2019)(Lahdenperä, 2012)(Uihlein, 2016)
	Factors derived from roles and responsibilities	Constructability program	(AIA California Council, 2007) (Kog and Loh 2012)(Badrinath & Hsieh, 2019)
		Accurate initial cost estimates and integration into model	(AIA California Council, 2007) (Nguyen, Ogunlana, and Lan 2004)(Belassi and Tukel 1996)
		Cost estimation	(Badrinath & Hsieh, 2019)
		Accurate initial construction schedule and integration into model	(AIA California Council, 2007)
		Meeting budget goal	(Sanvido et al. 1992) (Shenhar et al. 2001)
		Meeting functional performance	(Sanvido et al. 1992) (Shenhar et al. 2001)
		Meeting schedule goal	(Sanvido et al. 1992) (Shenhar et al. 2001)
		Meeting technical specifications	(Shenhar et al. 2001)
		Safety program/ policy (training, signs, staffs, and records)	(Sanvido et al. 1992) (Chan, Scott, and Chan 2004)(Aksorn and Hadikusumo 2008)(Alzahrani and Emsley 2013)(Nguyen and Chovichien 2013)(Gudiene et al. 2014)
		Construction Schedule (Accuracy)	(AIA California Council, 2007)
		Validation of target cost	(AIA California Council, 2007)
		Cost accuracy	(AIA California Council, 2007)
		Information about Procurement/ Assembly/ Layout/ Detailed Schedule/ Testing/ Commissioning	(AIA California Council, 2007)
		Ensuring accountability of all necessary work	(AIA California Council, 2007)
		Construction-related permits	(AIA California Council, 2007)
		Completeness of commitments for all works	(AIA California Council, 2007)
		Negotiating strategies	(AIA California Council, 2007)
		Relations with neighbors	(AIA California Council, 2007)
		Prime constructor's coordination with regulatory agencies	(AIA California Council, 2007)
		Necessary in site tests	(AIA California Council, 2007)
		Prefabrication opportunities	(AIA California Council, 2007)
		Tolerances	(AIA California Council, 2007)
		Coordination of building systems	(AIA California Council, 2007)
		Transfer process of BIM control	(AIA California Council, 2007)
		Model accuracy for quantity survey	(AIA California Council, 2007)
		good subcontractor buy out	(Sanvido et al. 1992) (AIA California Council, 2007)
		as-built model	(AIA California Council, 2007)

Figure A.10 : Comprehensive lists covering all processes and stakeholders 10.

APPENDIX B

Dear Participant,

This questionnaire survey is performed within the scope of the master's thesis on "An investigation into the current status of adoption of IPD characteristics and BIM in construction projects to overcome process and team-related problems" prepared by Hakan Taha Çetin, who is a student at Istanbul Technical University under the supervision of Prof. Dr. Begüm Sertyesilışık. This study aims to investigate the current status of adoption level of IPD's main characteristics and BIM in construction projects and to investigate impact of highly adopted characteristics on overcoming process and team-related problems. Furthermore, this study has objectives of identification of critical success factors related with IPD, BIM and IPD teams.

I would like to invite you to contribute to my questionnaire survey. Participation in this questionnaire survey is entirely voluntary. You can leave this questionnaire survey voluntarily at any time, at any stage, without facing any sanctions. This questionnaire survey can take approximately 15 minutes to accomplish. Data and information you will provide in this questionnaire survey, as well as the data and information to be obtained from this questionnaire survey, will be used anonymously in the specified master's thesis as well as in related publications (i.e., articles, papers, proceedings and chapters based on this thesis). Data and information obtained will not be shared except for the master's thesis, related publications based on this thesis.

If you have further questions or if you would like to get more information about this questionnaire survey, you can contact Hakan Taha Çetin (e-mail address:cetinhak@itu.edu.tr).

Kindest regards,
Hakan Taha Çetin
Istanbul Technical University Graduate School
Project and Construction Management MSc program student

START FORM

IPD in the construction industry

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Önizleme sırasında cevaplarınız kaydedilmeyecektir.

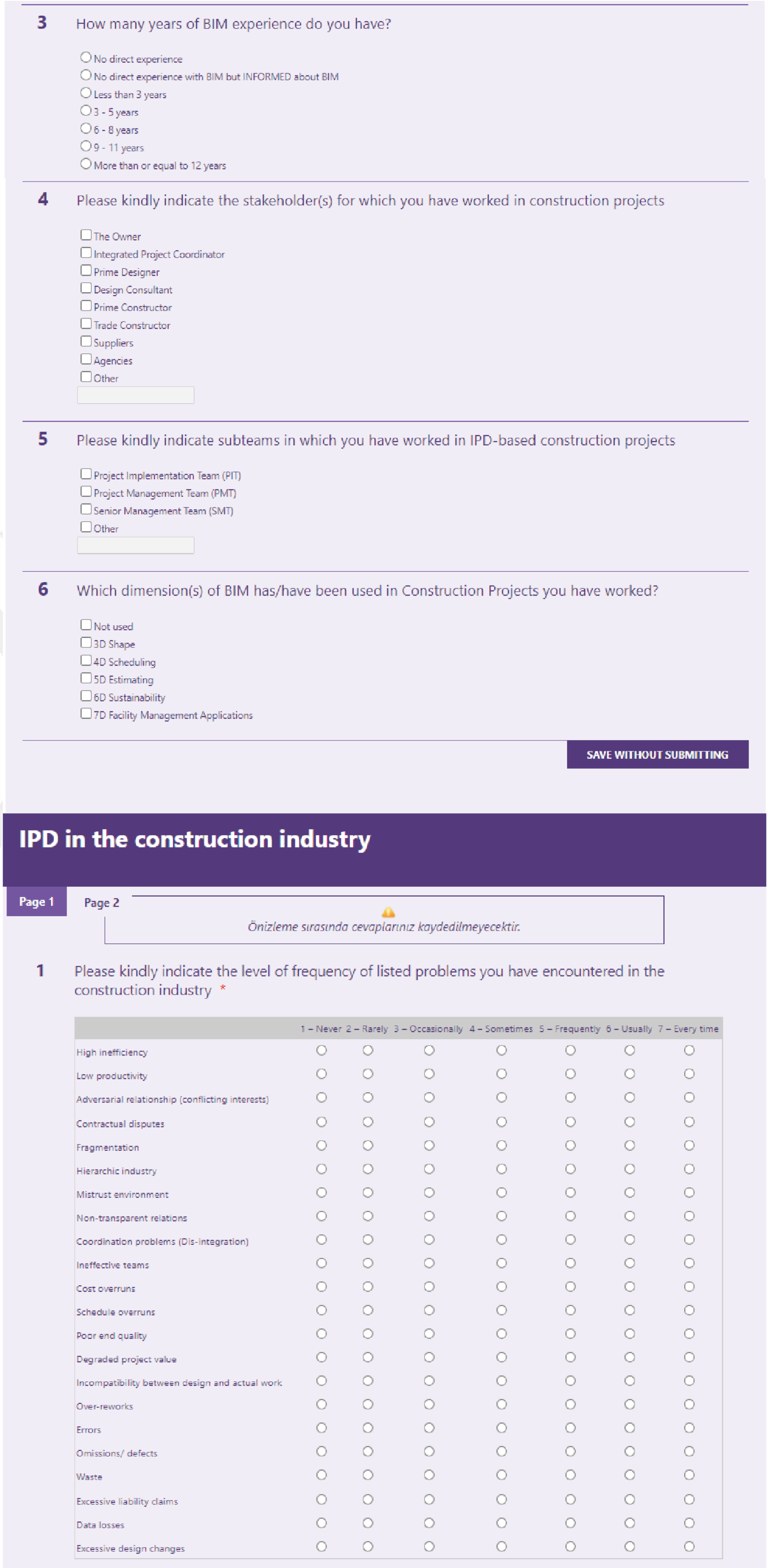
1 How many years of professional experience do you have in the construction industry?

- Less than 5 years
- 5 - 9 years
- 10 - 14 years
- 15 - 19 years
- 20 - 24 years
- More than or equal to 25 years

2 How many years of IPD experience do you have?

- No direct experience
- No direct experience with IPD but INFORMED about IPD
- Less than 3 years
- 3 - 5 years
- 6 - 8 years
- 9 - 11 years
- More than or equal to 12 years

Figure B.1 : Questionnaire survey questions 1.



3 How many years of BIM experience do you have?

○ No direct experience
○ No direct experience with BIM but INFORMED about BIM
○ Less than 3 years
○ 3 - 5 years
○ 6 - 8 years
○ 9 - 11 years
○ More than or equal to 12 years

4 Please kindly indicate the stakeholder(s) for which you have worked in construction projects

☐ The Owner
☐ Integrated Project Coordinator
☐ Prime Designer
☐ Design Consultant
☐ Prime Constructor
☐ Trade Constructor
☐ Suppliers
☐ Agencies
☐ Other

5 Please kindly indicate subteams in which you have worked in IPD-based construction projects

☐ Project Implementation Team (PIT)
☐ Project Management Team (PMT)
☐ Senior Management Team (SMT)
☐ Other

6 Which dimension(s) of BIM has/have been used in Construction Projects you have worked?

☐ Not used
☐ 3D Shape
☐ 4D Scheduling
☐ 5D Estimating
☐ 6D Sustainability
☐ 7D Facility Management Applications

SAVE WITHOUT SUBMITTING

IPD in the construction industry

Page 1 Page 2

Önizleme sırasında cevaplarınız kaydedilmeyecektir.

1 Please kindly indicate the level of frequency of listed problems you have encountered in the construction industry *

	1 – Never	2 – Rarely	3 – Occasionally	4 – Sometimes	5 – Frequently	6 – Usually	7 – Every time
High inefficiency	○	○	○	○	○	○	○
Low productivity	○	○	○	○	○	○	○
Adversarial relationship (conflicting interests)	○	○	○	○	○	○	○
Contractual disputes	○	○	○	○	○	○	○
Fragmentation	○	○	○	○	○	○	○
Hierarchic industry	○	○	○	○	○	○	○
Mistrust environment	○	○	○	○	○	○	○
Non-transparent relations	○	○	○	○	○	○	○
Coordination problems (Dis-integration)	○	○	○	○	○	○	○
Ineffective teams	○	○	○	○	○	○	○
Cost overruns	○	○	○	○	○	○	○
Schedule overruns	○	○	○	○	○	○	○
Poor end quality	○	○	○	○	○	○	○
Degraded project value	○	○	○	○	○	○	○
Incompatibility between design and actual work	○	○	○	○	○	○	○
Over-reworks	○	○	○	○	○	○	○
Errors	○	○	○	○	○	○	○
Omissions/ defects	○	○	○	○	○	○	○
Waste	○	○	○	○	○	○	○
Excessive liability claims	○	○	○	○	○	○	○
Data losses	○	○	○	○	○	○	○
Excessive design changes	○	○	○	○	○	○	○

Figure B.2 : Questionnaire survey questions 2.

2 Based on construction projects you have been involved in the last 5 years, please kindly indicate the level of priority of the IPD related factors

	1 – Not a priority	2 – Low priority	3 – Somewhat priority	4 – Neutral	5 – Moderate Priority	6 – High priority	7 – Essential priority
Early involvement of participants	○	○	○	○	○	○	○
Regular meetings	○	○	○	○	○	○	○
Collectively defined project goals	○	○	○	○	○	○	○
Establishing project's information specification	○	○	○	○	○	○	○
Establishing the communication protocol	○	○	○	○	○	○	○
Software choice	○	○	○	○	○	○	○
How develop/ accessed/ used the model	○	○	○	○	○	○	○
Information sharing protocols	○	○	○	○	○	○	○
BIM Protocol	○	○	○	○	○	○	○
Collaborative contracting arrangements	○	○	○	○	○	○	○
Joint Liability	○	○	○	○	○	○	○
Accountability	○	○	○	○	○	○	○
Financial intencives	○	○	○	○	○	○	○
Financial transparency	○	○	○	○	○	○	○
Shared financial risk and reward/ pain and gain sharing	○	○	○	○	○	○	○
Collaborative decision-making	○	○	○	○	○	○	○
Established process for handling change orders	○	○	○	○	○	○	○
Goals-owner's desired outcomes alignment	○	○	○	○	○	○	○
Proper organization setting before design	○	○	○	○	○	○	○

3 Based on construction projects you have been involved in the last 5 years, please kindly indicate the level of priority of the team related factors

	1 – Not a priority	2 – Low priority	3 – Somewhat priority	4 – Neutral	5 – Moderate Priority	6 – High priority	7 – Essential priority
Team involvement	○	○	○	○	○	○	○
Team collaboration	○	○	○	○	○	○	○
Commitment of team	○	○	○	○	○	○	○
Continuity of values	○	○	○	○	○	○	○
Continuity of team	○	○	○	○	○	○	○
Competencies of team	○	○	○	○	○	○	○
Subteams composition depending on purposes	○	○	○	○	○	○	○
Empowerment of team members	○	○	○	○	○	○	○
Good communication atmosphere	○	○	○	○	○	○	○

4 Based on construction projects you have been involved in the last 5 years, please kindly indicate the level of priority of the BIM related factors

	1 – Not a priority	2 – Low priority	3 – Somewhat priority	4 – Neutral	5 – Moderate Priority	6 – High priority	7 – Essential priority
Documented BIM execution plan	○	○	○	○	○	○	○
Organizational structure to support BIM	○	○	○	○	○	○	○
Standardized work procedures for BIM	○	○	○	○	○	○	○
Number of subcontractors/partners who have experienced BIM projects	○	○	○	○	○	○	○
BIM competence of in-house team	○	○	○	○	○	○	○
Communication of BIM objectives	○	○	○	○	○	○	○
Use of BIM for design and documentation	○	○	○	○	○	○	○
Allocation of budget toward BIM	○	○	○	○	○	○	○

5 Based on construction projects you have been involved in the last 5 years, please kindly indicate the level of priority of the roles and responsibilities of owner

	1 – Not a priority	2 – Low priority	3 – Somewhat priority	4 – Neutral	5 – Moderate Priority	6 – High priority	7 – Essential priority
Clear definitions of scope of services	○	○	○	○	○	○	○
Early owner participation	○	○	○	○	○	○	○
Clarity of owner's requirements	○	○	○	○	○	○	○
Owner's approval of design	○	○	○	○	○	○	○
Defining and controlling the relation between project and business case	○	○	○	○	○	○	○
Owner's internal review and decision process	○	○	○	○	○	○	○

Figure B.3 : Questionnaire survey questions 3.

Continual monitoring of project with respect to project goals and metrics related to performance	○	○	○	○	○	○	○
Clear definitions of teams' tasks and responsibilities	○	○	○	○	○	○	○
Evaluating and influencing design options	○	○	○	○	○	○	○
Providing site data	○	○	○	○	○	○	○
Clear definition and understanding of users' requirements	○	○	○	○	○	○	○
Effective change management	○	○	○	○	○	○	○
Suitability between project initial objective and final product	○	○	○	○	○	○	○
Negotiations with jurisdiction providing permits	○	○	○	○	○	○	○
Owner's contractual obligations	○	○	○	○	○	○	○
Final user reviews and approvals	○	○	○	○	○	○	○

6 Based on construction projects you have been involved in the last 5 years, please kindly indicate the level of priority of the roles and responsibilities of prime designer and design consultants

	1 – Not a priority	2 – Low priority	3 – Somewhat priority	4 – Neutral	5 – Moderate Priority	6 – High priority	7 – Essential priority
Effective consultation with key stakeholders	○	○	○	○	○	○	○
Coordination of RFI and submittal responses from all design consultants	○	○	○	○	○	○	○
Regulatory requirements for the building (i.e.: fire/life safety plan)	○	○	○	○	○	○	○
Integrity of the design intent and pre-fabrication studies	○	○	○	○	○	○	○
Identification of project and system requirements	○	○	○	○	○	○	○
Variety of design options	○	○	○	○	○	○	○
Design schedule (Accuracy)	○	○	○	○	○	○	○
3D detailing	○	○	○	○	○	○	○
Alignment of space program with project goals	○	○	○	○	○	○	○
Accurate identification of sustainable design outcomes	○	○	○	○	○	○	○
Designer's response to RFI's	○	○	○	○	○	○	○
Construction Contract Administration	○	○	○	○	○	○	○
BIM Model updates during construction	○	○	○	○	○	○	○
Ensuring coordination to selection of major building systems and performance requirements	○	○	○	○	○	○	○
Completeness of model for architecturally related design intent for construction	○	○	○	○	○	○	○
Providing descriptive information for fabrication and construction of architecturally related scope	○	○	○	○	○	○	○
Specification finalization	○	○	○	○	○	○	○
Interoperability of BIM with agencies to ensure code compliance	○	○	○	○	○	○	○
Using the BIM for life cycle benefit	○	○	○	○	○	○	○
Selection of major building systems	○	○	○	○	○	○	○
Identification of unique conditions in criteria design	○	○	○	○	○	○	○
Locating major pieces of equipment and routing in the project	○	○	○	○	○	○	○

7 Based on construction projects you have been involved in the last 5 years, please kindly indicate the level of priority of the roles and responsibilities of prime contractor, trade constructors and suppliers

	1 – Not a priority	2 – Low priority	3 – Somewhat priority	4 – Neutral	5 – Moderate Priority	6 – High priority	7 – Essential priority
Constructability program	○	○	○	○	○	○	○
Cost estimation	○	○	○	○	○	○	○
Meeting schedule goal	○	○	○	○	○	○	○
Compatibility with the design and work of other trades	○	○	○	○	○	○	○
Prefabrication opportunities	○	○	○	○	○	○	○
Coordination of building systems	○	○	○	○	○	○	○
Shop drawings/ model	○	○	○	○	○	○	○
Synchronized model for fabrication or installation purposes	○	○	○	○	○	○	○
Completeness of BIM and specifications for applicable scope of work	○	○	○	○	○	○	○
Trade contractors' coordination during construction	○	○	○	○	○	○	○
Identification of long lead items	○	○	○	○	○	○	○

Figure B.4 : Questionnaire survey questions 4.

APPENDIX C

Table C.1 : References of the question 1 in questionnaire survey.

Common problems	References
Disintegration	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; NASFA et al., 2010; Sive and Hays, 2009; Zhang et al., 2013)
Schedule overruns	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)
Over-reworks	(Yu et al., 2019)
Cost overruns	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; NASFA et al., 2010; Zhang et al., 2013)
Excessive design changes	(Baiden et al., 2006)
Omissions	(Baiden et al., 2006; NASFA et al., 2010)
Errors	(NASFA et al., 2010; Yu et al., 2019)
Waste	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011)
Adversarial relationship	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; Yu et al., 2019; Zhang et al., 2013)
Inconsistency between design and actual work	(Yu et al., 2019)
Low productivity	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; NASFA et al., 2010; Yu et al., 2019)
Ineffective teams	(Baiden et al., 2006; CURT, 2004)
Contractual disputes	(De Marco and Karzouna, 2018; Zhang et al., 2013)
Data losses	(Baiden et al., 2006)
High inefficiency	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; NASFA et al., 2010; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019; Zhang et al., 2013)
Fragmentation	(Baiden et al., 2006; Lahdenperä, 2012; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019)
Degraded project value	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016)
Mistrust environment	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011)
Poor end quality	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)
Excessive liability claims	(Baiden et al., 2006)
Non-transparent relations	(Baiden et al., 2006)

Table C.2 : References of the question 2 in questionnaire survey.

IPD-related characteristics.	References
Information sharing protocols	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)
BIM Protocol	(AIA, 2007)
Collectively defined project goals	z
Software choice	(AIA, 2007; Amuda-Yusuf, 2018; Ugwu and Kumaraswamy, 2007)
How develop, access, and use the model	(AIA, 2007)
Proper organization setting before design	(Yu et al., 2019)
Collaborative decision-making	(AIA, 2007; Ashcraft, 2014b; N. Azhar et al., 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Uihlein, 2016; Yu et al., 2019)
Establishing project's information specification	(AIA, 2007; Lahdenperä, 2012)
Establishing the communication protocol	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)
Collaborative contracting arrangements	(AIA, 2007)
Goals-owner's desired outcomes alignment	(N. Azhar et al., 2014; Yu et al., 2019)
Early involvement of participants	(AIA, 2007; Amuda-Yusuf, 2018; Ashcraft, 2014b; N. Azhar et al., 2014, 2015; Chang et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2019; Piroozfar et al., 2019; Ugwu and Kumaraswamy, 2007; Uihlein, 2016; Whang et al., 2019)
Established process for handling change orders	(Hamzeh et al., 2019; Yu et al., 2019)
Joint Liability	(AIA, 2007; Ashcraft, 2014b; N. Azhar et al., 2015; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
Accountability	(AIA, 2007)
Financial transparency	(AIA, 2007; Chang et al., 2017; Lahdenperä, 2012; Mesa et al., 2019; Yu et al., 2019)
Regular meetings	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)
Shared financial risk and reward	(AIA, 2007; Ashcraft, 2014b; N. Azhar et al., 2014, 2015; Fischer et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016, 2019; Piroozfar et al., 2019; Yu et al., 2019)
Financial incentives	(AIA, 2007; Chang et al., 2017; Kog and Loh, 2012; Yu et al., 2019)

Table C.3 : References of the question 3 in questionnaire survey.

BIM-related characteristics	References
Documented BEP	(Badrinath and Hsieh, 2019)
Use of BIM for design and documentation	(Yu et al., 2019)
Organizational structure to support BIM	(Won and Lee, 2010)
Standardized work procedures for BIM	(Won and Lee, 2010)
Communication of BIM objectives	(Amuda-Yusuf, 2018; Eadie et al., 2013; Morlhon et al., 2014)
BIM competence of in-house team	(Amuda-Yusuf, 2018; Morlhon et al., 2014; Singh et al., 2011)
Allocation of budget toward BIM	(Badrinath and Hsieh, 2019)
Number of subcontractors who have experienced BIM projects	(Won and Lee, 2010)

Table C.4 : References of the question 4 in questionnaire survey.

Team-related characteristics	References
Good communication atmosphere	(Hamzeh et al., 2019; Yu et al., 2019)
Team collaboration	(AIA, 2007; Ashcraft, 2011; Fischer et al., 2017; Franz et al., 2017; Hamzeh et al., 2019; Lahdenperä, 2012; Molenaar et al., 2014; Sun et al., 2015; Whang et al., 2019; Won and Lee, 2010)
Commitment of team	(AIA, 2007)
Team involvement	(AIA, 2007)
Empowerment of team members	(Yu et al., 2019)
Continuity of values	(AIA, 2007)
Sub-teams compositions	(Yu et al., 2019)
Continuity of team	(AIA, 2007)
Competencies of team	(Aksorn and Hadikusumo, 2008; Kog and Loh, 2012; L. D. Nguyen et al., 2004; Toor and Ogunlana, 2009)

Table C.5 : References of the question 5 in questionnaire survey.

Roles and responsibilities of the owner	References
Clear definitions of scope of services	(AIA,2007;Nguyen et al.,2004;Sanvido et al.,1992;Whang et al.,2019)
Owner's approval of design	(AIA,2007)
Clear definitions of teams' tasks and responsibilities	(Azhar et al.,2014; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Whang et al., 2019)
Clarity of owner's requirements	(Lam et al.,2008)
Owner's contractual obligations	(AIA,2007)
Evaluating and influencing design options	(AIA,2007; Hamzeh et al.,2019)
Clear definition and understanding of users' requirements	(Amuda- Yusuf, 2018; Morlhon et al., 2014; Ugwu and Kumaraswamy, 2007)
Continual monitoring of project with respect to project goals and metrics related to performance	(AIA,2007)
Owner's internal review and decision process	(AIA,2007)
Providing site data	(AIA,2007)
Early owner participation	(Yu et al.,2019)
Suitability between project initial objective and final product	(Nguyen and Chovichien, 2013)
Final user reviews and approvals	(AIA,2007)
Defining and controlling the relation between project and business case	(AIA,2007)
Effective change management	(Fortune and White, 2006; Toor and Ogunlana, 2009)
Negotiations with jurisdiction providing permits	(AIA,2007)

Table C.6 : References of the question 6 in questionnaire survey.

Roles and responsibilities of the prime designer and design consultants	References
Coordination of RFI and submittal responses from all design consultants	(AIA,2007)
Regulatory requirements for the building (i.e.: fire/life safety plan)	(AIA,2007)
Identification of project and system requirements	(AIA,2007)
Specification finalization	(AIA,2007)
Completeness of model for architecturally related design intent for construction	(AIA,2007)
Ensuring coordination to selection of major building systems and performance requirements	(AIA,2007)
Identification of unique conditions in criteria design	(AIA,2007)
Locating major pieces of equipment and routing in the project	(AIA,2007)
Using the BIM for life cycle benefit	(AIA,2007)
BIM Model updates during construction	(AIA,2007)
Designer's response to RFI's	(AIA,2007)
3D detailing	(Badrinath and Hsieh, 2019)
Providing descriptive information for fabrication and construction of architecturally related scope	(AIA,2007)
Interoperability of BIM with agencies to ensure code compliance	(AIA,2007)
Design schedule (Accuracy)	(AIA,2007)
Selection of major building systems	(AIA,2007)
Alignment of space program with project goals	(AIA,2007)
Integrity of the design intent and pre-fabrication studies	(AIA,2007)
Effective consultation with key stakeholders	(AIA,2007; Khang and Moe, 2008)
Variety of design options	(AIA, 2007; Fischer et al., 2017; Forbes and Ahmed, 2010; Hamzeh et al.,2019)
Accurate identification of sustainable design outcomes	(AIA,2007)
Construction Contract Administration	(AIA,2007)

Table C.7 : References of the question 7 in questionnaire survey.

Roles and responsibilities of the prime constructor and subcontractor	References
Compatibility with the design and work of other trades	(AIA, 2007)
Meeting schedule goal	(Sanvido et al., 1992; Shenhar et al., 2001)
Cost estimation	(Badrinath and Hsieh, 2019)
Shop drawings/ model	(AIA, 2007)
Trade contractors' coordination during construction	(AIA, 2007)
Constructability program	(AIA, 2007; Badrinath and Hsieh, 2019; Kog and Loh, 2012)
Coordination of building systems	(AIA, 2007)
Completeness of BIM and specifications for applicable scope of work	(AIA, 2007)
Trade contractors' participation in coordination and conflict resolution	(AIA, 2007)
Construction Schedule (Accuracy)	(AIA, 2007)
Trade contractors' contribution to model	(AIA, 2007)
Identification of long lead items	(AIA, 2007)
Synchronized model for fabrication or installation purposes	(AIA, 2007)
Prefabrication opportunities	(AIA, 2007)

APPENDIX D

Mülakat öncesi bilgilendirme (gönüllü katılımcılara mülakat öncesinde sözlü bir şekilde verilmiş olan bilgiler):

Bu mülakat Prof. Dr. Begüm Sertyeşilışık danışmanlığında Hakan Taha Çetin tarafından hazırlanan ve yazılan "An investigation into the current status of adoption of IPD characteristics and BIM in construction projects to overcome process and team-related problems" konulu Yüksek Lisans tezi kapsamında yapılmaktadır. Bu yüksek lisans tezinin amacı IPD'nin ana özelliklerinin ve BIM'in inşaat projelerinde güncel durumda benimsenme seviyesini incelemek ve benimsenme oranı yüksek olan özelliklerinin sektörün süreç ve proje takımı ile ilgili karşılaştığı problemler üzerindeki etkisini incelemektir. Ek olarak, bu yüksek lisans tezinde IPD, BIM ve IPD takımları ile ilgili kritik başarı faktörlerinin belirlenmesi hedeflenmektedir.

Sizi katılımın tamamen gönüllülük esasına dayandığı bu mülakata davet etmek isterim. İstediğiniz aşamada herhangi bir yaptırıma maruz kalmadan mülakattan ayrılabilirsiniz. Mülakat yaklaşık 40 dakika sürecektir. İzniniz olması durumunda görüşme ses ya da video kaydına alınabilir. Mülakat sürecinde elde edilecek bilgiler ve veriler Yüksek Lisans Tezi ve bu tez kapsamında yapılacak yayınlarda anonim bir şekilde kullanılacaktır. Bilgiler ve veriler Yüksek Lisans Tezi ve kapsamında yapılacak yayınlar haricinde herhangi bir çalışmada kullanılmayacaktır.

Mülakat ile ilgili sormak istediğiniz konuları istediğiniz zaman Hakan Taha Çetin'e sorabilirsiniz.

Saygılarımla,

Hakan Taha Çetin

İstanbul Teknik Üniversitesi

Lisansüstü Bilimler Enstitüsü

Proje ve Yapım Yönetimi Yüksek Lisans Programı Öğrencisi

Mülakat Soruları

Tecrübe Yılı:

BIM Tecrübesi (varsa):

Çalışılan Paydaşlar:

1- İnşaat sektöründeki 10-15 yıllık tecrübenize göre, artık daha sık ya da daha seyrek karşılaşıyoruz dediğiniz problemler nelerdir?

2- İnşaat sektöründeki 10-15 yıllık tecrübenize göre, inşaat projelerinde paydaşların görev ve sorumluluklarında zaman içinde nasıl değişiklikler olmuştur?

3- İnşaat sektöründeki 10-15 yıllık tecrübenize göre, inşaat projelerinde paydaşların projeye katılım zamanlarında nasıl değişiklikler olmuştur?

4- 10-15 yıllık süreç içerisinde inşaat sözleşmeleri hangi şekilde değişmiştir?

5- Paydaşlar arasındaki saygı ve güven ortamında bir değişiklik var mıdır? Kısaca açıklayınız.

6- Paydaşlar arasındaki iş birliği süreç içinde nasıl değişmiştir? Karar alma ve inovasyonlarda iş birliğinden faydalanılıyor mu? Kısaca açıklayınız.

7- Hedefler tek bir parti tarafından mı yoksa bütün paydaşlarla birlikte mi belirlenmektedir? Kısaca açıklayınız.

8- Paydaşlar artık iletişime daha mı açık? Kısaca açıklayınız.

9- Planlama sürecinde hangi değişiklikler olmuştur? Artık daha yoğun bir şekilde yapıldığını söyleyebilir misiniz? Kısaca açıklayınız.

10- Risklerin ve ödüllerin paylaşıldığı bir projede bulundunuz mu? Kısaca açıklayınız.

11- Anlaşmazlıkların çözümünde başvurulan yöntemde bir değişiklik oldu mu? Kısaca açıklayınız.

12- Finansal hesapların daha şeffaf bir şekilde yapıldığını ve taraflar arasında paylaşıldığını düşünüyor musunuz? Kısaca açıklayınız.

13- Ana paydaşların daha eşit roller üstlendiğini düşünüyor musunuz? Neden?

14- Paydaşların daha entegre ve şeffaf bir şekilde çalışmasını destekleyen faktörlerin neler olduğunu düşünüyorsunuz? Bu şekilde çalışmanın avantajı olarak nitelendireceğiniz faktörler nelerdir? Kısaca açıklayınız.

15- Paydaşların daha entegre ve şeffaf bir şekilde çalışmasını engelleyen faktörlerin neler olduğunu düşünüyorsunuz? Bu şekilde çalışmanın dezavantajı olarak nitelendireceğiniz faktörler nelerdir? Kısaca açıklayınız.

16- Önümüzdeki süreç içinde inşaat sektöründe nasıl değişiklikler bekliyorsunuz? Neden?

17- Çalışma konusuna dair düşünceleriniz, öneri, görüş ve tavsiyeleriniz nelerdir?

Pre-interview briefing (information that has been given to the volunteer participants verbally before the interview):

Dear Participant,

This interview is performed within the scope of the master's thesis on "An investigation into the current status of adoption of IPD characteristics and BIM in construction projects to overcome process and team-related problems" prepared by Hakan Taha Çetin, who is a student at Istanbul Technical University under the supervision of Prof. Dr. Begüm Sertyesilışık. This study aims to investigate the current status of adoption level of IPD’s main characteristics and BIM in construction projects and to investigate impact of highly adopted characteristics on overcoming process and team-related problems. Furthermore, this study has objectives of identification of critical success factors related with IPD, BIM and IPD teams.

I would like to invite you to contribute to my interview. Participation in this interview is entirely voluntary. You can leave this interview voluntarily at any time, at any stage, without facing any sanctions. This interview can take approximately 40 minutes to accomplish. With your permission, the conversation can be audio or video recorded. Data and information you will provide in this interview, as well as the data and information to be obtained from this interview, will be used anonymously in the specified master's thesis as well as in related publications (i.e., articles, papers, proceedings and chapters based on this thesis). Data and information obtained will not be shared except for the master's thesis, related publications based on this thesis.

If you have further questions or if you would like to get more information about this interview, you can contact Hakan Taha Çetin (e-mail address:cetinhak@itu.edu.tr).

Kindest regards,

Hakan Taha Çetin

Istanbul Technical University Graduate School

Project and Construction Management MSc program student

Interview Questions

Year of Experience:

BIM Experience:

Stakeholders worked on behalf of:

1. According to your 10-15 years of experience in the construction industry, what are the problems that you say you encounter more frequently or less frequently?

2. According to your 10-15 years of experience in the construction industry, how have the roles and responsibilities of stakeholders in construction projects changed over time?

3. According to your 10-15 years of experience in the construction industry, what changes have occurred in the participation of the stakeholders in the construction projects?

4. In what way have the construction contracts changed in 10-15 years?

5. Is there a change in the environment of respect and trust among the stakeholders? Please explain briefly.

6. How has the collaboration between stakeholders changed in the process? Does collaboration benefit from decision-making and innovation? Please explain briefly.

7. Are the project goals determined by a single party or together with all stakeholders? Please explain briefly.

8. Are stakeholders more open to communication now? Please explain briefly.

9. What changes occurred in the planning process? Would you say it's more intensified now? Please explain briefly.

10. Have you ever been in a project where risks and rewards were shared? Please explain briefly.

11. Has there been a change in the method used to resolve disputes? Please explain briefly.

12. Do you think that financial accounts are made more transparently and shared between the parties? Please explain briefly.

13. Do you think that the main stakeholders undertake more equal roles? Why?

14. What factors do you think that support the stakeholders to work in a more integrated and transparent way? What factors would you describe as an advantage of working in this way? Please explain briefly.

15. What factors do you think that prevent stakeholders from working in a more integrated and transparent way? What factors would you describe as a disadvantage of working in this way? Please explain briefly.

16. What kind of changes do you expect in the construction sector in the upcoming period? Why?

17. What are your thoughts, suggestions, opinions and recommendations on the subject of the study?

APPENDIX E

Information in the Appendix E was provided in the Delphi surveys. Other details and results of the 4 rounds of the Delphi surveys were provided within the main body of the thesis.

Dear Participant,

This Delphi study is performed within the scope of the master's thesis on "An investigation into the current status of adoption of IPD characteristics and BIM in construction projects to overcome process and team-related problems" prepared by Hakan Taha Çetin, who is a student at Istanbul Technical University under the supervision of Prof. Dr. Begüm Sertyesilışık. This study aims to investigate the current status of adoption level of IPD's main characteristics and BIM in construction projects and to investigate impact of highly adopted characteristics on overcoming process and team-related problems. Furthermore, this study has objectives of identification of critical success factors related with IPD, BIM and IPD teams.

I would like to invite you to contribute to my Delphi Study. Participation in this Delphi Study is entirely voluntary. You can leave this Delphi Study voluntarily at any time, at any stage, without facing any sanctions. This Delphi survey is prepared according to your answers to preliminary questionnaire survey. Each round of Delphi Study can take approximately 5-10 minutes to accomplish. Data and information you will provide in this Delphi Study, as well as the data and information to be obtained from this Delphi Study, will be used anonymously in the specified master's thesis as well as in related publications (i.e., articles, papers, proceedings and chapters based on this thesis). Data and information obtained will not be shared except for the master's thesis related publications based on this thesis.

If you have further questions or if you would like to get more information about this questionnaire survey, you can contact Hakan Taha Çetin (e-mail address:cetinhak@itu.edu.tr).

Kindest regards, Hakan Taha Çetin

Istanbul Technical University

Graduate School

Project and Construction Management MSc program student

APPENDIX F

Table F.1 : The normality test results of the process and team-related problems.

Common problems	References	Mean		95% Confidence Interval for Mean		5% Trimme d Mean	Me dia n	Varianc e	Std. Deviatio n	Skewness		Kurtosis	
		Statist ic	Std. Error	Lower Bound	Upper Bound					Statistic s	Std. Error	Statistic s	Std. Error
High inefficiency	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; NASFA et al., 2010; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019; Zhang et al., 2013)	3,9	0,305	3,28	4,53	3,91	4	2,89	1,7	0,03	0,421	-1,104	0,821
Low productivity	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; NASFA et al., 2010; Yu et al., 2019)	4,06	0,266	3,52	4,61	4,05	4	2,196	1,482	-0,184	0,421	-0,211	0,821
Adversarial relationship	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; Yu et al., 2019; Zhang et al., 2013)	4,13	0,257	3,6	4,65	4,11	4	2,049	1,432	0,05	0,421	-0,943	0,821
Contractual disputes	(De Marco and Karzouna, 2018; Zhang et al., 2013)	3,94	0,236	3,45	4,42	3,93	4	1,729	1,315	0,032	0,421	-1,156	0,821
Fragmentation	(Baiden et al., 2006; Lahdenperä, 2012; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019)	3,68	0,214	3,24	4,12	3,61	4	1,426	1,194	0,553	0,421	0,863	0,821
Mistrust environment	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011)	3,65	0,306	3,02	4,27	3,61	4	2,903	1,704	0,123	0,421	-0,595	0,821
Non-transparent relations	(Baiden et al., 2006)	3,1	0,319	2,45	3,75	3,05	3	3,157	1,777	0,263	0,421	-1,308	0,821
Dis-integration	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; NASFA et al., 2010; Sive and Hays, 2009; Zhang et al., 2013)	5,06	0,314	4,42	5,71	5,13	5	3,062	1,75	-0,424	0,421	-0,988	0,821
Ineffective teams	(Baiden et al., 2006; CURT, 2004)	3,97	0,243	3,47	4,46	3,96	4	1,832	1,354	-0,11	0,421	-0,054	0,821
Cost overruns	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; NASFA et al., 2010; Zhang et al., 2013)	4,71	0,279	4,14	5,28	4,73	5	2,413	1,553	-0,278	0,421	-0,945	0,821
Schedule overruns	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)	5,06	0,314	4,42	5,71	5,16	5	3,062	1,75	-0,584	0,421	-0,544	0,821
Poor end quality	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)	3,52	0,278	2,95	4,08	3,48	4	2,391	1,546	0,141	0,421	-0,471	0,821
Degraded project value	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016)	3,65	0,28	3,07	4,22	3,66	4	2,437	1,561	-0,148	0,421	-1,028	0,821
Incompatibility between design and actual work	(Yu et al., 2019)	4,13	0,285	3,55	4,71	4,12	4	2,516	1,586	0,042	0,421	-0,816	0,821
Over-reworks	(Yu et al., 2019)	4,84	0,29	4,25	5,43	4,91	5	2,606	1,614	-0,432	0,421	-0,533	0,821
Errors	(NASFA et al., 2010; Yu et al., 2019)	4,39	0,235	3,91	4,87	4,39	5	1,712	1,308	-0,309	0,421	-0,612	0,821
Omissions/ defects	(Baiden et al., 2006; NASFA et al., 2010)	4,42	0,244	3,92	4,92	4,43	5	1,852	1,361	-0,328	0,421	-0,566	0,821
Waste	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011)	4,19	0,306	3,57	4,82	4,16	5	2,895	1,701	0,024	0,421	-1,255	0,821
Excessive liability claims	(Baiden et al., 2006)	3,32	0,268	2,78	3,87	3,3	3	2,226	1,492	0,24	0,421	-0,866	0,821
Data losses	(Baiden et al., 2006)	3,94	0,347	3,23	4,64	3,93	4	3,729	1,931	-0,051	0,421	-1,432	0,821
Excessive design changes	(Baiden et al., 2006)	4,65	0,333	3,97	5,33	4,72	5	3,437	1,854	-0,48	0,421	-0,874	0,821

Table F.2 : The Independent-Sample T Test results of the process and team-related problems based on the use of BIM dimensions.

Common problems	References		Levene's Test for Equality of Variances		t-test for Equality of Means						
			F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
										Lower	Upper
High inefficiency	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; NASFA et al., 2010; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019; Zhang et al., 2013)	EVA*	0,512	0,48	1,461	29	0,155	1,048	0,717	-0,419	2,514
		EVNA*			1,661	12,143	0,122	1,048	0,631	-0,325	2,42
Low productivity	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; NASFA et al., 2010; Yu et al., 2019)	EVA*	4,302	0,047	1,03	29	0,312	0,655	0,636	-0,646	1,955
		EVNA*			1,675	28,374	0,105	0,655	0,391	-0,146	1,455
Adversarial relationship	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; Yu et al., 2019; Zhang et al., 2013)	EVA*	1,774	0,193	2,272	29	0,031	1,31	0,576	0,131	2,488
		EVNA*			2,644	12,715	0,021	1,31	0,495	0,237	2,382
Contractual disputes	(De Marco and Karzouna, 2018; Zhang et al., 2013)	EVA*	1,591	0,217	1,483	29	0,149	0,821	0,554	-0,311	1,954
		EVNA*			1,248	7,985	0,247	0,821	0,658	-0,697	2,339
Fragmentation	(Baiden et al., 2006; Lahdenperä, 2012; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019)	EVA*	1,273	0,268	0,808	29	0,426	0,417	0,516	-0,639	1,472
		EVNA*			0,914	12,043	0,379	0,417	0,456	-0,576	1,409
Mistrust environment	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011)	EVA*	2,374	0,134	0,62	29	0,54	0,458	0,74	-1,054	1,971
		EVNA*			0,748	13,742	0,467	0,458	0,613	-0,859	1,775
Non-transparent relations	(Baiden et al., 2006)	EVA*	4,231	0,049	1,302	29	0,203	0,982	0,755	-0,561	2,525
		EVNA*			1,551	13,374	0,144	0,982	0,633	-0,382	2,346
Dis-integration	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; NASFA et al., 2010; Sive and Hays, 2009; Zhang et al., 2013)	EVA*	0,489	0,49	1,653	29	0,109	1,208	0,731	-0,287	2,703
		EVNA*			1,873	12,069	0,085	1,208	0,645	-0,196	2,613
Ineffective teams	(Baiden et al., 2006; CURT, 2004)	EVA*	3,991	0,055	0,383	29	0,704	0,226	0,59	-0,98	1,433
		EVNA*			0,562	22,709	0,58	0,226	0,402	-0,607	1,059
Cost overruns	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; NASFA et al., 2010; Zhang et al., 2013)	EVA*	1,11	0,301	0,009	29	0,993	0,006	0,679	-1,382	1,394
		EVNA*			0,01	11,37	0,992	0,006	0,618	-1,35	1,362
Schedule overruns	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)	EVA*	0,533	0,471	1,121	29	0,271	0,839	0,749	-0,692	2,37
		EVNA*			1,244	11,605	0,238	0,839	0,674	-0,636	2,314
Poor end quality	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)	EVA*	0,397	0,534	0,657	29	0,517	0,44	0,671	-0,931	1,812
		EVNA*			0,653	9,715	0,529	0,44	0,674	-1,068	1,949
Degraded project value	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016)	EVA*	0,194	0,663	2,185	29	0,037	1,381	0,632	0,088	2,673
		EVNA*			2,285	10,482	0,044	1,381	0,604	0,043	2,719
Incompatibility between design and actual work	(Yu et al., 2019)	EVA*	0,087	0,77	1,114	29	0,274	0,756	0,679	-0,632	2,144
		EVNA*			1,102	9,646	0,297	0,756	0,686	-0,78	2,292

Table F.2 (continued) : The Independent-Sample T Test results of the process and team-related problems based on the use of BIM dimensions.

Common problems	References		Levene's Test for Equality of Variances		t-test for Equality of Means						
			F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
										Lower	Upper
High inefficiency	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; NASFA et al., 2010; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019; Zhang et al., 2013)	EVA*	0,512	0,48	1,461	29	0,155	1,048	0,717	-0,419	2,514
		EVNA*			2,091	14,764	0,054	1,131	0,541	-0,023	2,285
Errors	(NASFA et al., 2010; Yu et al., 2019)	EVA*	0,864	0,36	0,746	29	0,461	0,423	0,566	-0,735	1,581
		EVNA*			0,837	11,843	0,419	0,423	0,505	-0,679	1,524
Omissions/ defects	(Baiden et al., 2006; NASFA et al., 2010)	EVA*	2,369	0,135	2,009	29	0,054	1,119	0,557	-0,02	2,258
		EVNA*			2,765	19,102	0,012	1,119	0,405	0,272	1,966
Waste	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011)	EVA*	4,406	0,045	0,41	29	0,685	0,304	0,741	-1,212	1,819
		EVNA*			0,499	14,044	0,626	0,304	0,608	-1,001	1,608
Excessive liability claims	(Baiden et al., 2006)	EVA*	0,021	0,886	2,041	29	0,05	1,244	0,61	-0,003	2,491
		EVNA*			1,964	9,289	0,08	1,244	0,633	-0,182	2,67
Data losses	(Baiden et al., 2006)	EVA*	4,285	0,047	1,71	29	0,098	1,375	0,804	-0,27	3,02
		EVNA*			2,163	15,337	0,047	1,375	0,636	0,023	2,727
Excessive design changes	(Baiden et al., 2006)	EVA*	1,756	0,195	1,284	29	0,209	1,012	0,788	-0,599	2,623
		EVNA*			1,535	13,463	0,148	1,012	0,659	-0,407	2,431

*EVA= Equal variances assumed
*EVNA= Equal variances not assumed

Table F.3 : Significant correlations (Spearman's rho) between common problems.

Common problems	References		Pr1	Pr2	Pr3	Pr4	Pr5	Pr6	Pr7	Pr8	Pr9	Pr10	Pr11	Pr12	Pr13	Pr14	Pr15	Pr16	Pr17	Pr18	Pr19	Pr20	Pr21
High inefficiency (Pr1)	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; NASFA et al., 2010; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019; Zhang et al., 2013)	r	1																				
		Sig.	.																				
Low productivity (Pr2)	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; NASFA et al., 2010; Yu et al., 2019)	r	,777**	1																			
		Sig.	0,000	.																			
Adversarial relationship (Pr3)	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; Yu et al., 2019; Zhang et al., 2013)	r	,638**	,523**	1																		
		Sig.	0,000	0,003	.																		
Contractual disputes (Pr4)	(De Marco and Karzouna, 2018; Zhang et al., 2013)	r	,546**	,526**	,452*	1																	
		Sig.	0,001	0,002	0,011	.																	
Fragmentation (Pr5)	(Baiden et al., 2006; Lahdenperä, 2012; Nofera et al., 2011; Sive and Hays, 2009; Yu et al., 2019)	r	,444*	,630**	,526**	,682**	1																
		Sig.	0,012	0,000	0,002	0,000	.																

Table F.3 (continued) : Significant correlations (Spearman's rho) between common problems.

Common problems	References		Pr1	Pr2	Pr3	Pr4	Pr5	Pr6	Pr7	Pr8	Pr9	Pr10	Pr11	Pr12	Pr13	Pr14	Pr15	Pr16	Pr17	Pr18	Pr19	Pr20	Pr21
Mistrust environment (Pr6)	(Baiden et al., 2006; De Marco and Karzouna, 2018; Ghassemi and Becerik-Gerber, 2011)	r	,378*		,407*			1															
		Sig.	0,036		0,023			.															
Non-transparent relations (Pr7)	(Baiden et al., 2006)	r	,417*	,531**		,469**	,543**	,718**	1														
		Sig.	0,019	0,002		0,008	0,002	0,000	.														
Dis-integration (Pr8)	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011; Lahdenperä, 2012; NASFA et al., 2010; Sive and Hays, 2009; Zhang et al., 2013)	r	,451*	,394*		,419*		,376*	,459**	1													
		Sig.	0,011	0,028		0,019		0,037	0,009	.													
Ineffective teams (Pr9)	(Baiden et al., 2006; CURT, 2004)	r	,574**	,704**	,531**	,419*	,489**	,437*	,653**	,535**	1												
		Sig.	0,001	0,000	0,002	0,019	0,005	0,014	0,000	0,002	.												
Cost overruns (Pr10)	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; NASFA et al., 2010; Zhang et al., 2013)	r	,544**	,605**		,430*			,499**	,511**	,692**	1											
		Sig.	0,002	0,000		0,016			0,004	0,003	0,000	.											

Table F.3 (continued) : Significant correlations (Spearman's rho) between common problems.

Common problems	References		Pr1	Pr2	Pr3	Pr4	Pr5	Pr6	Pr7	Pr8	Pr9	Pr10	Pr11	Pr12	Pr13	Pr14	Pr15	Pr16	Pr17	Pr18	Pr19	Pr20	Pr21
Schedule overruns (Pr11)	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)	r	,653**	,696**		,596**	,370*		,543**	,510**	,594**	,831**	1										
		Sig.	0,000	0,000		0,000	0,04		0,002	0,003	0,000	0,000	.										
Poor end quality (Pr12)	(De Marco and Karzouna, 2018; Fakhimi et al., 2016; Ghassemi and Becerik-Gerber, 2011; Laurent and Leicht, 2019; Zhang et al., 2013)	r	,596**	,608**		,466**	,512**	,465**	,569**	,357*	,627**	,510**	,510**	1									
		Sig.	0,000	0,000		0,008	0,003	0,008	0,001	0,048	0,000	0,003	0,003	.									
Degraded project value (Pr13)	(Baiden et al., 2006; De Marco and Karzouna, 2018; Fakhimi et al., 2016)	r	,642**	,626**	,542**	,650**	,590**		,528**	,391*	,652**	,465**	,560**	,707**	1								
		Sig.	0,000	0,000	0,002	0,000	0,000		0,002	0,03	0,000	0,008	0,001	0,000	.								
Inconsistency between design and actual work (Pr14)	(Yu et al., 2019)	r		,510**		,482**	,535**	,474**	,683**		,536**	,440*	,490**	,600**	,735**	1							
		Sig.		0,003		0,006	0,002	0,007	0,000		0,002	0,013	0,005	0,000	0,000	.							
Over-reworks (Pr15)	(Yu et al., 2019)	r	,381*	,377*					,377*	,372*	,401*		,387*	,419*	,668**	,759**	1						
		Sig.	0,034	0,037					0,037	0,04	0,025		0,031	0,019	0,000	0,000	.						
Errors (Pr16)	(NASFA et al., 2010; Yu et al., 2019)	r				,431*	,369*				,382*			,374*	,582**	,521**	,512**	1					
		Sig.				0,016	0,041				0,034			0,038	0,001	0,003	0,003	.					

Table F.3 (continued) : Significant correlations (Spearman's rho) between common problems.

Common problems	References		Pr1	Pr2	Pr3	Pr4	Pr5	Pr6	Pr7	Pr8	Pr9	Pr10	Pr11	Pr12	Pr13	Pr14	Pr15	Pr16	Pr17	Pr18	Pr19	Pr20	Pr21
Omissions (Pr17)	(Baiden et al., 2006; NASFA et al., 2010)	r		,492**	,397*	,496**	,366*		,402*	,463**	,433*		,455*	,372*	,523**	,493**	,475**	,761**	1				
		Sig.		0,005	0,027	0,005	0,043		0,025	0,009	0,015		0,01	0,039	0,003	0,005	0,007	0,000	.				
Waste (Pr18)	(Baiden et al., 2006; Ghassemi and Becerik-Gerber, 2011)	r	,460**	,658**		,541**	,517**		,509**		,524**	,525**	,609**	,632**	,545**	,592**		,554**	,642**	1			
		Sig.	0,009	0,000		0,002	0,003		0,003		0,002	0,002	0,000	0,000	0,002	0,000		0,001	0,000	.			
Excessive liability claims (Pr19)	(Baiden et al., 2006)	r				,573**	,372*	,431*	,429*	,427*					,562**	,574**	,459**	,410*	,397*	,412*	1		
		Sig.				0,001	0,039	0,015	0,016	0,017					0,001	0,001	0,009	0,022	0,027	0,021	.		
Data losses (Pr20)	(Baiden et al., 2006)	r			,378*	,531**	,488**	,383*	,391*					,455*	,692**	,612**	,556**	,598**	,503**	,671**	,760**	1	
		Sig.			0,036	0,002	0,005	0,034	0,029					0,01	0,000	0,000	0,001	0,000	0,004	0,000	0,000	.	
Excessive design changes (Pr21)	(Baiden et al., 2006)	r												,357*	,509**		,641**	,360*				,515**	1
		Sig.												0,048	0,003		0,000	0,047				0,003	.

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table F.4 : Significant correlations (Spearman’s rho) common problems and other characteristics.

Characteristics	References		Pr1	Pr2	Pr4	Pr5	Pr7	Pr9	Pr10	Pr12	Pr13	Pr14	Pr16	Pr17	Pr18	Pr19	Pr20
Regular meetings	(AIA, 2007; Badrinath and Hsieh, 2019; Toor and Ogunlana, 2009; Yu et al., 2019)	r									-,433*	-,362*				-,355*	
		Sig.									0,015	0,045				0,05	
Collectively defined project goals	(AIA, 2007; Aksorn and Hadikusumo, 2008; Ashcraft, 2014b; Azhar et al., 2014, 2015; Badrinath and Hsieh, 2019; Hamzeh et al., 2019; Lahdenperä, 2012; Mesa et al., 2016; Toor and Ogunlana, 2009; Uihlein, 2016; Yu et al., 2019)	r											-,410*				
		Sig.											0,022				
Establishing project's information specification	(AIA, 2007; Lahdenperä, 2012)	r									-,379*						
		Sig.									0,035						
Establishing the communication protocol	(AIA, 2007; Lahdenperä, 2012; Yu et al., 2019)	r								-,366*							
		Sig.								0,043							
Software choice	(AIA, 2007; Amuda-Yusuf, 2018; Ugwu and Kumaraswamy, 2007)	r					-,445*			-,402*		-,395*	-,372*				
		Sig.					0,012			0,025		0,028	0,039				
How develop/ access/ use the model	(AIA, 2007)	r					-,381*			-,410*		-,456**			-,377*		
		Sig.					0,034			0,022		0,01			0,037		
Information sharing protocols	(AIA, 2007; Chang et al., 2017; Won and Lee, 2010)	r								-,475**			-,431*				
		Sig.								0,007			0,016				
BIM Protocol	(AIA, 2007)	r								-,369*			-,487**				
		Sig.								0,041			0,005				
Collaborative contracting arrangements	(AIA, 2007)	r										-,378*	-,401*				
		Sig.										0,036	0,025				
Proper organization setting before design	(Yu et al., 2019)	r														-,445*	
		Sig.														0,012	
Continuity of values	(AIA, 2007)	r										-,360*					
		Sig.										0,047					
Empowerment of team members	(Yu et al., 2019)	r											-,391*				
		Sig.											0,03				
Good communication atmosphere	(Hamzeh et al., 2019; Yu et al., 2019)	r											-,371*		-,484**		-,362*
		Sig.											0,04		0,006		0,045
Standardized work procedures for BIM	(Won and Lee, 2010)	r												-,400*			
		Sig.												0,026			
Number of subcontractors who have experienced BIM projects	(Won and Lee, 2010)	r		-,405*				-,413*	-,415*	-,409*					-,381*		
		Sig.		0,024				0,021	0,02	0,022					0,035		
Allocation of budget toward BIM	(Badrinath and Hsieh, 2019)	r								-,356*			-,389*	-,405*			
		Sig.								0,049			0,031	0,024			
Owner’s internal review and decision process	(AIA, 2007)	r													-,373*		
		Sig.													0,039		
Providing site data	(AIA, 2007)	r									-,386*					-,415*	-,480**
		Sig.									0,032					0,02	0,006
Final user reviews and approvals	(AIA, 2007)	r								-,367*							
		Sig.								0,042							

Table F.4 (continued) : Significant correlations (Spearman's rho) common problems and other characteristics.

Characteristics	References		Pr1	Pr2	Pr4	Pr5	Pr7	Pr9	Pr10	Pr12	Pr13	Pr14	Pr16	Pr17	Pr18	Pr19	Pr20
Effective consultation with key stakeholders	(AIA,2007; Khang and Moe, 2008)	r	-,425*							-,575**	-,452*				-,420*		
		Sig.	0,017							0,001	0,011				0,019		
Coordination of RFI and submittal responses from all design consultants	(AIA, 2007)	r	-,479**	-,419*	-,445*	-,572**				-,662**	-,526**				-,471**		
		Sig.	0,006	0,019	0,012	0,001				0,000	0,002				0,007		
Regulatory requirements for the building (i.e.: fire/life safety plan)	(AIA, 2007)	r			-,401*	-,482**				-,439*	-,357*	-,358*					
		Sig.			0,025	0,006				0,013	0,049	0,048					
Integrity of the design intent and pre-fabrication studies	(AIA, 2007)	r								-,395*							
		Sig.								0,028							
Accurate identification of sustainable design outcomes	(AIA, 2007)	r							-,397*								
		Sig.							0,027								
Designer's response to RFI's	(AIA, 2007)	r								-,432*							
		Sig.								0,015							
Construction Contract Administration	(AIA, 2007)	r				-,368*		-,362*		-,526**	-,357*						
		Sig.				0,042		0,046		0,002	0,049						
Ensuring coordination to selection of major building systems and performance requirements	(AIA, 2007)	r				-,411*				-,394*		-,420*			-,440*		
		Sig.				0,021				0,028		0,019			0,013		
Selection of major building systems	(AIA, 2007)	r				-,426*									-,373*		
		Sig.				0,017									0,038		
Constructability program	(AIA, 2007; Badrinath and Hsieh, 2019; Kog and Loh, 2012)	r				-,373*											
		Sig.				0,039											
Cost estimation	(Badrinath and Hsieh, 2019)	r											-,372*				
		Sig.											0,039				
Compatibility with the design and work of other trades	(AIA, 2007)	r				-,373*											
		Sig.				0,039											
Prefabrication opportunities	(AIA, 2007)	r	-,356*							-,507**	-,443*						
		Sig.	0,049							0,004	0,013						
Coordination of building systems	(AIA, 2007)	r				-,390*	-,357*			-,445*					-,491**		
		Sig.				0,03	0,049			0,012					0,005		
Shop drawings/ model	(AIA, 2007)	r				-,360*					-,397*						
		Sig.				0,046					0,027						
Synchronized model for fabrication or installation purposes	(AIA, 2007)	r				-,393*				-,538**	-,368*						
		Sig.				0,029				0,002	0,042						

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

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