A COLLABORATIVE CONTRACTING FRAMEWORK SUPPORTED BY BIM AND LEAN

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Abstract

The construction industry has been often criticised as being inefficient and fragmented. In response to the continuous dissatisfaction of many client organisations, the last few decades have seen the emergence of a spectrum of contracts that embrace different degrees of collaboration - from partnering agreements to hybrid forms of collaborative contracting, to a fully multi-party contract - promoting the development of integrated approaches to contracts and relationships.

In parallel, two other independent significant developments arose to challenge the silo mentality reshaping relationships: Building Information Modelling (BIM) and Lean management. BIM is a process for creating, sharing and managing information flows during the whole life-cycle of an asset. Lean is a philosophy and management approach used to deliver maximum value to the client through optimising the efficiency of the whole procurement process rather than optimising for single parties.

In the Australian construction market, the three trends are gaining momentum, however they are still mainly considered as separate and distinctive developments.

This research explored the integration of these three initiatives by focusing on how collaborative contracting together with a lean management approach could expand the opportunities of BIM processes to effectively increase the efficiency of the construction process in a collaborative environment. Therefore, the aim of this research is to develop a framework for collaborative contracting, which exploits the benefits of BIM processes and information management integrated within the Lean environments.

To answer the research questions mentioned above, hence accomplishing the research aim, four research objectives were formulated:

1. Identify contractual barriers to collaboration under conventional procurement models. Analyse collaborative contracting methods and identify how the barriers can be resolved.
2. Identify the challenges in adopting BIM for construction procurement in Australia.

3. Identify how collaborative contracting can improve the effectiveness of BIM and Lean throughout the procurement process.
4. Built a framework to describe the implementation of BIM within a collaborative contracting model supported by lean principles

The research methodology consisted of an initial exploratory study followed by 43 in depth semi-structured interviews. The interviews were addressed to professionals with high levels of BIM experience as well as strategic business managers across Australia, Canada, the United States of America and the United Kingdom.

The findings showed that the effectiveness of collaborative contracting in fostering collaboration is enabled by a combination of both legal and procedural features. In particular, three elements are considered vital to the success of collaborative contracting:

1. The risk and reward sharing mechanism;
2. The no-blame culture; and
3. A project insurance regime that covers the entire project.

This scenario creates the best environment to exploit BIM processes since cross-functional collaboration is fostered and opportunities for innovation are encouraged without fear of legal action as soon as problems arise.

Nevertheless, it emerged that Australian public clients prefer hybrid forms of collaborative contracting that partially incorporate the above characteristic in order to avoid exposure to risk. However, the research found that these hybrid forms, where commercial arrangements address the interest of a single party, will not necessarily deliver the same value as the pure forms of contract, since each party will behave in a more risk-averse manner to protect their commercial interests.

In Australia, pure forms of collaborative contracting have been reserved for large, complex and high risk projects because they require initial additional investment in cost and time and a high level of client engagement. However, most recent forms of collaborative contracting emerging in the United States and United Kingdom, developed taking in consideration the advantages provided by new technologies and processes, have been successfully used to deliver relatively small building projects that contain very complicated functions and systems that need to be integrated.

Therefore, it seems that there is no real reason for limited use of collaborative contracting apart for the client's unwillingness to be exposed to the perceived risks. The challenge is to educate the client to understand and embrace a risk sharing regime allowing the procurement team to work within an environment that focuses on problem solving rather than relying on legal action when the problems occur. The result will be avoidance of unnecessary disputes and conflicts with their time and cost implications.

This research created a framework based on existing collaborative contracting models to illustrate, in five stages, how to leverage digital practices and information management along the project life cycle. The purpose is to incentivise and support client organisations to step into a new era of collaborative contracting supported by advancing digital technology and lean processes. The framework was examined, refined and confirmed by experts and the BIM-based collaborative contracting framework is presented.

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List of Abbreviations

AU	Australia
AIA	American Institute of Architects
AOC	Actual Outturn Cost
BIM	Building Information Modelling
BEP	BIM Execution Plan
BMP	BIM Management Plan
CAD	Computer-aided design
CBA	Choosing By Advantage
CoS	Condition of Satisfaction
D&C	Design & Construct
CDE	Common Data Environment
ECI	Early Contractor Involvement
EIR	Exchange Information Requirement
GDP	Gross domestic product
GMP	Guaranteed Maximum Price
ICT	Information and Communication Technologies
IDDS	Integrated Design and Delivery Solution
IFC	Industry Foundation Classes
IFOA	Integrated Form of Agreement
IPD	Integrated Project Delivery
IPI	Integrated Project Insurance
IPR	Intellectual Property Rights
ISO	International Organization for Standardization
LOD	Level of Development
LPDS	Lean Project Delivery System
LPS	Last Planner System
MEA	Model Element Author
MEP	Mechanical, Electrical and Plumbing
NOP	Non-Owner Participant
OP	Owner Participant
PDCA	Plan-Do-Check-Act Cycle

PPC	Percent Plan Complete
PPP	Public Private Partnership
QA	Quality Assurance
QC	Quality Control
TOC	Target Outturn Cost

Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signature: QUT Verified Signature

Date: 12/06/2020

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Chapter 1: Introduction

1.1 BACKGROUND

Construction projects have become more and more complex, requiring expert knowledge in various areas. Consequently, more stakeholders are involved in projects today. A large number of actors constantly need to work together to deliver a project on time, on budget and to a level of functionality that meets client and end-user expectations.

However, the construction industry has often been criticised for being highly fragmented with a propensity toward adversarial relationships (Ashcraft, 2014; Eastman, Teicholz, Sacks, & Liston, 2011). Several authors described the traditional delivery model as a system characterized by a notable lack of communication and a ‘silo mentality’ in which each team member seeks to maximize their own profits without any integration, collaboration or coordination (Harper & Molenaar, 2014; Lichtig, 2006; Palacios, Gonzalez, & Alarcón, 2013). Each project phase – Design, Construction, Operation – works with different stakeholders and decision-makers who have different values (Hall et al., 2014).

These features are not just limited to the relationship between client, design consultants and the main contractor but rather, they also reflect the relationship between the entire consultant’s team, including engineers and sub-consultants as well as the contractors and their supply chain. This lack of integration is manifest through a cascade of sub-contracts and often inappropriate risk transfer, that leads to an industry that tends to be cost-focused rather than value-focused (Farmer, 2016).

In addition, the fragmented process has prevented the smooth flow of high-quality information within the supply chain. As a result, information is often found to be missing, misinterpreted or repeated, generating waste in the form of frequent rework (Ashcraft, 2008; Eastman, et al., 2011). For instance, project stakeholders may not have access to information that others have created, or they may not work to the latest version of the design project. High levels of design negligence such as errors, conflicts, and incoherence between drawings, specifications, and other contract documentation are often created (Eastman, et al., 2011). In 2004, the National Institute of Standards and Technology performed a cost analysis on the capital facilities industry in the USA and found that over $15.8 billion (~AU$22.3 billion) of construction capital is wasted annually due to the poor information flow and lack of consistency of project data (Gallaher, O'Connor, John, Dettbarn, & Gilday, 2004).

It has been argued that the fragmented and adversarial nature of the industry coupled with the lack of reliable and high-quality information are the main reasons for projects often failing to meet client's expectations by continuously exceeding budget costs, increasing time and providing low quality work (Eastman, et al., 2011; Lichtig, 2006; Wright, 2012). Hence, the conventional procurement and contractural model has proven to be inefficient and unproductive, causing frequent conflicts and growth of disputes to the detriment of innovation (Halttula, Aapaoja, & Haapasalo, 2015; Perlberg, 2009).

The Latham report (1994) followed by the Egan report (1998) outlined several industry inefficiencies and expressed the need for leading the industry towards more integrated processes by adopting partnering and collaborative working. These aspects forced the industry to consider alternative procurement models based on relational management technique that promote better collaboration and construction team integration (Blayse & Manley, 2004; Wickersham, 2009)

The Construction User RoundTable (2004) took this a step further, not only encouraging clients to adopt more collaborative procurement routes but also endorsing the use of advanced technologies that promote open, timely and reliable information sharing. As outlined in the report, by eliminating artificial barriers between project members to promote full information sharing, the full process could be optimised. Indeed, earlier and smarter design decisions can be taken leading to better, faster and more cost-effective projects (CURT, 2004). Collaboration, therefore, requires movement from a blame-culture toward a culture of sharing and collaborative working with the support of advanced technologies and data sharing.

In addition, the International Council for Research and Innovation in Building and Construction's Integrated Design and Delivery Solution (IDDS) priority research theme defines integrated design and delivery as using 'collaborative work processes and enhanced skills, with integrated data, information, and knowledge management to minimize structural and process inefficiencies and to enhance the value delivered during design, build, and operation, and across projects' (Owen et al., 2010).

IDDS states that improvements in construction projects are considered as a holistic combination of process, technology, and people and recognise the needs, for all three of these aspects, to be addressed in a parallel way (Owen, et al., 2010) . In light of this, integrated forms of contracts, Building Information Modelling (BIM) and Lean management have been identified as key factors to transforming the construction sector by using new processes and tools in a more collaborative and productive environment (Owen, Amor, Dickinson, Prins, & Kiviniemi, 2013)

This work uses the term collaborative contracting to refer to the type of delivery methods that present the maximum extent of collaboration, where a single, multi-party contract governs the relationship between client and key players, who are all working together in good faith, focussing on fixing problems without blame through a risk sharing and reward mechanism (Ashcraft, 2014; Kent & Becerik-Gerber, 2010; Lahdenperä, 2012). Alliance contracting in Australia, Integrated Project Delivery (IPD) in the United State of America and Integrated Project Insurance (IPI) in the United Kingdom all fall under the collaborative contracting framework since they incorporate the same features such as:

(i) Collaborative multi-party agreement;
(ii) Sharing risk and reward;
(iii) Early involvement of key parties;
(iv) Transparent financials;
(v) Joint decision making.

Building Information Modelling (BIM) is the process for creating, sharing and managing information flow during the whole life-cycle of an asset. By using BIM authoring software and digital engineering tools with accurate and structured information management, a digital twin of the asset can be created long before the construction has started, thus empowering more data-driven decision making.

Finally, Lean management is a philosophy as well as a business approach based on a set of values, principles, methods, and tools used to continuously strive towards flow efficiency, by eliminating waste and superfluous work, in order to meet the customer’s needs and objectives (Modig & Åhlström, 2012). The lean approach and tools can be used in construction to manage the project lifecycle by optimising the whole process rather than single systems.

Studies have shown that significant advantages can be obtained when BIM and collaborative contracting are used in an integrated manner (Circo, 2014; Eastman, et al., 2011; Halttula, et al., 2015; Succar, 2009; Wright, 2012). Other studies have demonstrated the synergy between BIM and Lean and the advantages achievable when they are coupled (Massport, 2015; Sacks, Koskela, Dave, & Owen, 2010).

It appears that the use of BIM and Lean management within the collaborative contracting framework could enable a very high level of collaboration which would not only improve efficiency but also enable exploration of different approaches, methodologies, and techniques to optimize the whole process.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Australia's construction industry is the largest non-service related industry contributing $134.2 billion to the country's economy (8.1% of GDP) and employing nearly 1.1 million workers (Office of the Chief Economist, 2016)

A recent report published by StartupAUS (2017) has shown that successful implementation of a digital solution could provide an increase of value to the sector of $25 billion over the next decade. BIM sits under the umbrella of wider digital innovation and represents for many the construction sector's moment of digitalisation (EU BIM Task Group, 2017). State Governments and Government Agencies around Australia have intensified their efforts to develop strategies and lead the industry towards digital transition (Transport for NSW, 2018; Victoria State Government, 2016), with some starting to mandate the use of BIM in their projects (NSW Health Infrastructure, 2013; Queensland Government, 2018).

However, it seems that BIM is still often understood as a technology and less as a process to support decision making since it is not really integrated in the procurement strategy. While it might be used by a single organisation to improve their own performance, still there is a lack of a cohesive approach to create, share and manage information in a more holistic way across the project life cycle to improve overall project performance.

The literature however showed that successful adoption of BIM and information management along the project life-cycle the degree of integration within the entire project delivery process is critical (Larson & Golden, 2007). Indeed, considering the whole project life-cycle, the choice of procurement model and contract plays a fundamental role, since not all of them allow for the level of integration and transparency required for gain maximum advantage from BIM. Several authors argue that BIM requires a collaborative approach between those involved in the project (Azhar, Khalfan, & Maqsood, 2012; Eastman, et al., 2011; Larson & Golden, 2007). However, this seems to be inhibited by the conventional contract models that do not fully support collaborative working (Love, Smith, & Regan, 2017; Olatunji, 2014; Sebastian, 2010).

The limitations of the role and reasonability of conventional contracts, therefore, have suggested that the objectives of BIM do not fit well with these types of models (Circo, 2014). Conversely, features of collaborative contracting – such as the multi-party contract, early stakeholder engagement, the sharing of financial risk and reward, as well as the no-blame culture – could help to address the legal challenges impeding BIM uptake from scoping to risk management allowing a smooth workflow of information (Circo, 2014). In Australia, however, a traditional fixed-price contract is still the predominant method used to deliver construction projects (Rahmani, Maqsood, & Khalfan, 2017; Sharkey, Bell, Jocic, & Marginean, 2014) despite the fact that Australia was one of the pioneering countries in relationship-based contracting.

Furthermore, while countries such as the United States of America and the United Kingdom have developed new collaborative contracting models that encourage the use of BIM (AIA, 2009, 2013a, 2013b, 2013c; Integrate Project Initiatives Ltd, 2014; NEC, 2017), Lean management and collaborative practices (AIA, 2007; ConsensusDOCS, 2016a, 2016b) , the current contract models mainly used in Australia are still inappropriate for the new digital age.

The literature also lacks a consistent framework that shows how to implement a BIM data-centric process from initial strategic planning, to design, construction and maintenance in the context of collaborative contracting.

This work aims to explore how Lean could be used as approach to implementing BIM processes and information management within the framework of collaborative contracting to drive profitability growth.

1.3 RESEARCH QUESTIONS

Based on the background and research problem discussed previously, the aim of this research is to address the following research question:

How can we build a framework for collaborative contracting that exploits the benefits of the integration of BIM and information management with Lean principles and tools?

In order to answer the research question, three sub-questions have been identified, and need to be addressed:

1. What are the contractual barriers to collaboration under conventional procurement models and how can these be overcome using collaborative contracting?
2. What are the challenges in adopting BIM in construction procurement in Australia?
3. How can collaborative contracting enhance the effectiveness of BIM and Lean?

1.4 RESEARCH AIM AND OBJECTIVES

In order to gain the potential benefits from the significant advances made by technology in the last few years, the way projects are procured needs to change, embracing more integration and collaborative practices. Therefore, the aim of this research is to develop a framework for collaborative contracting, which exploits the benefits of BIM processes and information management integrated within the Lean environments.

To answer the research questions mentioned above four research objectives are formulated. The following are the research objectives:

1. Identify contractual barriers to collaboration under conventional procurement models. Analyse collaborative contracting methods and identify how the barriers can be resolved.
2. Identify the challenges in adopting BIM for construction procurement in Australia.
3. Identify how collaborative contracting can improve the effectiveness of BIM and Lean throughout the procurement process.

4. Built a framework to describe the implementation of BIM within a collaborative contracting model supported by lean principles

It should be emphasised that this research did not examine how the IPD, BIM and Lean processes could be improved separately. The goal was to provide a framework that maximised the benefits within the current state of development of these three approaches.

1.5 THESIS OUTLINE

This thesis is structured in six chapters:

Chapter 1 provides an introduction to the thesis, outlines the background and identifies the research problems. The research question and objectives are formulated in order to address the research problem and accomplish the research's aim. Research significance is also outlined in this section.

Chapter 2 reviews the body of the existing literature that support the research questions. Firstly, it presents an overview of the principal procurement's strategies making a distinction between 'conventional' and 'collaborative' procurement models. This section is particularly useful to better understand the second part of the chapter, which provides a background of the implication of using BIM in different types of procurement systems as well as the legal and contractual challenges that may arise when BIM is used. The chapter concludes with a presentation of the Lean management principles and tools as a business approach to managing construction projects to optimise value to the client and end user.

Chapter 3 presents the research design and methodology carried out in the investigation undertaken as part of this research, including the motivation of selecting a qualitative approach based on semi-structured interviews as a primary method of data collection. The chapter describes the approach and method employed to identify the research participants, the design of the research instrument for data collection, and lastly, the method used to analyse the data gathered. A total of 43 interviews were undertaken between March and July 2018. The interviews were addressed to professionals with high BIM experience as well as strategic business managers across Australia, Canada, the United States of America and the United Kingdom. The finding (Chapter 4) allowed the development of the collaborative contracting framework that was then confirmed through interviews with experienced BIM and business managers (Chapter 5).

Chapter 4 presents the outcome of the semi-structured interview through an in-depth discussion of the overall research findings. The chapter is divided into three sections; the first section presents the results regarding the benefits and challenges of using collaborative contracting, and the second section discusses the key contractual barriers to collaboration under conventional delivery methods, comparing it with collaborative contracting. Finally, the last section presents the findings of the application of BIM in Australian construction projects, focusing on understanding the approach used by the client in demanding BIM as a procurement strategy, the challenges within different procurement approaches and the legal and contractual implications.

Chapter 5 presents the framework developed based on theories and the empirical findings. The framework has been discussed and confirmed with four experts who were already involved during the interview stage. The framework aims to align the collaborative procurement model with BIM and digital engineering processes throughout an agile and Lean management approach.

Lastly, Chapter 6 concludes with a summary of the research's contributions, both theoretical and practical, originating from this thesis. It also outlines the research limitations and recommends areas for further research in the field of Lean, procurement and BIM.

Chapter 2: Literature Review

2.1 INTRODUCTION

This section provides firstly a background about the most popular types of procurement models, distinguishing among conventional models and innovative ones. In particular, focus is given to compare traditional procurement models against collaborative systems. Mapping the collaborative contracting systems worldwide, an overview of three main methods has been provided, respectively: the Australian Alliancing Contracting model, the American IPD and the English IPI procurement model. In addition, characteristics of the three models have been highlighted and a list of the common principles and key features have been presented. Successively, the chapter provides an overview of BIM, outlining the main features and benefits. This section then focuses on the relationship between BIM and Procurement, analysing the legal and contractual aspects that may arise when BIM is used in construction projects as well as the impact of BIM under different types of procurement methods. The last paragraph of the chapter introduces the concepts of Lean management and its applicability in the construction industry. The section first describes the values and principles of Lean production, then it focuses on the application of Lean in the construction industry, including the concept of the Last Planner System. The chapter concludes with a brief overview of the integration between Lean and BIM.

2.2 PROCUREMENTS & CONTRACTS

A procurement system is defined by Love, Skitmore, and Earl (1998) ‘as organisational system that assigns specific responsibilities and authorities to people and organisations, and defines the various elements in the construction of a project’. Masterman (2002) classified procurement systems broadly into four main groups:

(1) Separated procurement systems;

(2) Integrated procurement systems;

(3) Management-oriented procurement systems;

(4) Collaborative systems.

The separated method is probably the most used worldwide and it is often referred to as a 'traditional' model. The procurement model, known also as Design-Bid-Build or Construction-only is characterized by having different contracts for design and construction.

The integrated method is so called because a single contractor acts as a unique point of responsibility with the client for both design and construction. Under this category falls the Design-Build or Design-Construct procurement model and all the several variants. In private sector finance procurement models, the term Public Private Partnership (PPP) and its variant referred to the same form of procurement model (Rahmani, et al., 2017).

The management-oriented arrangements are characterised by having the management function separate from design and construction. Indeed, a client signs a contract with an independent professional team who perform as a management consultant on behalf of the client for both design and construction services. Two procurement systems belong to this category: construction management and management contracting (Rahmani, et al., 2017).

Finally, the collaborative procurement models are based on the commitment between the client and two or more parties who collaborate and share investment in order to achieve successful outcomes. They are also known as relationship-based contracting, a name that identifies the establishment and maintenance of a particular relationship among project stakeholders to meet the objectives of all parties involved. The most common variation of collaborative procurement systems are Project Partnering, Early Contractor Involvement (ECI), Two-Stage Open Book, Project Alliancing, Integrated Project Delivery (IPD) or Integrated Project Insurance (Acif, 2015; Lahdenperä, 2012; UK Cabinet Office, 2014). The procurement models can also be categorised based on the degree of collaboration.

The National Association of State Facility Administrators (NASFA, 2010), distinguish the delivery methods into three levels of collaboration (Fig.1): (i) Collaboration Level 1 or 'Typical' where collaboration in not contractually a

requirement; (ii) Collaboration Level 2 or 'Enhanced' where some contractual collaboration is a requirement, and ; (iii) Collaboration Level 3 or 'Required' where collaboration is required through a multi-party contract. Clients, by choosing the procurement strategy for a particular project, drive the degree of collaboration they want in the project (NASFA, 2010).

Figure 2.1 Level of Collaboration (NASFA, 2010)

Conventional contracts, like Design & Construct or Construction Management at Risk, try to apply some principles of collaboration (Level 1) for instance by having limited team risk sharing, or may try to enhance collaboration by including contractual obligation to co-operate and give early warning notices. However, as pointed out by Hayford (2018) these types of contract do not resolve the main barrier of collaboration that are per nature in the conventional fixed price contract. In contrast, in Level 3, collaboration reaches the highest level through collaborative contracting, in which at least the owner, designer and contractor and potentially other important key members, sign a single contract for design and construction (NASFA, 2010). To this level belong: Alliancing contracting, Integrated Project Delivery and Integrated Project Insurance.

The following sections provide an overview of the most popular procurement models in order to depict the differences in terms of level of team's integration and collaboration. It will describe a conventional procurement model such as Construction-only, Design-Construct and Private Sector Finance Procurement Methods and a more innovative one like the Early Contractor Involvement and collaborative contracting.

The collaborative contracting model, since it is the main focus of this work, will be discussed in a highlighted section, namely ‘Collaborative System’.

2.2.1 Construction-only

In the Australia market place this type of delivery model is referred to as ‘Construction only’ and it is the predominant procurement method particularly in many State Government clients (Davis, Love, & Baccarini, 2008).

This model is based on two procurement steps where the delivery design and construction services are split into two separate contracts with two separate entities doing two separate works. Consultants are appointed by the client on a fee basis, to generate design work and tender documentation based on the requirements provided by the client. These documents are successively used by the client as the basis for the bid to select the party responsible for the construction. The contractor therefore does not provide input into the design process and is involved only from the construction phase to carrying out the work (Rahmani, et al., 2017). Contractors and subcontractors are excluded from the early design and project planning. This type of procurement aims to increase competitiveness in the bidding process, since the bid is won by the firm that provide the lowest price (Hale, Shrestha, Gibson Jr, & Migliaccio, 2009; Holzer, 2015). However, disputes may arise if the tender documents are incomplete (Davis, et al., 2008). There are three main variants of the separated systems: Lump Sum, Measure and Pay and Prime Cost.

According to Regan, Love, and Jim (2015) the degree of adversity of traditional contracts is determined by the form of contract, the allocation of risk, the mechanisms for dealing with disputes, the alignment of incentives and responsibility for decision-making.

The system follows a linear and sequential process which may provide better management for the client, however it gives limited consideration to the design and information communication, since no input into the design or planning stages are provided by the contractor and subcontractor (Davis, et al., 2008; Rahmani, et al., 2017).

In terms of risk allocation, the client is responsible for the complete design while the contractor for the construction. Sub-contractors are responsible to the main contractor for the quality of construction work performed by them, but not for the construction work performed by other sub-contractors (Hayford, 2018).

2.2.2 Design and Construct

The Design & Construct (D&C) method can be defined as using a single contractor to act as the unique point of responsibility with the client, normally on a lump sum fixed (Rahmani, et al., 2017). The contractor can be either an integrated firm with in-house design expertise, a construction team, or a consortium of independent design and construction firms joined together for a specific bid (Rahmani, et al., 2017).

Under D&C the client does not assume the design risks (Austroads, 2014). Typically, all design risks as well as construction risks are allocated to the contractor, who is therefore taking the full risk of cost and schedule overruns (Davis, et al., 2008).

However, once the clients and the contractor sign the main contract, a series of bilateral contracts are still signed by the contractor with design consultants, engineering, trade contractor and supplier. This circle produces a network of new contracts that maintain separate and independent risk management (Circo, 2014).

From a client's perspective, this model presents only a single point of responsibility, which often can bring advantage in terms of time and cost saving by combining the design and construction role and knowledge. At the same time, conflict of interest may arise when a single entity controls both the design and construction activities (Circo, 2014). The client also loses the possibilities to retain control over the project and also loses the flexibility to change the design without incurring new costs (Lloyd-Walker & Walker, 2015). According to Darrington (2011), the typical D&C risk allocation results in less integration between client and the single entity, increasing danger of adversarial behaviour.

The D&C model is considered more efficient than traditional methods since it allows a contractor to be engaged early in the process and provide constructability knowledge. Rahmani, Khalfan, and Maqsood (2014) studied several delivery models that incorporate the ides of early contractor involvement and found that under D&C the design is often developed from conceptual design drawings and specified through functional performance. Therefore, the contractor is not involved during the earliest stage when the project is defined and scoped, preventing the client to take the full advantage of the contractor's knowledge and expertise.

There are several types of D&C possibilities, including:

• Direct: there is no competition between several tenders, only one tender is obtained (Davis, et al., 2008; Turner, 1997).

• Competitive: several contractors take part of the tender and offer competition in designs and in prices (Davis, et al., 2008; Turner, 1997).

• Develop and construct: consultants are appointed by the client to develop a partial stage of the design, referred to as 'scope design', then a selected list of contractor are invited to bid to develop and complete the design and construct the facilities (Davis, et al., 2008; Turner, 1997).

• Package deal: it is often used where the contractors competing will use a significant part of their own or another proprietary building system, or they will be constructing variations of a repetitive theme (Davis, et al., 2008; Turner, 1997). This method presents a limited scope for innovation. Some contractors may offer to find a site, to sell, mortgage or lease their product, obtain approvals at a risk to themselves or at a charge to the client (Davis, et al., 2008; Turner, 1997)

• Novation: sometimes referred to a design, novate and construct. It is similar with develop and construct, in the sense that the client appoints the designer to develop the conceptual design and tender documentations. However in this case, the designer team is then novated to the contractor by the client (Davis, et al., 2008; Turner, 1997) This type of D&C procurement is merely used by agencies in the non-residential building sector (Austroads, 2014).

The terms of Build, Own, Operate (BOO), Build, Own, Transfer , Design, Own, Operate, Transfer (BOOT), Design, Construct, Maintain and Operate (DCMO), Design, Construct and Operate (DCO) and Design, Construct, Finance and Operate (DCFO) are all variations of the identical form of project procurement (Acif, 2015; Rahmani, et al., 2017). They have the same structure of a standard D&C contract except that the client also transfer the majority of the maintenance and operating risks to the contractor for a defined period of time, minimum 10 years, at agreed prices, without the need for private financing that characterises the PPP-type delivery models (Austroads, 2014).

2.2.3 Private Sector Finance Procurement Methods

A PPP is a long-term agreement between a public authority and private entities for the delivering of services (Love, Liu, Matthews, Sing, & Smith, 2015). The process begins with the project's owner inviting selected organisations for a competitive bidding process (Regan, et al., 2015). The successful bidder enters an 'upstream' contract with the owner and 'downstream' contracts with constructors, suppliers and service providers until the facility is transferred back to the owner after the concession period (Rahmani, et al., 2017).

According to Regan, et al. (2015) the PPP agreement is not fully collaborative, but it reaches a degree of transactional transparency and cooperation not found in conventional procurement models. Risks are, in general, allocated to the party who is most capable to handle them, the party that can perform the most effective risk management with reduced amount of fees (Li, Li et al., 2008). Ideally this is located with the party that has the appropriate field of competence (Zimmermann & Eber, 2014)

Although this type of procurement can provide a network of relationship and incorporate different expertise including the operation and maintenance services, Kuiper and Holzer (2013) stated that the model does not necessarily inhibit the adversarial nature, such as design and construct, that can still occur with the arrangements.

2.2.4 Early Contractor Involvement (ECI)

Early Contractor Involvement (ECI) model focuses on increasing the buildability by involving the contractor in the design stage (Rahmani, et al., 2014). ECI is a two-stage collaboration process (Love, O'Donoghue, R. Davis, & Smith, 2014). During the first stage, the contractor acts like a consultant and is paid by hours (Rahmani, et al., 2014). The aim of this stage is to develop a target price, production plan, and to allocate risk. At the end of the first stage if the client is satisfied with the contractor, the same contractor will be awarded the contract for the second stage. The second stage assume the aspect of a D&C contract, where the contractor is responsible for design and construction, and paid on a lump sum fixed price basis. As reported by the Australian National Alliance Contracting Guideline (Australian Government, 2015) despite the advantages of early collaboration with the contractor and better identification of risks during the first stage, problems can arise, such as contractors' designers disregard or redesigned elements undertaken by the client's designers, leading to an overall increase in design development works, and concerns due to the complexity of two substantially different forms of contracts.

2.3 COLLABORATIVE PROCUREMENTS

Traditional delivery methods are known for their transactional nature, which promotes silo behaviour and adversarial relationships (Matthews & Howell, 2005). Over the past decade, collaborative contracting, also known as relationship-based contracts, have emerged as an important alternative to traditional forms of project delivery. They represent a drastic cultural shift within the construction industry (Harper & Molenaar, 2014; Matthews & Howell, 2005; Palacios, et al., 2013).

Collaborative contracting has contracts that incorporate features that are specifically designed to overcome the misalignment of commercial incentives associated with conventional fixed price contracts (Hayford, 2018) They have been increasingly adopted by Australian public sector clients to deliver large, complex and high risk infrastructure projects (Morwood, Scott, & Pitcher, 2008). This approach allows public sector clients to benefit from much better knowledge sharing and exchange, and ultimately a much higher level of knowledge creation and innovation than during traditional adversarial delivery methods (Edwards 2008; Love et al. 2010; Miller et al. 2009; Styhre et al. 2004).

Under collaborative procurements, also called collaborative construction project arrangement (Lahdenperä, 2012) or relational project delivery arrangements (Halttula, et al., 2015), all the project's members are involved at the very beginning of the project and committed to a mutual single goal.

Lahdenperä (2012) identified three types of collaborative delivery method: Project Partnering, Project Alliancing and the IPD. However, project partnering is characterized by not having contract force in itself, whereas alliancing and IPD are formally expressed in contractual form (Lahdenperä, 2012; Manley, 2002). For that reason, only project alliancing and IPD will be considered in this study.

To these, can be added the recent new UK procurement model, namely Integrated Project Insurance which shares many similarities with the other three models:

(i) collaborative multi-party agreement,

(ii) early involvement of key parties,

(ii) transparent financials,

(iii) shared risk and reward,

(iv) joint decision-making.

In Project Alliance, all parties assume joint responsibility for design and construction and share positive and negative risk until the project handover. Principles of collaboration and open communication are followed to promote collaboration and 'no fault, no blame' culture. All participants are required to work as an integrated project team to make unanimous decisions for all key project issues in order to determine the best solution to deliver the project (Morwood, Scott, & Pitcher, 2008).

IPD principles reflect the tenets of project alliance (Kent & Becerik-Gerber, 2010; Raisbeck, Millie, & Maher, 2010; Starzyk, 2014). However, IPD introduces some management approaches not included in project alliancing, such as the use of lean principles and BIM (Lahdenperä, 2012; Raisbeck, et al., 2010).

Last but not the least is the IPI model, introduced in UK in 2014 as a new method of procurement. The unique aspect of this method is the adoption of single insurance policy that covers risks associated with the delivery of the project, including any cost overruns above and beyond a 'pain-share' threshold, which is split transparently between client and the contracted parties (UK Cabinet Office, 2014).

The following section begins with an overview of the three procurement models, followed by a comparison between collaborative and traditional procurement, and concludes with a list of the main features that the three approaches share.

2.3.1 Alliance Contracting

Alliance contracting is an innovative delivery approach generally suitable to deliver large, complex and high-risk projects (Chen, Zhang, & Xie, 2010; Department of Infrastructure Transport, 2015; Morwood, et al., 2008; Ross, 2003). In particular, it works best for complex projects where the scope is not well defined at the start and therefore a flexible delivery model that allows change and adaption is needed (Briggs, 2007). The ‘National Alliance Contracting Guidelines’ released by the Australian Department of Infrastructure Transport (2015) defines alliancing ‘as a legal/ commercial arrangement between a public sector agency “Owner Participant” (OP) with one or more private sector parties as “Non-Owner Participants” (NOPs) for delivering major capital assets.’ Under a contractual framework where commercial interests are aligned with actual project outcomes, a client and one or more service providers works as an integrated project team to deliver the specific project.

Alliancing originated in the early 1990s in the UK, where it was first used in the North Sea by British Petroleum in order to improve the delivery of complex oil & gas projects (Morwood, et al., 2008). An eight-party alliance was established and resulted in 21% of reduction in capital expenditures. Following the UK experience, Australia embarked on its first two Alliance projects in 1994, the Wandoo B Offshore Oil Platform Project and the East Spar Gas Project both in Western Australia (Morwood, et al., 2008). Since then, the alliancing model started to be used in other infrastructure projects, with the catalyst example of North side Storage Tunnel Alliance for Sydney Corporation, the first alliancing project in the Australian public sector, completed between 1997 and 2001. From a building sector perspective, the Australian National Museum in Canberra, opened in 2001, was the first building project procured through Alliance (Manley, 2002).

While it originated elsewhere, since it was first used in Australia, Alliancing has evolved, becoming an accepted form of procurement for public sector infrastructure engineering projects in both Australia and New Zealand, making a significant contribution to the body of alliance knowledge (Ross, 2009). There are several types of legal and commercial relationships in use around the world that are referred to as ‘alliance’, from traditional risk-transfer under a collaborative manner to ‘pure alliance’ arrangements where all risks are equitably shared among all participants (Ross, 2009). Most of the Australian alliances have been undertaken in their pure form (Ross, 2009).

Alliancing contracting can also be classified into two categories: project alliance and strategic alliance. Project alliance is a short-term relationship undertaken for a single project until project handover, whilst, strategic alliance is a long-term agreement and it is usually used to deliver a program of projects. Despite the differences, both of them are relationship-based contractual forms founded on principles of equity, mutual trust, respect and open communication (Henneveld, 2006; Morwood, et al., 2008).

By having in force a high level of collaboration and cooperation, with successful integration among different parties involved in the project, it has been found to occur more under alliancing rather than traditional approaches that are transactional in nature (Love, Mistry, & Davis, 2010; Walker, Harley, & Mills, 2015). Indeed, the collaborative nature of the arrangement, by providing greater flexibility and effectiveness in handling uncertainty, reduces the energy spent by participants in establishing defensive administrative procedures to cover potential liability for risk and consequent litigation (Briggs, 2007; Walker, et al., 2015).

The alliance project can be outlined in four core stages (Briggs, 2007):

- Stage 1 – selection process: proponent is selected on qualification-based criteria by the evaluation panel who assess each tender on project understanding, commitment to alliance principles and capacity to innovate through interviews and workshop.
- Stage 2 – project development: the alliance team is assembled, design developed, a target outturn cost (TOC) is developed and the commercial framework for the alliance is finalised.
- Stage 3 – project execution: if the owner is satisfied with the TOC and the status of the project generally, it will commit to the execution phase. Design is finalised concurrent with construction.
- Stage 4 – finalisation: following practical completion and project handover, the alliance carries out maintenance obligations and the commercial project outcomes are closed out.

Despite the successful applications and superior value for money provided in comparison to a traditional approach such as Design and Construct, debate still continues in regard to its applicability (Walker, et al., 2015). Briggs (2007) noted that some sceptics are still arguing whether alliancing delivers value for money as there is not competitive price in the selection process and thus the TOC is more likely to be conservative and ‘fat’. Indeed, people may claim that if the Actual Outturn Cost (AOC) is considerably less than the final TOC, the estimates and rules used to develop the

TOC were too easy to achieve. However, this may be the result of a combination of high levels of innovation, excellent management, excellent teamwork or just good luck (Walker, et al., 2015).

To address this issue, independent reviews and estimators are normally involved to produce a check TOC selection process and therefore more transparency into the pricing component (Briggs, 2007).

A study conducted in 2009 by the Alliancing Association of Australasia showed that to date, approximately 300 construction projects in Australia at a total value of 90 billion dollars have been successfully completed under alliancing. Alliances have proven to be effective in delivering infrastructure projects in Australia (Henneveld, 2006; Love, Mistry, et al., 2010; Walker, et al., 2015).

Walker, et al. (2015) compared AOC with the initial TOC with 60 projects. They found that only 4 out of 60 projects were above 5% over, with three being between 3% and 5% and three cases at less than 1% above zero. Many of the projects were delivered on-cost (17 of the 60) and 34 were delivered below cost. Most of these involved scope changes. They also stated that there was no evidence to suggest that these TOCs had over-generous budgets.

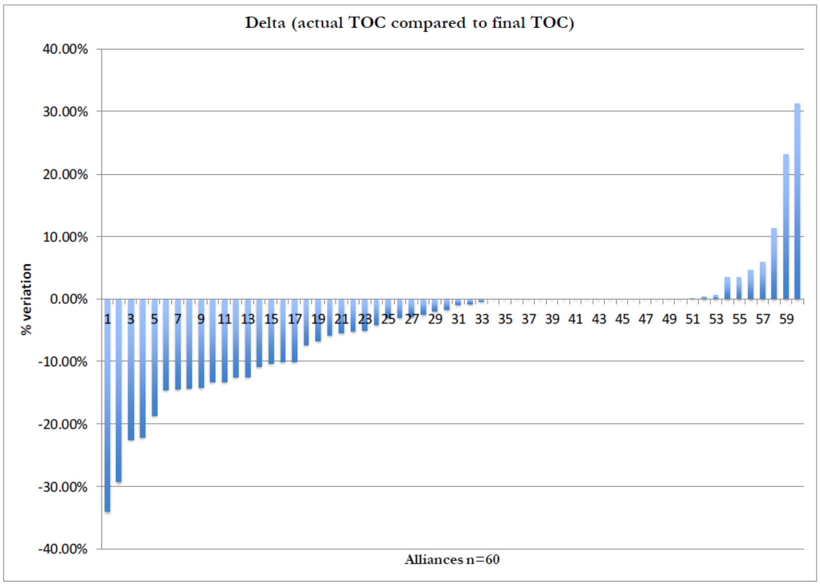


Figure 2.2: Delta (actual AOC compared to final TOC) (Walker, et al., 2015)

Regarding the time, 18 projects were completed under the initial proposed time, with four of these being more than 20% under schedule and eight of the remainder greater than 10% under time. Twenty-eight projects were delivered on time; thirteen projects were delivered over schedule time; seven of these were under 10% over that time. Four projects were between 10% and 20% over scheduled time and three projects were over 20%, two of those around 60% over time.

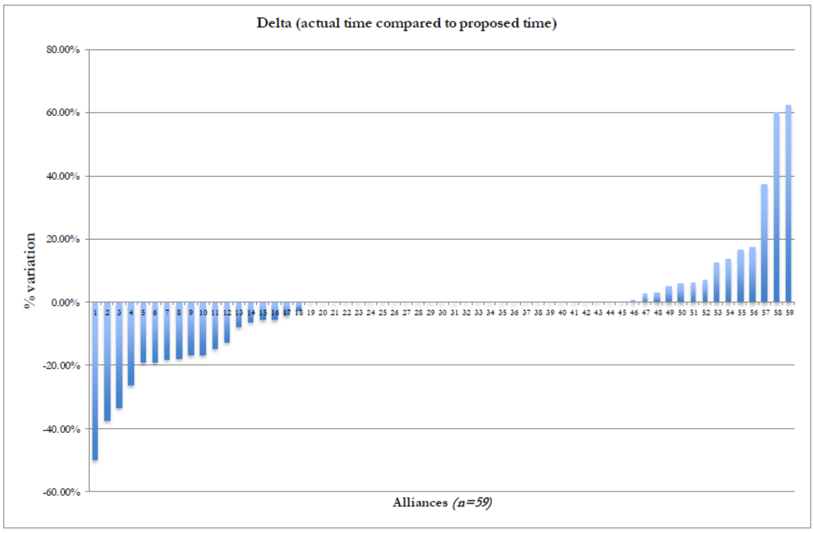


Figure 2.3: Delta (actual time compared to proposed time) (Walker, et al., 2015)

2.3.2 Integrated Project Delivery

Integrated Project Delivery (IPD) represents the latest trend in the US construction market and is driving toward a more collaborative approach to delivering large and complex projects (Azhar, 2011; Ghassemi & Becerik-Gerber, 2011; Kent & Becerik-Gerber, 2010; Lichtig, 2006).

It is a project delivery method that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction. It contains, at a minimum, all of the following elements (AIACC, 2014).:

- Continuous involvement of key participants from early design through to the end of the project;
- Aligned business interest through shared risk and reward;
- Joint project control by key participants;

• A multi-party agreement or equal interlocking agreement;

• Limited liability among owner and key participants.

IPD focuses on solving the inefficiencies associated with traditional delivery methods (Ashcraft, 2014), which can be grouped into four systematic problems: holding back good ideas; limiting cooperation and innovation; lack of coordination; and encouraging local optimization (Matthews & Howell, 2005). According to Wilson and Dal Gallo (2013) IPD differs from other forms of contracts by the kind of contract model, the level of owner involvement in the decision making and the fee structure and certain waivers of liability (shared risk) between the owner and the other key members.

The IPD approach is built around team's collaboration by creating a virtual organisation (Ashcraft, 2011). A single multi-party contract is signed between owner, designer, contractor and all the others relevant parties. The organizations' mission to commit to 'best for the project' is supported by aligning the participant's interests through shared risk and reward (Kent & Becerik-Gerber, 2010). Indeed, the success of IPD projects depends on the outcomes of the project not individual organisation outcomes. In addition to collaboration and integration, IPD incentivizes waste elimination and delivering the highest-value for the client (Ghassemi & Becerik-Gerber, 2011; Lichtig, 2006). These aspects are supported by using BIM tools, process improvement metrics and Lean design and construction techniques (AIACC, 2014).

Cohen (2010), in collaboration with the AIA California Council Integrated Project Delivery Steering Committee and the AIA National Integrated Project Delivery Interest Group, has released in 2010 the 'Integrated Project Delivery: Case Studies' report in which 6 IPD projects were analysed. The goal of the studies is to encourage clients to adopt a collaborative approach to improve projects performance.

El Asmar, Hanna, and Loh (2013) conducted a statistical comparison of 35 recently completed pure IPD and non-IPD projects. The results show that IPD achieves significant improvements in 14 metrics across six performance areas: quality, schedule, project changes, communication among stakeholders, environmental, and financial performance.

Fakhimi, Sardroud, and Azhar (2016) claim some benefits that can be reached following IPD principles:

(i) Reducing or eliminating conflict between the project teams,

(ii) Optimizing the efforts of the workforce,

(iii) Improved communication and better understanding among project participants,

(iv) Clearer definition of project goals,

(v) Creating incentives for exceptional results,

(vi) Minimizing waste by better planning and shared costs,

(vii) Improving project delivery timelines,

(viii) Reducing operational and maintenance costs of the finished project,

(ix) Limiting requests for interpretation (rfi) from the contractor,

(x) Easier sharing of rewards and risks among stakeholders,

(xi) Encouraging the team to take a broader, more creative approach to addressing the client's needs.

El Asmar, Hanna, and Loh (2015) compared the performance of the IPD method with three conventional procurement models - Design-Bid-Build, Construction Management at Risk and Design and Build - in six areas: (1) customer relations, (2) schedule (3) cost, (4) quality, (5) financial metrics, and (6) communication. Their findings, based on a project quarterback rating system (PQR), showed overall higher performance of IPD in comparison with the other delivery methods in these seven areas.

Some critics argue that IPD should be reserved for larger, complex projects because it requires a significant initial cost investment and additional design efforts as well as increased owner involvement (Azhar, Kang, & Ahmad, 2014). However, experienced IPD teams have successfully executed projects as small as $1.5M, and some owners use IPD on their projects starting at $5M (Allison, Ashcraft, Cheng, Klawans, & Pease, 2018). Therefore, this goes against the general belief that IPD can be applied to large projects only. In this regard, experts suggest that if a team has never undertaken an IPD project, it must invest time in contract creation, organization, and training. Therefore, project minimums are often closer to $15M in order to absorb first time coaching and training expenditures, while projects below that price may not be able to absorb these additional costs and additional level of effort (Allison, et al., 2018).

However, due to the high level of client involvement required in such arrangements, IPD may not be allowed in public projects where regulation and law can preclude entering three or multi-party contracts with profit and risk sharing (Darrington, 2011).

Mapping of US Collaborative Project Delivery

In the last decade, several forms of agreement have been developed in the US construction sector in order to enable IPD adoption. ConsensusDOCS, a coalition of more than 40 design and construction industry organizations, published in 2007 the 'ConsensusDOCS 300 Standard Form of Tri-Party Agreement for Collaborative Project Delivery' (ConsensusDOCS, 2007). Later on, the American Industry of Architects (AIA) followed with a family of Integrated Project Delivery Contract Documents, which include: 'AIA Document C195-2008 Standard form Single Purpose Entity Agreement for integrated Project Delivery' and 'AIA Document C191-2009 Standard Form Multi-Party Agreement for Integrated Project Delivery'. The following section provides an overview of the new forms of collaborative agreements.

ConsensusDOCS300

ConsensusDOCS 300 was the first standard IPD construction contract (Perlberg, 2009). It is a tri-party agreement for Collaborative Project Delivery (CPD), which fully incorporates collaboration and Lean construction principles, including the Last Planner System, Target Value Design and Built-in Quality (ConsensusDOCS, 2007). Its structure was based on the 'Integrated Form of Agreement' (IFOA) used by leading healthcare provider, Sutter Health, to deliver all projects in the form of Lean Project Delivery. An updated version of the document was released in January 2016 (ConsensusDOCS, 2016a) and provides a clear structure on how to contract for Lean integrated project delivery by addressing the organizational structure, operating system and commercial terms. The agreement intends to get the key participants (owner, designer and contractor) under the same single contract to join as a collaborative project team, at both the project management and project development levels, at the earliest stage of design project.

The IPD Team has the aim of governing the IPD project through a collaborative decision-making process and to take actions considering the best interest for the whole project. Additional key players can join the IPD Team using the new 'ConsensusDocs 396 Standard Joining Agreement for Integrated Project Delivery' (ConsensusDOCS, 2016c) or modifying the initial contract in any step of the design phase in order to develop a fully integrated design process. All the decisions related to the project need to be made by the core team through a consensus. If the group fails to reach the consensus, the owner reserves the right to make a final decision.

Commercial terms regarding how participants will be paid and risk/reward shared, are addressed through a Risk Pool Plans template and Responsibility Allocation Matrix. Mutual trust, transparency and open communication are the essential components of this approach. ConsensusDOCS 300 has no lump sum or guaranteed maximum price (GMP) approach. Instead, owner, architect and contractor collaboratively agree on Estimated Maximum Price (EMP), which represents the total cost to the owner for design and construction of the projects. In this model, the core group shares the risk of cost overruns and through financial incentive, aligns the interest of each team member with the interest of the whole project. The estimate is then used to measure the project's success. Profits can be achieved if the project meets the targets established by the group and if the estimated target cost is higher than actual cost (Perlberg, Gregory, & Orien, 2011).

AIA Agreement for Integrated Project Delivery

The AIA has developed agreements for three levels of integrated project delivery which may be referred to as the three levels of collaboration described by NASFA (2010), from lowest to highest collaboration: Transitional agreements, Single Purpose Entity (SPE) Agreement and Multi-Party Agreements. The AIA's Transitional IPD agreements consist of: 'AIA Documents A195-2008 Standard Form of Agreement between Owner and Contractor for Integrated Project Delivery' (AIA, 2008a) and 'AIA Document B195 Standard Form of Agreement between Owner and Architect for Integrated Project Delivery'(AIA, 2008b). Both the two forms of contracts allow the projects that may not yet be engaged within a fully integrated approach, to use some of the IPD principles, such as early information sharing and collaboration between main parties, from the design phase to-end-of construction.

In the AIA Transitional IPD contracts, designer and contractor are not placed under a single entity, as happens in a Design-Built agreement, but sign two separate contracts. However, even if both A195 and B195 are also denominated as integrated agreement, due to their transitional nature they are not considered as true IPD (Dal Gallo, O'Leary, & Lourida, 2009). The second level corresponding to the 'AIA Document C195-2008 Standard form Single Purpose Entity Agreement for integrated Project Delivery' (AIA, 2008c) embraces IPD principles by creating a Limited Liability Company for the single purpose of planning, designing, construction and commissioning the project. The 'Company' is formed by the owner, architect, and construction manager as well as other key participants they might invite to join and who do not own any real property. The 'AIA Document C191-2009 Standard Form Multi-Party Agreement for Integrated Project Delivery' (AIA, 2009) is a tri-party contract in which the parties jointly develop project definition, goals, schedule and target costs. At a minimum, the contract requires the owner, architect and the general contractor to sign a single agreement and be involved from the very earliest steps.

2.3.3 Integrated Project Insurance

The Integrated Project Insurance (IPI) was included in the UK Government Construction Strategy in 2011 as a new form of innovative procurement system (UK Cabinet Office, 2014). The innovative concepts and processes of the Integrated Project Insurance model have now been consolidated through a new Alliance Contract and IPI insurance policy and they have been tested in the first trial on the Advance II pilot project at Dudley College.

The IPI model incorporate a new type of insurance called 'Insurance Backed Alliancing' which aligns the interests of all the participants covering cost overrun and latent defects insurance. So far, this type of insurance has been made available for building projects and programmes valued between £10m (~AUD 18m) and £25m (~AUD 45m) (IPInitiatives, 2018).

Special measures have been embedded in the model to ensure optimum collaboration including commitment to collaborative principles and a no blame/no claim culture to be agreed among the integrated project team before entering into the alliance agreement.

The innovative concepts and processes of the IPI model have now been consolidated with those of alliancing having undergone their first trial on the Advance II pilot project at Dudley College.

2.3.4 Comparison between collaborative and traditional model

Back in 2004 the Construction Users Roundtable (CURT 2004) encouraged the industry to move towards a new procurement model called Integrated Project Delivery alongside with requirements for collaboration and the use of advance technologies. This proposal may be seen as an extension of the call made in UK a decade before by Latham (1994) and followed by Egan (1998), who both promoted collaborative working practices as a key to reducing the inefficiencies of traditional construction models and to increase value to end users.

Collaborative delivery methods are based on a multi-party agreement between the key participants of the project. They present several differences to the other more conventional models. The main difference concerns the allocation of risks. Under traditional methods, each participant is responsible for individual risk without taking into account the other party's view (Department of Infrastructure Transport, 2015). Whereas, under the collaborative model the risk and reward are collectively shared among the participants based on the success of the entire project (AIA, 2007; AIACC, 2014; Ashcraft, 2014; Kent & Becerik-Gerber, 2010; Lahdenperä, 2012; Morwood, et al., 2008; NASFA, 2010; Starzyk, 2014).

All parties need to work as an integrated project team and make decisions that are the best for the project, rather than for their own interest (AIACC, 2014; Ashcraft, 2014; Department of Infrastructure Transport, 2015; Lahdenperä, 2012; Morwood, et al., 2008). The basic idea of sharing provides the foundation for the collaborative delivery method principles, including: collaboration, making best-for-project decisions and innovation.

In the collaborative procurement model structure, all team members benefit or suffer together (Lahdenperä, 2012). Disputes that typically lead to claims are prevented in a collaborative way (AIACC, 2014; Morwood, et al., 2008). For instance, as reported by AIACC (2014) at the date of publication of the document, no IPD project has gone into litigation.

The early involvement of key participants combined with their knowledge and expertise, is one of the main factors that distinguish collaborative models from traditional approaches (AIA, 2007; Ashcraft, 2014; Department of Infrastructure Transport, 2015; Kent & Becerik-Gerber, 2010; Lahdenperä, 2012; Morwood, et al., 2008; NASFA, 2010). By s1etting up an integrated project team during the early stage of the project, innovative ideas and collaborative behaviour are more like to happen (Morwood, Scott et al., 2008).

All the key members - client, designer, consultants, constructor, subcontractors and suppliers – need to understand the value of collaboration and commit to work as a single team for the best interests of the project by building an environment based on trust and openness (AIA, 2007; AIACC, 2014; Ashcraft, 2014; Department of Infrastructure Transport, 2015; Morwood, et al., 2008; NASFA, 2010). Mutual trust is fundamental, otherwise alignment of everyone's interests with the project is unlikely (Perlberg, 2009).

The 'MacLeamy Curve' (CURT, 2004) (Figure 2.4) shows how an integrated approach transforms the traditional phases of the projects enabling a full collaborative environment. The time-effort distribution curves describe four important concepts: (i) line 1 represents the declining ability of the team to impact on project cost and schedule, as the project progress; (ii) line 2 shows how making change at the late stages of the project can impact on the cost; (iii) line 3 indicates the distribution of design effort in a traditional process when most of the design documents are developed in the late design phases; (iv) line 4 represents the distribution of design effort under a full collaborative approach.

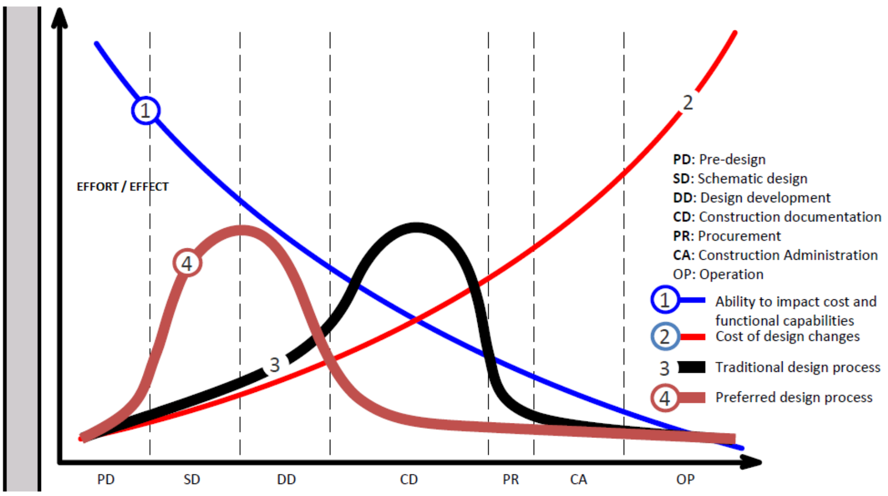


Figure 2.4: The MacLeamy Curve

The graph shows how the new approach differs from the traditional, by collecting and integrating all the information at the earliest stage of design when the costs of change are minimized. This mechanism requires major effort at the early stage of the design in comparison to the traditional method. However, due to the higher level of design completion, the next phase requires less effort than the traditional (AIA, 2007).

The early involvement of contractors at the early design stage allows leveraging of the contractor's construction knowledge and helps to prevent continuous misunderstandings and poorly informed design decisions that often create delays during construction (Eastman, et al., 2011). As a result, the project can be defined and coordinated at a higher level before construction starts, allowing a more efficient construction phase and eventually, a shorter construction period (AIA, 2007; Eastman, et al., 2011).

2.3.5 Collaborative System Characteristics

Collaborative procurement systems lead by the following principles and features (Table 2-1):

<u>Agreement:</u> the nature of the agreement among all project's parties is documented in a single multi-party contract. The agreement does not only describe the expected performances, called Key Result Area in the alliancing contracting, but also incorporate behavioural 'value' that may compromise the alliance principles. These include a no-blame culture based on consensus decision making. Parties therefore cannot sue each other unless there has been demonstrable illegality or gross negligence (Walker, et al., 2015).

<u>Responsibility:</u> The concept of mutual responsibility plays a vital role to develop the legal/commercial framework, which is the base of successful collaborative contracting. Indeed, it is very hard to create a 'virtual organisation', if participants do not share obligations with the client but rather, those remain clearly distinct (Department of Infrastructure Transport, 2015, Ross, 2009). Under collaborative contracting, the client is engaged and assumes position as much as the other participants. Both client responsibilities and individual rights are transferred into the agreement (Henneveld, 2006, Morwood, Scott et al., 2008).

Risk and Reward Sharing: The commercial framework influences the behaviour of all participants to achieve an outcome that provides for mutual success (Morwood, et al., 2008). It is based on the promise of we all win/we all lose together, thus parties share gain and pain depending on project outcomes. Decisions are taken according to 'what's best for project' behaviour, such as by providing incentives tied to achieving project goals (AIA, 2007; AIACC, 2014; Ashcraft, 2014; Department of Infrastructure Transport, 2015; Kent & Becerik-Gerber, 2010; Lahdenperä, 2012; Morwood, et al., 2008; NASFA, 2010; Starzyk, 2014). The project participants jointly developed TOC and agreed on performance targets. If targets are not reached, participants lose an amount of their profit. Conversely, if the project is delivered under TOC they all share savings. Under alliance, the compensation model is structured in '3-limb' , where Limb-1 is the guaranteed cost, Limb-2 gathers the cost overheads and profit for each NOP and is 100% at risk under the Limb-3. Limb-3 is the predetermined gainshare/painshare associated to pre-arranged targets non-cost key result areas (KRAs) (Morwood, Scott et al., 2008, Ross, 2003)

Open book: transparency is evidenced by the 'open-book' approach, which provides accurate financial information to all project participants and gives them a clear view of the client's needs and values. This approach reinforces the 'we are all in the same boat' mindset and encourages making decisions following the best-for-project behaviour. It is also beneficial from the client's perspective, as it allows them to keep track of the actual cost of construction (Henneveld, 2006).

No-fault No-blame culture: The 'no blame' liability framework and the governance structure of an alliance combine to eliminate, or at least drastically reduce adversarial conduct between parties (Briggs, 2007). The 'no dispute' helps to avoid the traditional adversarial claim-based culture and encourages the teams to join and find new solutions (Lloyd-walker, Mills et al., 2014). In fact, by establishing a 'no fault – no blame' culture, collaborative contracting supports innovation by asking each party to commit to not assigning blame in case of error or poor performances, but rather to share joint responsibilities and resolve the issue in the best behaviour for the project (Department of Infrastructure Transport, 2015, Lloyd-walker, Mills et al., 2014, Manley, 2002, Morwood, Scott et al., 2008). While under alliancing, parties agree that there will not be litigation or arbitration between them, as well as that any failure will not be entitled to reimbursement (Department of Treasury and Finance, 2010d), the IPD approach seems to follow much the same lines with the adding of alternative contractual options that enable the use of more traditional practices (Dal Gallo et al., 2009).

Joint Project Control and Unanimous Decision Making: Ideas are freely exchanged among all participants and unanimous decisions are taken to determine the best project solution to deliver the project. This process increase commitment to the no-dispute culture and to mutual liability waivers among the key participants (AIA, 2007; Ashcraft, 2014; Department of Infrastructure Transport, 2015; Ghassemi & Becerik-Gerber, 2011; Lahdenperä, 2012; NASFA, 2010; Starzyk, 2014).

Insurance: Traditional insurance tries to protect and cover each project entity. Because in collaborative contracting, each party's work impacts that of another and risk are shared, it important to provide an insurance that covers the whole project and not the individual parties.

Client Focus: The client's role is very significant since theirs is the one that defines goals, provides direction, and models transparency and collaboration to the entire project team. The client is part of the team and maintains close involvement with the design and delivery teams throughout the project's execution. The close interaction also allows the client to control the outcomes (Young, Hosseini, & Lædre, 2016).

Team selection: the team selection is the first most important step for a client to drive toward successful collaborative contracting. Clients need to be able to establish which team has most potential to deliver outstanding outcomes working as an integrated team with them for the duration of the project (Ross, 2009). Normally, proponents respond to the client Request for Proposal (RFP) and successively, the most qualified firms will be shortlisted and invited to continue the selection process. The team selection is normally based on best value by choosing the 'best for the project' proponent. Therefore, in contrast with conventional methods, clients cannot select participants based on price alone (Cleves and Dal Gallo, 2012).

The current Australian Alliancing national guideline, however, recommends partial or full price selection to increase the competitive tension of the selection (Department of Infrastructure Transport, 2015; Lahdenperä, 2012). In the full price selection process, the NOPs are selected using both non-price and price criteria. In relation to price criteria, this process requires the proponents to tender a full TOC (Department of Infrastructure Transport, 2015). The partial-price selection process does not require the proponents to tender the full TOC and various options that can be used including both non-price criteria, and some price and commercial criteria (Department of Infrastructure Transport, 2015).

The categories that are generally used for selecting the team members vary from technical ability to more intangible skills, such as the ability to collaborate, sound judgment, compatibility with other members, and willingness to learn (Allison, Ashcraft et al., 2018, Cleves and Dal Gallo, 2012). The preferred party is identified through a series of structured interviews and set of workshops that help to review the team’s performance and capability (Morwood, et al., 2008) and the team’s plan to accomplish the project, value assessing their ability to collaborate (Wilson and Dal Gallo, 2013).

The team selection process is designed to physiologically prepare the teams towards a very different type of delivery model that they have often experienced by developing elements of self-awareness, communication and team integration (Morwood, et al., 2008). Under some circumstances, parties can be selected separately in a sequential process. For instance, in case of lack of clarity of the scope of the project, the client can select the design consultant first to develop the concept design for the works. With clear understanding of the scope the constructor with the most appropriate skills can be selected. Conversely, if the key challenges for the works are construction related, the constructor can be chosen first. Under alliancing, the client may or may not include the designer in the selection process for the constructor and vice versa. However, this approach may lead to a situation where it is hard to create a multiparty culture and lack of enough diversity in the initial stage to stimulate innovation (Lahdenperä, 2012; Morwood, et al., 2008).

In the IPD approach the party selected, either the architect or the contractor, then participates in the selection of the other main project participant. Subsequently, the client, main design consultant and the contractor together choose key design consultants and trade contractors. While design consultants are usually among the key participants, not every trade contractor is. The integrated project team needs to include only those whose work would have significant effect on the project outcome. Therefore, parties should be added when they bring value to the project (Allison, Ashcraft et al., 2018). Prime examples include mechanical, electrical, and plumbing contractors. These are among the players who benefit from, and benefit the project by, closer integration and collaboration (Cleves and Dal Gallo, 2012).

Goal Definition & Team Alignment: project goals are developed early and agreed upon by all participants. The project's goals range from the standard 'iron triangle' (Time/Cost/Quality) performance criteria, to performance expectations on environmental and social dimensions (Elkington, 1997; Australian Agency for International Development, 2003). Moreover, in addition to those, the team add important criteria they believe to be critical for project success. The conditions of satisfaction should be co-developed as soon as possible, but should not be finalized until all the key players are engaged to ensure everyone can agree on them. The project's objectives need to be communicated to all project participants, moreover, measuring how the team is doing against the project's goals needs to be done with regularity (Allison, et al., 2018) (AIA, 2007; AIACC, 2014; Ashcraft, 2014; Ghassemi & Becerik-Gerber, 2011).

Best for the project: share a mutual single project objective to deliver the highest-value for the client. This requires all parties to work as an integrated project team and make decisions that are best for the project, rather than for their own interest. The collaborative contracting structure can be compared with an integrated 'virtual organization'. The organization which includes the individual team members - the owner, design consultants and contractor - are encouraged to make reliable commitments which are written in the agreement, and pursue them to achieve rewards (Henneveld, 2006). The project organization's mission and responsibilities are committed to 'best for project' decision making, and this commitment is supported by alignment of the firms' business interests through shared risk and reward (AIACC, 2014; Ashcraft, 2014; Department of Infrastructure Transport, 2015; Lahdenperä, 2012; Morwood, et al., 2008).

Integration/Early Involvement of Key Participants: All participants are required to work as an integrated project team, which enables early contribution of knowledge and expertise (Henneveld, 2006). This is most powerful during the early stage of the project where informed decisions have the greatest effect. By having the contractor on board since the early design stage, contractor capabilities of constructability can be leveraged and the risks of inconsistency, ambiguity and missed information between design and construction phase are reduced (AIA, 2007; Ashcraft, 2014; Department of Infrastructure Transport, 2015; Eastman, et al., 2011; Kent & Becerik-Gerber, 2010; Lahdenperä, 2012; Morwood, et al., 2008; NASFA, 2010).

Culture and Behaviour: It is critical for participants to enthusiastically drive the cultural change that is necessary to achieve alliance objectives (Briggs, 2007). A strong client commitment, team attitude and leadership skills to collaborate are vital to achieving optimum outcomes (Walker, et al., 2015). Client, designer, consultants, constructor, subcontractors and suppliers understand the value of collaboration and are committed to working as a team in the best interests of the project. Trust is fundamental to align interests of participants. For a client to truly gain advantage from collaboration, the client must also be collaborative. Indeed, the situation in which the project's parties feel that the client is only concerned with their own issues and assumes an authoritarian behaviour, will bring the parties to place their own firm's need above the need of the project (Allison, et al., 2018). Clients also need to be reliable and committed to meeting obligations and keeping to what has been promised. Therefore, open, direct, and honest communication among all participants, including the client, is paramount. Moreover, subcontractors are usually contracted through sub-alliances and relationship-based contracts, which allow the spread the alliance behaviour throughout the entire supply chain (AIA, 2007; Department of Infrastructure Transport, 2015; Morwood, et al., 2008) (AIA, 2007; AIACC, 2014; Ashcraft, 2014; Department of Infrastructure Transport, 2015; Morwood, et al., 2008; NASFA, 2010) (AIACC, 2014; Ashcraft, 2014; Department of Infrastructure Transport, 2015; Morwood, et al., 2008; NASFA, 2010; Perlberg, 2009).

Intensified Design and Planning: increased effort in planning results in increased efficiency and savings during construction execution (AIA, 2007; NASFA, 2010).

Co-location: Co-location enables movement from 'silo' behaviour towards a culture of sharing and collaborative working. It promotes physical office sharing by the project participants such as the general contractor, architect, engineer, subcontractors, suppliers, owner representatives and end users such as tenants and facility managers during the course of the project (Morwood, et al., 2008; NASFA, 2010). Project team coordination, decision making and problem solving are drastically improved when teams are co-located, as any questions can be quickly resolved in real time and face-to-face contact (Jefferies, John Brewer, & Gajendran, 2014; Love, Mistry, et al., 2010).

<u>Performance measure:</u> continual examination and improvement. Learning is a daily process and is turned into action, tested, modified, and tested again over the duration of the project. The goal is to deliver the project better than originally planned (AIACC, 2014; Ashcraft, 2014; Young, et al., 2016).

Table 2-1: Key Features of Collaborative Contracting

KEY FEATURES	AIM
Agreement	A single multi-party contract. The agreements also incorporate behavioural 'value'
Mutual Responsibilities	Both client's responsibilities and individual's rights are transferred into the agreement
Risk and Reward Sharing	Compensation is based on project outcomes rather than individual contribution. Decisions are taken according to 'what's best for project' behaviour.
Open Book	Transparency is evidenced by the 'open-book' approach which provides accurate financial information to all project participants and gives them a clear view of the client needs and values.
No-fault No-blame culture	The 'no dispute' helps to avoid the traditional adversarial claim-based culture and encourages the team to jointly find new solutions
Join project control and decision making	Ideas are freely exchanged among all participants and unanimous decisions are taken to determine the best project solution to deliver the project.
Insurance	Insurance that covers the whole project not the single party to support the culture that all win or lose together
Client Focus	Client is part of the team and maintains close involvement with the design and delivery teams throughout the project's execution.
Team Selection	The team selection is normally on qualification-based selection by choosing the 'best for the project' proponent. Selection process is through structured interviews and workshops that help to review the team's performance and capability
Goal Definition & Team Alignment	Project goals are developed early and agreed upon by all participants.
Best for the project	Share a mutual single project objective to deliver the highest-value for the client. All parties need to work as an integrated project team and make decisions that are best for the project, rather than for their own interest.

Integration / Early Involvement of Key Participants	Early contribution of key members' knowledge and expertise. This is most powerful during the early stages of the project where informed decisions have the greatest effect.
Culture & Behaviour	A strong client commitment, team attitude and leadership skill to collaborate are vital to achieving optimum outcomes. Trust is fundamental to align interests of participants. Project teams must collaborate closely, deeply and continuously.
Intensified Design and Planning	Increased effort in planning results in increased efficiency and savings during construction execution.
Optimize the whole, not the parts	Share a mutual single project objective to deliver the highest-value for the client. All parties need to work as an integrated project team and make decisions that are best for the project, rather than for their own interest.
Co-location	Maximise the opportunity for collaboration, interaction and innovation. Project commitments are more likely to be met when one becomes closer to other.
Performance measure	Continual examination and improvement. The goal is to deliver the project better than originally planned

2.4 BIM IN THE CONSTRUCTION INDUSTRY

BIM implementation in the construction industry has been accelerating worldwide in recent years and it can be seen by a growing number of initiatives undertaken by Government agencies worldwide, industry bodies, academic institutions, non-profit organisations and standardisation bodies such ISO.

The recently published report by Zion Market Research (2017) reported that the global BIM market is predicted to reach approximately USD 10.36 billion by 2022 (Figure 2.6). According to the report, the improved visualisation, increased productivity and dramatic reduction in costs that follow from implementing BIM are the main factors that contribute to the predicted rapid growth.

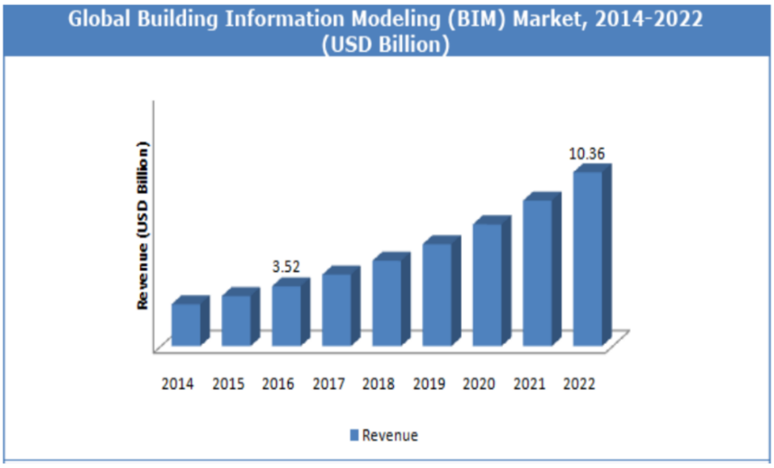


Figure 2.5: Global BIM Market, 2014-2022 (Zion Market Research, 2017)

Governments worldwide are increasingly recognising the efficiencies that can be added with this change and they are undertaking initiatives to accelerate the adoption of BIM (Farmer, 2016).

The United States is long recognised as a world leader in BIM adoption. Several levels of public sectors from national and state government organizations, to public universities, are contributing on BIM implementation. To date, 47 BIM documents among standards, protocols and guidelines are publicly available in the US construction industry (Cheng & Lu, 2015). The General Services Administration (GSA), the major public sector clients around the United States responsible for the construction and operation of all federal assets, is the pioneer in implementing BIM in the US on public sector projects.

In Europe, countries such as Scandinavia and the Netherlands had already started requiring the use of BIM on public building projects since 2007, while others have shown a particular enthusiasm following the 2014 European Public Procurement Directive (EUUPD) published by the European Parliament, the aim of which was to modernize public procurement rules by encouraging, specifying or mandating the use of BIM for public works by 2016.

The most notable example is the UK, where in 2016 the minimum target on Level 2 mandate came into effect for centrally-procured government projects and equal applicability to the private sector, both for building and infrastructure, as well as refurbishment and new buildings (UK Cabinet Office, 2011). The UK Government Construction Strategy, published in May 2011 (UK Cabinet Office, 2011), is considered by many to be the most ambitious and advanced centrally-driven BIM implementation program in the world.

In Spain, since March 2018, the use of BIM is mandatory in public sector projects and will be extended to infrastructure projects that cost in excess of €2 million by July 2019. In France, the continuing adoption of BIM began with the set goal of 2017 when BIM is anticipated to streamline all public sector projects. The German government's roadmap expected the implementation of BIM on all infrastructure projects by 2020 and going forward in building construction (McAuley, Hore, & West, 2017).

Emerging countries such as China, Japan, and India are fostering the BIM adoption across the Asia Pacific region. Singapore is the leading country on BIM adoption around Asia. In 2008, the Building and Construction Authority (BCA) led the implementation of the first BIM electronic submission on the world (e-submission) CORENET e-Plan Check system. Since 2010, CORONET have started accepting architectural and engineering BIM e-submissions.

At the standard level, organisations such as CEN (European Committee for Standardization) and ISO (the International Organization for Standardization) have set up programmes to develop and define standards for BIM (Building Information Modelling) across all European countries and Internationally. An important achievement has been accomplished by ISO with the publication at the end of 2018 of the ISO 19650-1:2018 *'Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1: Concepts and principles'* and ISO 19650-2:2018 *'Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 2: Delivery phase of the assets.'*

The ISO 19650 define the concept and processes to support the management and production of information during the life cycle of built assets (referred to as 'information management') when using BIM. Through the production and use of the project and asset information models, beneficial outcomes such as de-risk of the project and reduction of costs, for clients as well as the supply chain, can be achieved.

2.4.1 Definition of BIM

Building Information Modelling (BIM) is considered as emerging technology and a paradigm shift that is revolutionizing the AEC industry in the way in which the projects are conceived, planned, designed, built and managed (Succar, 2009). In the multi-dimensional model presented by Succar et al. (2009) BIM is described as a set of interacting processes, technologies and policies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle.

While the term BIM is relatively new, the concept dates back to the middle of the 1970's when Eastman (Eastman, 1974) presented a prototype system called 'Building Description System' as 'a computer system useful for storing and manipulating design information at a detail allowing design, construction, and operational analysis'. With the BDS Eastman first introduced the idea of parametric design, an object-oriented modelling approach and automatic checking.

Since then, the concept has evolved and so has its definition, to the point that not a single clear terminology exists. Indeed, BIM often assumes different meanings to different stakeholders. Some associate BIM with a software product, for others it is a process for designing and documenting information of a facility and others see it as a holistic approach to design, construction and maintenance of assets (Aranda-Mena, Crawford, Chevez, & Froese, 2009).

This research follows the definition proposed by BuildingSMART (2012) where BIM is described as an acronym that represents three separate but linked functions within the project delivery process:

• Building Information Model is a DIGITAL REPRESENTATION of the physical and functional characteristics of a facility,

• Building Information Modelling is a BUSINESS PROCESS for generating and leveraging building data to design, construct and operate the building during its lifecycle. BIM/DE

• Building Information Management is the ORGANISATION and CONTROL of the business process by utilising the information in the digital prototype to affect the sharing of information over the entire lifecycle of an asset (information management)

Originally, the term applied to building construction projects, but it now encompasses infrastructure through to operations and maintenance (Shou, Wang, Wang, & Chong, 2015).

2.4.2 Characteristics of BIM

BIM is a process for creating and managing information on a construction project across the project lifecycle. The key output of the process, the model, is a data-rich, objective-oriented, intelligent parametric digital representation of the facility that contains information supplied by all project participants following the project's progress (Eastman, Teicholz et al., 2011, NBIMS-US, 2007). Indeed, the core of the acronym BIM is the 'I' of Information which differentiates it from traditional CAD. For instance, in most CAD applications, a building element, like a wall, is created by connecting lines that define the geometric limitations of the wall.

By using BIM software, the wall is a parametric object, rich with information in addition to its geometry or physical shape, such as material specification, structural mechanical, acoustic and thermal properties, manufacturer information, cost, along with the location and relationship of the wall with the other components.

Different single-disciple models can be connected together, through a 'Federated Model', without depriving them of their identity or integrity by being so linked (ConsensusDOCS, 2016b; Grilo & Jardim-Goncalves, 2010; Halttula, et al., 2015). Thus, a change to one component in a single-discipline model does not change another component model in the Federated Model. Within the federated model, different views can be extracted and analysed by various users to better inform the decision-making process (Eastman, Teicholz et al., 2011, NBIMS-US, 2007). For instance, by linking the design model, structural model and mechanical, electrical and plumbing (MEP) model together, model checking and clash detection can be executed to detect design mistakes and conflicts between disciplines before construction starts (Eastman, et al., 2011). If properly adopted, BIM should increase the project efficiency by reducing duplicative and potentially inconsistent data entry (Ahn, Kwak, & Suk, 2015; Azhar, 2011; Eastman, et al., 2011).

BIM also serves as a framework for collaboration (Ashcraft, 2008). By centralizing all information in a single database, BIM creates a real-time collaboration among project participants, which strongly increases the level of communication among them. As a centralised model for all participants involved in the project, BIM develops and evolves as the project progresses. It is meant to be a living model that can be used during the planning, design, construction, and operation of an asset (Sebastian, 2011).

BIM is increasingly known to add value across a multitude of areas in a project. During design phases, BIM enables clients and architects to work together to better define and understand the project’s scope (Bryde, et al., 2013; Eastman, et al., 2011). Using BIM, the proposed design and engineering solutions can be measured against the client’s requirements and expected building performance (Sebastian, 2011). Architects can easily analyse the client’s requests and rapidly generate design alternatives or manipulate design models, evaluate building performance and quickly develop the estimated costs (Sacks, Dave, Koskela, & Owen, 2009).

Visualisations facilitate clients to better understand the project’s need and quickly analyse and explore the design alternatives, thus promoting efficiency and improved quality (Eastman, et al., 2011; Grilo & Jardim-Goncalves, 2010). (Sebastian, 2011). Furthermore, improved end-user buy-in can be achieved during the design as they understand what will be constructed (Love, Liu et al., 2015). Linking the model with a cost database allows one to perform cost analysis (Eastman, et al., 2011). Indeed, the model contains geometrical information of the asset and therefore quantitative information can be extracted; cost estimation based on the model quantity can be quickly generated (Grilo & Jardim-Goncalves, 2010). The functionalities of BIM to support the design process are several, including three-dimensional visualisation and detailing, clash detection, material schedule, planning, cost estimate, production and logistic information, and as-built documents (Sebastian, 2011).

Simulations help project stakeholders to make decisions toward the best value-add for the client (Halttula, et al., 2015). When the model is linked to schedule, timing simulations can be performed (Eastman, et al., 2011). During the coordination process, this allows simulation of constructability and construction sequences, all becoming a rich source for construction planning (Grilo & Jardim-Goncalves, 2010; Halttula, et al., 2015). Moreover, software such as Autodesk Navisworks®, and cloud based technologies, such as BIM 360™ Field, allows to record in real-time the progress on site –using a smart phone, PC or tablet - and synchronised the information back to the model (Ahn, et al., 2015). Potential problems can be detected and solutions can be easily actioned among the team, improving the overall construction process. Comments can be added, stored and updated into the model in a way that they are accessible for everyone, making the process faster and more efficient (Ahn, et al., 2015; Azhar, 2011; Halttula, et al., 2015). Thus, BIM enhances construction efficiency by improving information flow and communication between the construction site and the design office (Ahn, et al., 2015; Alwash, Love, & Olatunji, 2017; Azhar, 2011; Bryde, Broquetas, & Volm, 2013; Eastman, et al., 2011).

At construction handover, typically, asset owners are provided with 'as-built' documentation in a paper-based format that often does not actually reflect what has been installed (Love et al., 2016). Such documentation may contain errors and omissions, which can jeopardize the integrity of the asset (Love et al., 2016). If the BIM model is properly developed during both the design and construction stage, the information embedded into B could be helpful for a variety of facility management activities including: commissioning and closeout, quality control and assurance, energy management, maintenance and repair, and space management (Becerik-Gerber, Jazizadeh, Li, & Calis, 2011). The main characteristics of BIM have been listed in Table 2-2.

Table 2-2: Key Features of BIM

KEY FEATURES	AIM
BIM uses and goals	Define the purpose of using BIM within the project. What is expected to be achieved by using BIM
Information Management	Defining the flow of information: what information will be delivered, by who and when
Visualization	Visualization to support problem-solving and decision making
Simulation	The model can be used to analyse different options and simulate, for instance, cost, time, and energy consumption. It helps to reduce waste and facilitate decision-making and improve overall construction planning
Clash checking	The model can be used to find design mistakes and conflicts between disciplines, resulting in less waste
Single source of truth	Centralized database where information is upgraded, exchanged, shared and reused among all team members during the whole process

2.4.3 BIM adoption in Australia

In Australia, there has not been any BIM Government mandate. However, a number of individual initiatives have been undertaken in the last five years from both public bodies and private organizations.

In 2009 the Australian Cooperative Research Centre (CRC) for Construction Innovation published the *National Guidelines for Digital Modelling* and *National Guidelines for Digital Modelling: Case Studies* (CRC-CI, 2009). Both of the guidelines provide an overview of BIM and its implementation, with recommendations and guides regarding project definition and model creation.

In 2011 NATSPEC, a not-for-profit organization supported by the Government, released its *NATSPEC National BIM Guide* which defines BIM role and responsibilities, uses, modelling requirements, and final deliverables.

The guide is supported by several documents including: *NATSPEC BIM Brief Template*, *NATSPEC BIM Reference Schedule and NATSPEC BIM Object/Element Matrix*. The last one, in particular, is composed of a series of Excel worksheets that describe the properties of objects and elements by using Uniformat/OminClass classification and Level of Development (LOD) for any stage of the building lifecycle. In 2012, NATSPEC released as a supplementary document of the BIM Guide, the *Project BIM Management Plan Template* to define how to develop, monitor and control the BIM model.

On 15th March, 2016, The Standing Committee on Infrastructure, Transport and Cities published a report on the inquiry into the role of smart ICT in infrastructure, in which was set out a number of recommendations to be undertaken by the Australian Government, among which requires BIM LOD 500 in all major infrastructure projects exceeding $50M and to create a Smart Infrastructure Task Force, modelled on the UK BIM Task Group, to develop and implement a national strategy and accelerate the adoption of new technologies and innovations. However, the Australia Government has elected to favour a gradual approach to BIM implementation rather than mandate the use of it in funded infrastructure projects.

State Governments are intensifying their research and efforts towards BIM adoption. The Victoria State Government (2016) launched the *Construction Technology Strategy* with an aim to drive the industry towards the digital transition and support the innovation and production of construction technologies. In the light of this, one of the main objectives of the strategy is to increase the use of BIM across Victoria's construction industry by 'developing a plan with industry to provide for the greater uptake of BIM' (point 7) and 'build expert skills in BIM' (point 8).

Likewise, in March 2016, the Queensland Government released the *QLD State Infrastructure plan (SIP) (Queensland Government, 2016)*, which sets out the Queensland Government's infrastructure priorities. Among these, the program announces the progressive implementation of BIM into all major state infrastructure projects by 2023 (Part B action 15, Opportunity 10).

The QLD Department of Transport and Main Roads published in 2017 the 'Building Information Modelling (BIM) for Transport and Main Roads. A guide to enabling BIM on Road Infrastructure Projects' and is also undertaking several pilot projects.

In New South Wales, the NSW Health Infrastructure (HI) is the first government agency to mandate BIM for projects. By 2013, HI started to require BIM for work projects over $10M. The NSW HI follows the NATSPEC BIM Guide and BIM Management Plan. Recently, in 2018 in the infrastructure sector, Transport for NSW (TfNSW) launched the Digital Engineering Framework Program. The program will be delivered incrementally, through a number of key releases, commencing with the DE Framework Interim Approach.

2.5 BIM, PROCUREMENT AND CONTRACTS

It is often stated that BIM has the potential to affect the entire project life cycle from the design through engineering, construction, operation, maintenance and demolition, by allowing the creation and sharing of information along the project life-cycle. Within this cycle, the procurement model plays a fundamental role that has long been underestimated (Holzer, 2015). While BIM can be applied to any type of delivery method, depending on the selected method, difficulties can arise that limit the effectiveness of its use. Indeed, not all the procurement models and contracts allow for the level of integration and transparency required for BIM to perform fully (Larson & Golden, 2007).

The optimal cross-disciplinary and cross-phase collaboration that many attempt to realise with BIM is hindered by the contractual limitation of the role and responsibilities under the traditional procurement method (Sebastian, 2011). Although idealistically, BIM tools and processes may foster cooperation and collaboration among parties, allowing members with different expertise to provide their input, in reality, the most common contracts hardly encourage that level of collaboration (Circo, 2014). The situation where client, consultants and contractors signed individual and distinguished contracts has led to frequent disputes, labelling the industry as adversarial. Indeed, while isolated parties may gain some productivity benefits by working in disciplinary silos, the whole project would suffer from it (Loke, 2012).

In this scenario, it is often argued that the full potential of BIM is still unfulfilled (Love, Smith et al., 2017, Olatunji, 2014, Papadonikolaki and Wamelink, 2017, Sebastian, 2011b). Love, Smith et al. (2017) state that 'simply superimposing a 21st century innovation such as BIM to procurement practices where contracts do not wholly support collaborative working and have been essentially developed for the 20th century, will not leverage the benefits that can be delivered from its adoption.'

The challenge therefore is to leave behind the old conventional practices of bipartite approaches and change the way the projects are contracted, developed and managed. Instead of a fragmented and linear approach, where a project's stages are developed in sequence and decisions are taken separately, consideration of the whole asset life-cycle should be concurrently addressed at each project stage by a multidisciplinary team involving all the key stakeholders. This approach demands collecting and integrating all the information, such as detailed design, engineering and quantity specification, at the earliest stage of design when the costs of change is minimized (CURT, 2004; Kane, McAuley, Hore, & Fraser, 2015). Larson and Golden (2007) argued that the use of BIM becomes more integrated and efficient when contractors start modelling their work during the design stage, enabling the contractor's knowledge to inform the design and making the model as a primary tool for collaboration among all project 'stakeholders'. In their survey Kane, et al. (2015) found that BIM *on its own* is not the answer to achieving a more collaborative outcome, and that the collaborative contractual environment of integrated project delivery (IPD) would allow BIM to be used to optimise benefits.

In light of this, the following paragraphs briefly analyse the use of BIM under several procurement models in order to provide a picture of the challenges and opportunity of adopting BIM in different contexts

Construction-only (Design-Bid-Build)

The traditional delivery method is still the most applied form of contract for construction projects in Australia (Holzer, 2015). The traditional procurement approach is characterized by a clear separation of responsibilities and risks between consulting party and contracting party. The contractor is selected once the detailed design is completed, through competitive bidding based on the lowest price. Designing and constructing are considered two separate activities; the communication and reporting among the two parties is therefore not necessarily guaranteed. Consultants need to make an assumption of what information the contractors need within the model and as a consequence, the contractor is unlikely to receive the information needed from BIM (Holzer, 2015). This separation obstructs and limits the integration of life-cycle information in the model (Lu, Fung, Peng, Liang, & Rowlinson, 2015; Sebastian, 2011). Indeed, while members of a project team intend to use BIM for collaborative purposes, different firms also operate independently of one another.

When the contract is awarded, the model should be transferred from the architect to the contractor. At this stage, Sebastian (2011) points out two important considerations that parties need to be agreed on: 1) necessary measures to prevent or minimise the loss of data once the model passes between the two different BIM systems, 2) the intellectual property rights of the model and information are embedded in the model, including the division of liabilities if errors are found in the model.

However, in the majority of projects, the complete model developed by the consultants does not replace the traditional drawings, details and specifications as the main documentation for tender (Sebastian, 2011). Legal aspects related to the right to rely on the information contained in the model and interoperability issues among different software applications when the model is transmitting to the receiving party are the two main reasons behind this. As a result, the efficiency promised by BIM is wasted, as the receiving party needs to recreate its own model (Larson & Golden, 2007).

Design-Construct (Design-Build)

This type of procurement model is increasingly being demanded by clients for medium and large projects as it allows reduction of client risks by transferring them to a main contractor that is responsible for both design and construction phases (Holzer, 2015). The fact that a single entity takes responsibility for the two phases is considered more time and cost efficient than design–bid–build and therefore an excellent opportunity for successfully applying BIM (Eastman, et al., 2011; Holzer, 2016).

Moreover, the model can be set up already, having the BIM requirement for construction in mind (Holzer, 2015). On the other hand, after the tender, the client's representative is not actively involved anymore. Consequently, a total integration of the knowledge from all parties from both the demand side and the supply side is less obvious (Sebastian, 2011).

Public Private Partnerships (PPPs)

Public-private partnerships (PPPs) are contractual agreements between a public agency and a private sector entity. PPPs are predominantly used to procure large infrastructure projects where government and private sectors work together (Love, et al., 2015). At the heart of a PPP, is the 'partnership phase' where the facility is constructed, managed and operated over a fixed time period, which can range from 20 to 30 years, depending on the conditions imposed in the contract for concessionaire.

The level of collaboration that embraces the whole project life-cycle is expected to encourage those using BIM to direct their efforts towards minimising lifecycle cost and maximising sustainability on the project (Holzer, 2015). According to Love, et al. (2015) PPP offers an ideal environment for implementing BIM as the private sector will be responsible for maintaining and operating the asset.

Early Contractor involvement

Early Contractor involvement is a two-stage process where the contractor is invited by the client in the early design phase to oversee the costing of the design proposal and provide constructability knowledge. According to Mosey et al. (2016) this type of model is more suited to BIM than the single stage tendering, as the contractor enters into the project earlier than usual. According to Hallgren and Haggblad (2017) the potential synergy between BIM and ECI should be considered, as ECI may facilitate BIM and vice versa. In this regard, Mason and Brook (2015) pointed out that BIM facilitates ECI by exchanging information rapidly among parties, which is needed to create value in an ECI collaboration.

Alliancing/IPD

Alliancing or Integrated Project Delivery (IPD) is classified as a form of relationship contracting. The relationship agreement between the parties is based on good faith and trust support by risk and reward sharing mechanisms.

According to Holzer (2015), the non-adversarial nature of collaboration based on no-blame culture, represents the perfect open and transparent environment for intelligent sharing of digital project data with substantial knowledge-transfer across all stakeholders. Succar (2009) defined IPD as an ultimate goal of BIM implementation. Sebastian (2011) argued that collaborative contracting promotes and fosters an open and integrated work environment throughout the whole project, enabling BIM processes and data management to fully perform. Becerik-Gerber and Kent (2010) also stated that by aligning the team’s goals and incentivizing them to work together, IPD provided an atmosphere enabling a level of collaboration that increased efficiency and minimized errors.

Circo (2014) explored the synergy between BIM and IPD, analysing how collaborative contracting principles address four of the most important legal concerns that arise when BIM is used, respectively risk management, dispute avoidance, control of and access to the model, and protection of intellectual property. He found that five features of collaborative contracting could help to address the liability and risk management problems: 1) the multi-party contract, 2) gain/pain sharing mechanism of compensation, 3) collective management structure of the project, 4) comprehensive liability control, 5) claims management and dispute resolution processes. The second legal concern is addressed by the collaborative contracting’s approach of dispute avoidance, which is extremely compatible with the high collaborative and transparent environment that BIM requires and in which BIM is most effective.

The third issue regarding the control and use of the model is one of the main legal concerns for lawyers. Traditional contracting establishes a clear line of responsibility among stakeholders, and to address the legal challenges regarding model control and use, special BIM protocols have been developed and often used as an addendum to the main contract. Although using protocols can help to accommodate some legal concerns, what still persists is the fact that none of the traditional procurement models provide ideal structures to enable the integrated teamwork best suited to achieving the full potential of BIM (Circo, 2014). In this regard, Circo analysed that the aspects of risk management, dispute avoidance and claim management also create advantage on managing and using the model. Another two legal concerns, such as the right to rely on the model and whether or not the model should be a contract document, are also potentially addressed through the collaborative contracting structure. Indeed, he also stated that this type of procurement provides a framework for collective responsibilities of possible error in any of the data embedded in the model. Therefore, projects' members should be more willing to consider the model as a contract document and agree to rely on the accuracy of the model. Also, according to Love, Davis, Chevis, and Edwards (2010) and Alwash, et al. (2017) since the sharing risk and reward is the main objective of collaborative contracting, all the parties involved in a BIM-based project are still required to perform their work collaboratively in alignment with such objectives.

Finally, the IPD structure may present a unique option to manage the intellectual property rights. For instance, in the case of having a limited liability company, the company can own the model and the members of the management team collectively can decide on the nature and terms of all licences.

Several authors point out the synergy and potential benefits achievable when BIM is coupled with collaborative contracting, often related to BIM being an enabling tool for IPD/Alliancing. There is a common belief that the collaborative contracting environment can facilitate the adoption of BIM, however, it seems that there are constraints and difficulties in applying IPD/Alliance. For instance, Rowlinson (2017) found that IPD is usually used by large property developers that already have experience with IPD processes within their organisation. In Australia, the use of collaborative contracting such as Alliancing is restricted to large and complex projects. In other countries it may not be suitable, due to different tendering regulations (Sebastian, 2011). Collaborative contracting requires a changed mindset. As mentioned above, this type of framework provides a perfect environment for BIM. At the same time, high collaborative technology and digital processes may encourage a radical shift toward collaborative contracting practices in the construction industry.

According to Circo (2014): *"To the extent that BIM provides a powerful incentive for project participants to collaborate for joint success, the industry's nascent interest in truly collaborative contractual structures may lead to more genuinely relational contract behaviour. But this will be possible only if BIM's* *collaborative philosophy can overcome the industry's pragmatic commitment to contract perspectives and practices that give primacy to each firm's competing profit motives."*

2.5.1 Clients adopting BIM

While a benchmark of the value for clients in adopting BIM is not yet available in the literature, interesting results have been found by Saxon (2016), who combined the results coming from two surveys conducted by McGraw Hill Construction (2014) and (2015). The results outline that:

- 93% affirm that BIM improved quality and functionality of design
- 92% said that BIM analytics and simulation capabilities produced a better understanding-reasoned design
- 90% sustain that BIM reduces design errors and omissions substantially, reducing risk
- 87% saw increased site labour productivity and use of off-site fabrication
- 83% saw few unplanned changes or rework
- 78% found that BIM increased their ability to control project scope through the design stages
- 78% saw improved achievement of project milestones
- 73% said that BIM increased their and their stakeholder's engagement with, and understanding of, the proposed design solution
- 66% said that BIM improved accuracy of cost estimating and ability to control costs
- 65% were able to compress the schedule, accelerating completion by 5-10%
- 45% saw cost reduction of 5-10%

Several authors argue that clients play a vital role in promoting and accelerating BIM adoption (Al Ahbabi & Alshawi, 2015; Lindblad, 2018). The survey conducted by McGrawHill Construction (2014) indicated that by actively demanding BIM in their projects, clients push the process of implementing and proliferating the use of BIM in the construction industry. According to Porwal and Hewage (2013) the most effective way for a technology to be accepted is when clients mandate it in the contract, as it is not negotiable. When clients require BIM, *whether* they use BIM or not is no longer an issue, the attention shifts to *how* to use BIM in the project to achieve the client's goals (Linderoth, 2010). Therefore, clients, as a change agent, should be engaged and demanding that collaborative teams use appropriate technology to openly share information (CURT, 2004).

Though it is also important to consider the way in which BIM is required by the client. Mosey, et al. (2016) stated that just mentioning BIM in the contract is not the most effective way of ensuring BIM and data management. Hurtado and O Connor (2008) believe that clients, through the contract, should clearly define the purpose for which the model and the information embedded into the model will be used to be able to better assess project risk, and contractual rights and responsibilities. In this regard, it appears that many clients struggle to clearly formulate their objective and expectation of BIM into the procurement contracts (Sebastian, 2010; Vass & Gustavsson, 2017) providing contract agreements that poorly define the BIM scope (Papadonikolaki & Wamelink, 2017).

2.5.2 Key legal Issue of BIM

The legal and contractual aspects related to the use of BIM in the project have been recognised as the main barriers against effective BIM adoption in the industry (Alwash, et al., 2017; Gu & London, 2010; Kuiper & Holzer, 2013). Indeed, BIM implementation raises many contractual concerns that need to be properly understood among all parties involved, such as design liability, risk allocation, model ownership and intellectual property right (Ashcraft, 2008; Chao-Duivis, 2011; Eadie, McLernon, & Patton, 2015). The purpose of this section is to provide a short review of the key legal issues related to the adoption and implementation of BIM.

Responsibility and Risk

The increasing number of persons involved in modifying and using a single model arise issue around responsibility and design liability, in particular, related to the possibility that the traditional legal allocation of risk might be shifting (Arensman & Ozbek, 2012; Hamdi & Leite, 2013).

With several parties working closely together in a collaborative environment and providing input to the same model, the primary fear for architects is to assume responsibility for means and methods, while for the contactors, it is assuming design responsibilities for design services (Larson & Golden, 2007).

According to Chao-Duivis (2011) however, working in BIM creates no new or different law of liability. This is also supported by Sebastian (2010) who states that working with BIM under traditional contracting does not change the liability position since the liability of each party is limited within the scope of its contract with the client.

This can be true when BIM is adopted under traditional types of procurement, where the legal system is based on clear boundaries and definite responsibilities. Those definite roles and responsibilities may not be inherent when BIM is used in projects delivered under collaborative procurement methods. The importance of this is emphasized by Jensen (2018) who states that the introduction of collaborative delivery systems makes the designation of design control increasingly important.

However, the spectrum of collaborative procurement is wide. While alliancing and IPD share liabilities, other models of procurement, such as early contractor involvement, still maintain a clear separation between liability and responsibilities of the team.

In this regard, Henderson and Croft (2013) observed that implying that there will be an 'integrated project team' goes beyond merely increasing the level of collaboration and could create an informal alliancing arrangement, which may conflict with the contractual arrangements and create a number of risks that would need to be addressed in the appointment, such as the potential for 'cross liabilities' to arise.

According to Circo (2014), IPD provides five principal solutions to address the liability issue, including (1) the multi-party contract, (2) the sharing risk and reward, (3) collective management of the project, (4) comprehensive liability of controls and (5) dispute avoidance and claims management.

Rights to rely on the model and data

The integrated use of BIM includes the involvement and contributions by all key project participants in developing the federated model. Hence, the various disciplines' models are continuously exchanged among the different parties. An example reported by Larson and Golden (2007): *'The architectural model may be transferred to mechanical, electrical, and structural designers, who in turn may provide their electronic models to the architect. Along with the architectural model, the mechanical,* *electrical, and structural models (and possibly others) may be transferred to contractors, subcontractors, and suppliers for the purpose of allowing the recipients to develop derivative models to further develop the design (in the case of engineers and some contractors and suppliers), or to develop the means-and-methods by which to construct the project.'*

Therefore, the right to rely on the model and information embedded in it is one of the main concerns in a BIM-based project. The firm receiving the model desires to rely on the model in order to perform their work and therefore, they expect the model will be free of errors and omission. On the other hand, the firm transmitting the model does not want to be responsible for the work created from its model and therefore wants to limit their liability (Arensman & Ozbek, 2012). The designers in particular are concerned by the improper use, re-use or alterations of the designs as well as by the potential alterations during the file transmission (Larson & Golden, 2007)

As a result, models are often shared with disclaimers limiting the receiving part to rely on the completeness and accuracy of the model (Larson & Golden, 2007). Thus, without a right of reliance, the potential efficiency enabled by BIM and information management is limited as the receiving party has to recreate its own model, probably from 2D drawings, as it cannot rely on the model that was given to them (Arensman & Ozbek, 2012; Larson & Golden, 2007). By recreating the work there is no value adding. On the contrary, further error and discrepancy among data can be created (Ashcroft & Hurtado, 2009). Preparing models that other parties may rely upon requires additional effort and generates additional risks. Indeed, BIM can hardly achieve its potential without modifying the commercial and legal structures to rebalance compensation, risk, and reward (Ashcraft, 2008).

Ownership and Intellectual Property Rights

The collaborative nature of BIM requires cross-firm collaboration to develop the model. This can potentially create legal difficulties as the BIM model comprises information from different parties and each wish to retain the intellectual property rights to the model that they contributed to (Arensman & Ozbek, 2012; Kuiper & Holzer, 2013; Larson & Golden, 2007; Manderson, Jefferies, & Brewer, 2015)

Some argue that the ownership and intellectual property right should rest with the individual who creates the information, as prescribed by the law, not the party that pays for its creation. Therefore, the architect, as the creator of the model, should own the intellectual rights to their model (Arensman & Ozbek, 2012; Hurtado, 2016; Thomas, 2013).

On the other hand, others argue the ownership of the model itself and of the data incorporated into the model, and thus, the native file format of the model, should lie with the client once the project is completed (Circo, 2014; Guerin, 2016; Winfield, 2015). This is reinforced by the fact that clients could take advantage of using the BIM model strategically for the lifecycle management of the asset (Eastman, et al., 2011; Hurtado & O Connor, 2008).

However, architects are often reluctant to release the model on the perceived risk that confidential information and trade secrets embedded into the model could become easily available to someone else benefiting from them (Larson & Golden, 2007; Manderson, et al., 2015; Porwal & Hewage, 2013). For instance, the models owned by the client could be repurposed for other projects or in ways not licensed by the owner of the intellectual property, exposing to anyone the architect's ideas (Arensman & Ozbek, 2012; Jensen, 2018)

For most of a project, the ownership of the model is expected to be retained by the owner of the asset, however, the ownership of the data contained in the model itself can be considered a separate issue (Barnes & Davies, 2015). For instance, a licence could be granted to the client with restrictions related to the term of the project. This is aligned with Jensen's (2018) finding, which states that the actual model itself can belong to the client for a limited use, regardless of the entities that have contributed to the development of the model.

The contract should clearly document the ownership and the intellectual property rights of the model and embedded data in the model (Chao-Duivis, 2011; Larson & Golden, 2007). Moreover, clarity should be provided within the agreement around roles and responsibilities about who enters what data and when, and who is then responsible for the maintenance of the data and how data are to be protected and archived (Thomas, 2013).

2.5.3 BIM Protocol/Addendum

As discussed above, important contractual issues related to project responsibilities and risks, copyright and intellectual property arise when BIM is used

(Ashcraft, 2008, Lowe and Muncey, 2009, Porwal and Hewage, 2013). Winfield (2016) argued that existing forms of contracts used by the industry do not fit the purposes in a BIM-based project. In the NBS (2015) Nation Construction Law survey, only 14% of the respondents indicated that BIM was fully integrated in the contract and 33% reported that BIM was referred to in some way in the contract.

In recent years, in order to address some of the legal challenges related to BIM and data sharing, BIM protocols and addendum have been developed. In the United States of America, two organisations, ConsensusDOCS and the American Institute of Architects (AIA), started publishing in 2008 separate BIM protocols to provide a contractual framework for the use of BIM on a project (Abdirad, 2015, Lowe and Muncey, 2009). In the United Kingdom, the Construction Industry Council (CIC) published, in February 2013, and updated in 2018, the ‘Building Information Modelling Protocol: Standard protocol for use in projects using Building Information Models’ to support Level 2 BIM in line with the UK Government Construction strategy.

All the three BIM documents take into account and address issues related to information management, copyright and model ownership, role and responsibility and BIM standards. The following sections provide an overview of the above BIM protocols used to contractually address BIM-based projects.

AIA E203:2013 - Building Information Modeling and Digital Data Exhibit

The ‘AIA Document E202-2008 Building Information Modeling Protocol Exhibit’ (AIA, 2008d) created by AIA in 2008 is one of the first BIM Addendum templates released. In 2013, the document was revised and updated with the purpose of establishing the parties’ expectations for the use of digital data and BIM on the project and provide a process for developing the protocols and procedures that will govern the development, use, transmission and exchange of digital data and BIM.

The new configuration consists of three separately documents designed to be used as a suite: ‘AIA Document E203-2013 Building Information Modeling and Digital Data Exhibit’ (AIA, 2013a), ‘AIA Document G201-2013 Project Digital Data Protocol Form’(AIA, 2013b) and the ‘AIA Document G202-2013 Project Building Information Modeling Protocol Form’ (AIA, 2013c). Moreover, in order to help the user know how to use all these documents, AIA has also released the ‘Guide, Instructions and Commentary to the 2013 AIA Digital Practice Documents' (AIA, 2013d).

The E203 is a contract exhibit which takes legal effect and it must be incorporated into both the Owner-Architect and Owner-Contractor Agreements and those parties must then incorporate AIA-E203 into their other project contracts with relevant lower tier project participants (Baker, 2017). Through this process, the various project participants begin the project with a common understanding of how digital data and BIM will, generally, be utilized on the project (AIA, 2013b).

The AIA's Digital Practice Documents play a prominent role in its newly-released 2017 Contract Documents. Use of the Digital Practice Documents is expressly required by the AIA's new Owner-Architect Agreements and Owner- Contractor Agreements (Baker, 2017). For example, the B101-2017 Owner-Architect Agreement states:

'1.3 *The parties shall agree upon protocols governing the transmission and use of Instruments of Service or any other information or documentation in digital form. The parties will use AIA Document E203–2013, Building Information Modeling and Digital Data Exhibit, to establish the protocols for the development, use, transmission, and exchange of digital data.'*

While the AIA-E203 is intended to be used as a contract document, it only sets forth the parties' agreement to establish a Protocol. The actual details of such Protocols are to be included in AIA-G201 and AIA-G202 (Kapp, 2013).

The separation of the exhibit and protocols allows the project participants to first discuss and document their general expectations regarding the use of digital data and BIM on the project and subsequently, at a time that makes the most sense for the project, to negotiate and agree upon the protocols (e.g., after the key design and construction contracts are negotiated, and after all the relevant Project Participants are on-board) (AIA, 2013b).

The AIA-E203 contract exhibit and AIA-G201 protocol form are always used together. If BIM will be used for a project, the AIA-E203 also provides for the establishment of Protocols necessary to implement the use of BIM within the project.

The AIA-G201 and AIA-G202 are not standalone agreements or contract exhibits, thus, they take legal effect through E203 – so E203 must be incorporated into the contracts of any project participant who may use digital data (Baker, 2017). A party who fails to incorporate E203 into its downstream contracts may become contractually responsible for others' misuse of digital data (Baker, 2017).

The E203-2013 is a legal document and once incorporated into the contract normally will not be revised. Conversely, AIA-G012 and AIA-G02 are not contract documents and are frequently updated – with the agreement of relevant parties – as the project progresses and circumstances on the project change, without the need to modify each of the project participants' contracts (Baker, 2017; Kapp, 2013).

For example, a late-project G201 revision may address mechanical coordination – a subject perhaps addressed only lightly in the original G201. A late-project G202 revision may, for example, change a Model Element author from the mechanical engineer to the mechanical subcontractor at LOD 400. Keeping a record of each party receiving and approving any revised G201 or G202 protocols prevents a party from claiming it did not agree to comply with the latest revised protocols.

AIA G201:2013 - Project Digital Data Protocol Form

The AIA-G201 is normally completed in the early phases of the project – after the owner, architect, and contractor determine how they plan to use digital data. The G201 requires the parties to list the project participants (those parties who have incorporated the E203 into their project contracts) and their intent to utilize a centralized electronic document management system on the project, including requirements for the last, such as (i) digital data storage requirement and (ii) digital data archiving requirements. The Digital Data Protocol Table identifies the Digital Data to be used, the authorized formats, transmission methods and authorized uses of digital data, including: (i) modify as required (ii) incorporate additional Digital Data (iii) store and view only and (iv) reproduce and distribute.

AIA G202:2013 - Project Building Information Modeling Protocol Form

Similar to the G201, the G202 sets forth all project participants and their responsibilities for implementing the BIM Protocols. It establishes the requirements for model content at five Levels of Development (LOD100-200-300-400-500) and the authorized uses of the model content at each LOD. The LOD is described as 'the minimum dimensional, spatial, quantitative, qualitative, and other data included in a model element to support the authorized uses associated with such LOD'. In other words, LODs identify, at various stages in the design and construction process, the degree of content requirements - both graphical and non-graphical information - and associated authorized uses for each model element at five progressively detailed level of completeness. Through the Model Element Table completed for each project, G202 assigns authorship of each model element by project milestone and defines the extent to which model users may rely on model content by indicating the LOD required for each model element. Any conflict found in the model needs to be notified to the MEA, who is responsible for managing and coordinating the development of a specific element, who will promptly provide to mitigate and resolve the conflict. It also asks for technical requirements relating to the use of BIM, including specific software and hardware.

C106–2013, Digital Data Licensing Agreement

AIA Document C106™–2013 serves as a licensing agreement between two parties who otherwise have no existing licensing agreement for the use and transmission of digital data, including instruments of service. AIA Document C106–2013 defines digital data as information, communications, drawings, or designs created or stored for a specific project in digital form. C106 allows one party to: (1) grant another party a limited non-exclusive license to use digital data on a specific project, (2) set forth procedures for transmitting the digital data, and (3) place restrictions on the license granted. In addition, C106 allows the party transmitting digital data to collect a licensing fee for the recipient's use of the digital data.

ConsensusDOCS 301:2015 – Building Information Modeling Addendum

The consensusDOCS 301 BIM Addendum published in 2008 was the first-industry BIM standard contract document to be developed (Lowe & Muncey, 2009). In 2015, ConsensusDOCS released an update of the Addendum (ConsensusDOCS, 2016), which reflects more the current BIM practices. The BIM addendum is an extremely flexible document designed to be attached or incorporated into any governing contracts, and it does not change any contractual responsibility among the parties (Lowe & Muncey, 2009). The 301 BIM addendum is intended for use on projects on which the project owner and other major participants commit in the very early stage of the project to utilise BIM as the primary means of communicating information for the design, procurement, and construction processes of a project. The BIM Addendum is intended to be used with traditional project delivery methods with negotiated guaranteed maximum price (GMP). The Addendum is articulated in six sections: general principles, definitions, BIM manager, BIM execution plan, risk allocation and model intellectual property rights.

The new version includes updating liability, insurance and intellectual property terms; adding provision for turnover, operations and maintenance, and analyses of sustainability. It also incorporates the Level of Development (LOD) as defined by BIM Forum's Levels of Development Specification (LOD 100-200-300-350-400) (BIMForum, 2016). Moreover, the new Addendum introduces the figure of the BIM Manager, referred to before as Information Manager. The BIM manger is a central figure within the Addendum, as the single party responsible for the use, implementation and creation of BIM for the project design and/or construction, and for providing a thorough list of the BIM Manager's functions and responsibilities, including scheduling and managing the meetings for development of a BIM execution plan (ConsensusDOCS, 2016).

UK CIC BIM Protocol

The CIC BIM Protocol is the only standard contractual protocol published in the UK for use in projects using Building Information Models. The original protocol was published in 2013 to support the UK government's BIM Strategy, including the mandate to use BIM Level 2 on centrally procured government construction projects from 2016. The Protocols was developed with the aims of making BIM a contractual requirement, minimalizing amendments to existing contracts and building consistency across project teams. The protocol is intended to be incorporated into and appended to contracts and puts in place specific additional obligations and liabilities on the use of the BIM.

Since the original protocol was published, new standards have been released and the industry has moved on to making BIM a standard practice and business as usual. To reflect the current industry practices and meet industry demand, in April 2018 the CIC published the second edition of the BIM Protocol. The Second Edition of the Protocol is closely aligned with PAS 1192-2. The protocol now refers to 'information' rather than just 'models' reflecting more consistency with the terms of PAS 1192-2. It is also a more flexible document, which can be used alongside a range of different contractual arrangements. The Protocol now includes additional provisions in relation to security, an increasingly important issue, which reflects PAS 1192-2.

2.6 LEAN MANAGEMENT

In the 1970s, a research team led by James Womack at MIT's International Motor Vehicle Program, began to define and introduce the new paradigm of Lean Production System (LPS) based on the successful sample model of the Toyota Production System (TPS). The term 'lean production' was first coined by John Krafcik (1988), a member of the research team, to describe the new paradigm that was challenging the American System of mass production by using less of everything. With the publication of the best-selling book 'The Machine That Changed the World' (1990) and 'Lean Thinking' (1996) the term 'Lean' became known worldwide as a new method of thinking, being and doing.

In recent years, the term 'lean' has become a buzzword within the construction industry. However, due to the fact that no single clear definition of 'Lean' exists, it is often subject to different interpretations (Modig & Åhlström, 2012). It is a generally accepted that the central focus of Lean lies in maximizing customer value by minimizing waste and striving for continuous improvement. Liker (2004) pointed out the importance of cultivating strong leadership and building a lean culture of people, empowering them, and maintaining a learning organization. Modig & Åhlström (2012) define Lean as an operational strategy to continuously improve flow efficiency. Depending on the context, different means can drive a Lean strategy, from an abstract level of value and principles being implemented to a more concrete tools-based or method-focused approach (Modig and Åhlström, 2012).

In construction, Lean philosophy is considered as a new paradigm of construction project management (Howell and Ballard, 1998). It is an ongoing process to continuously reduce waste from a production system in order to generate and deliver the maximum amount of value (Koskela, Howell et al., 2002, Reed, 2008). Several Lean tools and methods from Lean manufacturing, including PDCA cycle and A3 problem solving, have been implemented by construction companies worldwide at their operational level (Barbosa, Andrade et al., 2013, Gao and Low, 2014, O. AlSehaimi, Tzortzopoulos Fazenda et al., 2014, Parry and Turner, 2006, Tezel and Aziz, 2017, Tezel, Koskela et al., 2010). To guide the Lean implementation on a project-based production system, Ballard (2000a) developed the Lean Project Delivery System (LPDS), a conceptual framework for managing construction projects. In this regard, Sutter Health took the first big step to develop an approach to Lean integrated project delivery, creating a relational contract known as the Integrated Form of Agreement (IFOA) (Lichtig, 2005). The main features of Lean have been listed in Table 2-3.

Table 2-3: Key Features of Lean

KEY FEATURES	AIM
Optimise the whole not the parts	Lean focuses on what is called 'the system', which is the way that the team operates as a whole. In Lean construction, the concept of optimising the whole not the parts is an essential part of a collaborative contracting model where decisions are taken for the best of the project.
Client value	Clearly understanding value for the client and client' needs.
Value Mapping/ Waste elimination	Improves the process not just a single task. Helps to understand the current state of a process to identify and remove waste
Flow	Developing project information flow.
Pull	Performing only the work needed to accomplish the goal. Planning step by step backwards, to determine what each step in the process requires from the one before it.
PDCA Continuous Improvement	It is a never-ending process. Involves all project stakeholders to actively participate in making improvements. It seeks to standardize processes and eliminate or reduce waste.
Big Room	Space where all stakeholders come together and work. This allows open communication and dialogue. Results in more efficient and real-time work, less revision and rework.
Collaborative planning/LPS	A collaborative, commitment-based planning approach that integrates should-can-will-did planning and measure the reliability of the plan.
Target Value Design	Design based on a detailed estimate, rather than estimate based on a detailed design.
Choosing by Advantage	Collaborative and transparent type of multiple-criteria decision-making used to choose the best option among two or more alternatives that are not of equal cost.
A3 Learning and Decision making	A technique that uses the size of A3 sheets of paper to evaluate problems, make important decisions and make improvements in a visual and simple way.

The interest in Lean construction and Lean project delivery is also reflected by the growing number of clients and public agencies that are implementing a Lean deployment strategy for delivery of capital projects (Ballard & Kim, 2007; Haarr &

Drevland, 2016; NASFA, 2010), among them: Highways England (Highways England, 2015), Massachusetts Port Authority (Massport, 2015), Sutter Health, Universal Health Services (UHS, 2013) and University of California San Francisco (Bade & Haas, 2015)

The following paragraph provides a brief overview of Lean, its origins and philosophy, to help the reader to better understand the Lean management approach and why particular tools and methods are used.

2.6.1 Brief history of Lean

Kiichiro Toyota founded Toyota Motor Corporation in 1937 with the idea of producing cars for the local Japanese market. After the Second War World, there was the need to rebuild the Japanese industry and some representatives of Toyota travelled abroad included to the United States, seeking ideas for how to set up successful car production. In the US, they looked at the mass production approach developed by Henry Ford and they discovered that mass production was producing large proportions of stock and high inventory, yet a low variety of car. Defects were carried along the process and as a consequence, many products needed to be repaired at the end of the production line.

Faced with little capital, limited marked and lack of resources, they had to invent a new way of thinking about efficiency. An approach that produced small amounts of a wide variety of products, with the least waste of money, materials, space, time, and capacity. The answer was to focus on flow efficiency.

Between 1948 and 1975, Taiichi Ohno, developed what is well known today as The Toyota Production System (TPS). Toyota's goal was to produce the best quality of cars, at the lowest cost and with the shortest lead time through the elimination of waste. In other words, to give customers what they want, and deliver it instantly, with no waste.

Ohno (1978) describes the Lean production as:

"All we are doing is looking at the time line from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that time by removing the non-value-added waste."

To produce only what has been ordered, Toyota learned the importance of really knowing their customer's needs.

The TPS is based on two main pillars: Just-in-time (JIT) production and Jidoka (autonomous automation). JIT is about creating flow in production by eliminating all inventory and only producing what the customer wants. It describes how material should be processed and moved in order to arrive 'just-in-time' for the next operation. The idea of automation is to 'build quality' in the process, in which all operatives are allowed to stop the entire production line, whenever there is a problem or a defective product is detected, making it immediately possible to identify, analyse and eliminate problems that arise. The principle of Jidoka can be broken down into a few simple steps: (1) Discover an abnormality, (2) Stop the machine, (3) Fix the immediate problem, (4) Investigate and correct root cause. This principle is not just confined to use in manufacturing through automation; Jidoka is visible in almost every aspect of lean manufacturing.

Through the use of JIT and Jidoka important goals of TPS have been reached, such as zero waste and better manufacturing efficiency. In 2008 Toyota became the world's largest automotive maker and achieved the fastest product development process in the world. Toyota's continued success created an enormous demand for greater knowledge about Lean thinking all around the world.

2.6.2 Lean Values and Principles

Lean is often describe as a set of tools and methods to improve efficiency, as exhibited in Toyota's values and principles. Modig and Åhlström (2012) described Lean as a hierarchical pyramid composed of: Value, Principles, Methods and Tools (Figure 2.7):

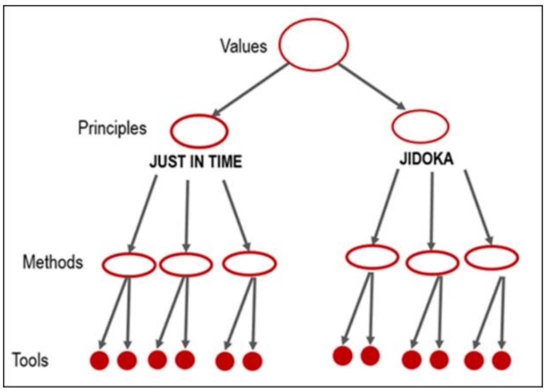


Figure 2.6: Lean philosophy adopted from (Modig & Åhlström, 2012)

Values: the main value of Lean focuses on how to satisfy customer's needs. Once the value for the customers is identified, employees begin working together to deliver that value as efficiently as possible. The culture generated based on the value empowers workers to solve problems and come out with innovative ideas, as well as to feel safe to ask for guidance - i.e. not afraid to ask questions and to seek help - in order to continually improve the process.

Principles: identify 'how' and 'what' should be prioritized in the business. For example, applying JIT to create the flow and automation to create a visible and clear picture so that anything that happens to, hinder or disturb the production flow can be identified immediately.

Methods: help to ensure that the principles are achieved. For instance, through standardisation, the process of carrying out certain tasks is standardised across different individuals and function groups, and ensures everyone has received the same set of instructions on how a particular task should be carried out. Through visualisation, it helps to create and allow individuals to see the overall picture.

Tools: are the means to realise method. Example of tools are: A3 problem-solving and whiteboard.

In 2001, Toyota Motor Corporation adopted *'The Toyota Way 2001'*, as an expression of values and principles of the Toyota culture (Liker, 2004). The Toyota's values are supported by two main pillars:

(1) Continuous Improvement, and

(2) Respect for People.

The two pillars encompass several principles that form the Lean culture:

(i) Challenge,

(ii) Kaizen,

(iii) Genchi Genbutsu (go and see),

(iv) Respect

(v) Teamwork.

The Toyota' values and principles (Figure 2.8) describe the philosophy behind lean which focuses on empowering people to think, learn and grow together in order to continuously improve the process. Tools are the means provided to achieve a goal.

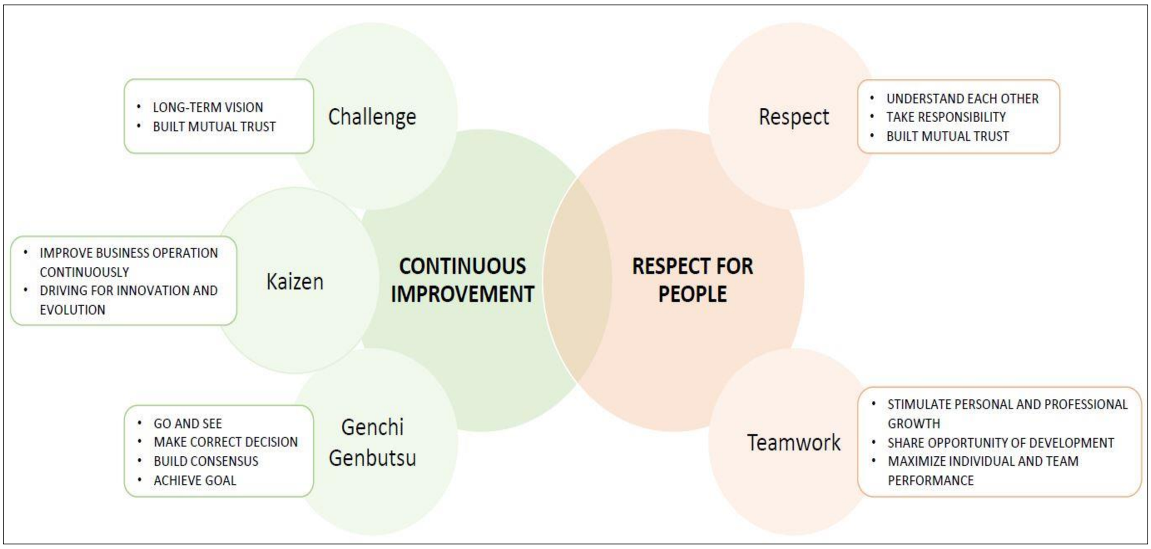


Figure 2.7: Toyota core values and principles (Liker,2004)

2.6.3 Five Steps to Lean

As formulated by Womack and Jones (1996), the Lean manufacturing approach of TPS can be applied to any kind of organisation by following five principles in a continuous loop (Figure 2.9):

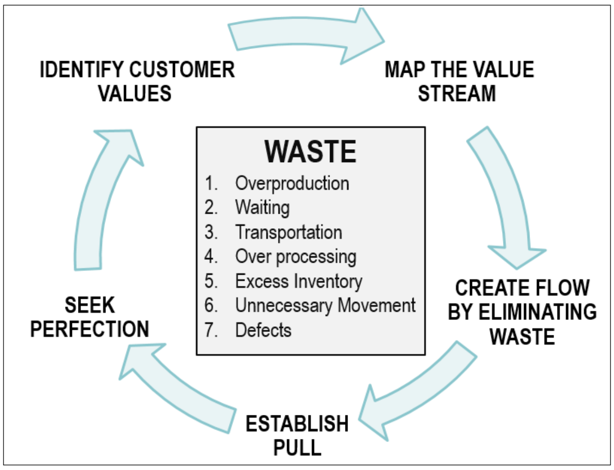


Figure 2.8: The Five Lean Principles and the Seven Wastes of Lean (Womack, Jones 1996)

1) Identify value from the client perspective:

The first step consists of clearly understanding the client's requirements and objectives, making sure that all the specifications are well illustrated. Indeed, the client's value is delivered when client needs are met. Therefore, the primary focus is understanding the 'why" and then 'what to do' and 'how to do'. To do so, it is important to bring together all the stakeholders to provide advice and define expectations in order to deliver exactly what the client wants.

2) Understand all steps and map the value streams:

Once the value from the customer's point of view is clear and understood by all teams, the process for delivering the value is mapped. Tasks are broken down to the lowest level to determine the value of each small detail. This helps to individuate non-value adding activities and removes them from the process. For each activity, the necessary labour, information, equipment, and materials are defined and any steps or resources that do not add value are removed.

3) Create value flow process:

Establish an efficient flow related to movement of materials and humans when and where they are needed. The all idea of lean is to create a continuous and reliable workflow. Clear communication between all parties is pivotal to achieving an uninterrupted flow.

4) Achieve pull by making and delivering only what the client wants:

Materials are only made available at the time of the need and in the quantity needed. Creating reliable workflows depends on work being released based on downstream demand. Lean construction recognizes that this is best done by those performing the work, often the subcontractors. Participants need to communicate and collaborate closely with each other along the process, to determine the schedule of tasks.

5) Strive for perfection:

Seeking perfection through continuous improvement until every process is value added is the core of the Lean philosophy. During the project is necessary to never stop searching for opportunities to improvement. During the project is necessary to never stop searching for opportunities for improvement, and once they are acted upon, applied them to future projects.

2.6.4 Waste

Value is considered the fundamental starting point for Lean thinking and can only be defined by the customer (Womack & Jones, 1996). Value is always defined by asking ‘What does the customer want from this process?’ A customer, however, could be the internal customer, e.g. at the next step in the process, as well as the external customer (Liker, 2004).

Reducing time and maximising the value by eliminating waste are the fundamentals of the Lean management approach. Ohno (1988) recognised two types of activities in each process: (1) Value Adding activities and (2) Non-Value Adding activities. Non-Value Adding activities are essentially waste. Waste is any activity that requires resources to be completed but creates no value from the client’s perspective and thus, needs to be eliminated. When wastes start to compile one upon the other, the process starts to become inefficient. In order to detect and eliminate all waste, the process needs to be carefully examined to identify activities that add value and activity that do not add value and consequently eliminate those that do not add value.

Ohno (1988) identified seven main types of non-value-adding waste, where the first five refer to the flow of materials and the last two refer to human action:

1. Overproduction. Production of items that are not required or are made earlier than necessary, ‘making too much, too early or “just-in-case”'. This often generates waste of materials, people and equipment, and incurs extra cost due to excess of inventory.

2. Waiting. Refers to the period of inactivity that occurs because preceding activities were not delivered on time or were not completed. For instance, waiting for the next processing step, tool, supply, part, etc., or just planning to have no work due to materials out of stock, lot processing delays, equipment downtime, and capacity bottlenecks.

3. Transportation. Unnecessary movement of materials or products that do not support immediate production. For instance, delivering materials to a secondary location (stock or storage) rather than bringing them directly to the location at which they will be used. Types of waste might be waste of man hours, waste of energy, waste

of space on site, and the possibility of material waste during transportation. Waste reduction starts with monitoring the flow steps of products and materials through a site or paper through an office (in particular, the number of non-value-adding steps)

4. Over-Processing. Taking unnecessary steps in operation such as re-processing. Examples of waste due to inappropriate processing include excessive material, re-work, uncoordinated shop drawing, redundant or unnecessary information. As such, more waste is generated when providing higher-quality products than is necessary.

5. Inventory. Excess raw material or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay. Also, extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.

6. Motion. Any movement of people that does not add value to the product or service. The people's movement that adds value is called work, the movement that does not add value is called motion. Any movement that employees have to perform during the course of their work, such as looking for, reaching for, or stacking parts, tools, etc. causes waste. This type of waste can be minimized, for instance, by placing tools and materials in an efficient way that does not affect the quality, the productivity of work and the outputs.

7. Defects. All products, materials or services that do not meet expectation or are not conformed to the specifications, such as: repair or rework, scrap, replacement production, lack of information, and inspection. Defects cost money and time and damage the quality of reputations in the delivery of the product. Defects in construction are a major cause of waste as they lead to re-work and/or poor quality; this should be a major construction waste reduction target.

In recent years, several research studies have been undertaken regarding waste in the construction industry. According to Koskela (2004), 'making-do' is a waste and refers to a situation in which the task is started without its input (tools, machinery, people, etc.) and should be added to the list as the eighth category of waste.

2.6.5 Learning and Continuous Improvement

Continuous improvement, in Japanese Kaizen, is an approach of constantly evaluating and improving processes in order to deliver maximum value to the customer by enhancing process efficiency.

The Plan-Do-Check-Act (PDCA), also known as the Deming Cycle or Deming Wheel, is a well-known framework for implementing continual process improvement. It has been developed to help in establishing what needs to be changed in the process to meet customer ‘expectations. It should be used at all levels of a learning organization, from the top level down to the work level (Liker, 2004). The cycle consists of four steps connected through a loop. All these steps are continuously repeated as part of a never-ending cycle of continual improvement (Figure 2.10).

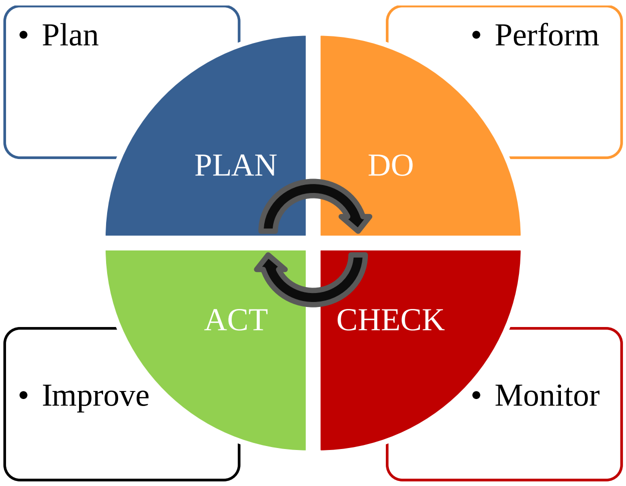


Figure 2.9: PDCA Cycle of never-ending improvement

Below, a brief explanation of the four steps is provided:

- PLAN: is the first step of the cycle in which a plan has to be defined. The plan should address scope and targets that need to be achieved in a certain amount of time by identifying processes necessary to deliver the goals. At this stage, four questions should be answered: who, how, what, where.
- DO: implementing and executing the plan to see if it is supported

- CHECK: monitoring the progress by tracking and checking the plan's execution. Doing regular evaluation between the original plan and the actual condition, to investigate the effect of changes.
- ACT: is the last step of the cycle where the learning generated by the entire process can be integrated in order to adjust the goal, change methods or reformulate a theory.

2.6.6 Last Planner System

Improve planning and process control is considered as one of the most successful ways to enhance efficiency in the construction industry.

In a Lean environment, this can be facilitated by using the Last Planner System (LPS), as one of the most effective tools for managing the construction process (Aziz & Hafez, 2013). The LPS is a collaborative process of production control (Ballard, 2000), developed in the early 1990s by Glenn Ballard and Gregory Howell, both consulting work in the construction industry. It is the only approach that does not come from the Toyota Production System, but it was specifically created for the construction industry by construction practitioners (Daniel & Pasquire, 2016).

In recent years, the LPS has achieved a high degree of consensus in the construction industry and has been considered by many practitioners, as a very powerful system to produce predictable work flow, constant monitoring and rapid learning during all process flows (Ballard, 1999; Ballard, Hammond, & Nickerson, 2009; Ballard & Howell, 1997; Ballard & Tommelein, 2016; Hamzeh, Kallassy, Lahoud, & Azar, 2016; Lindhard & Wandahl, 2012; Salvatierra, et al., 2015). Moreover, when applied properly, the LPS has showed a drastic reduction in time and costs, and simultaneously a significant improvement in quality and safety of the project (Mossman, 2015).

The LPS aims to improve workflow and plan reliability by asking the right information from the right people at the right time. This process thereby leads to performance improvement (Ballard, 2000). Mossman (2015) describes LPS as a system to manage a network of relationships through a set of conversations that allow decision making in regard to program and planning in a collaborative way at the lowest level.

The main goals of LPS are (Ballard, Hamzeh, & Tommelein, 2007):

a) Planning the tasks in detail as soon as they are near execution,

b) Involving the people who are going to perform the work in the planning,

c) Identifying and removing constraints ahead of time in order to clear the path for the execution team,

d) Coordinating between team parties and trade partners in order to make reliable promises to execute the planned work,

e) Identifying the root causes of the problems and learning from failures to continuously improve.

The LPS is divided into five levels of planning steps – namely: master schedule, phase pull scheduling, lookahead planning, weekly work plan or commitment planning and learning from the errors made and defining how the process can be improved.

Master schedule and phase pull schedule define what SHOULD be done, when and by whom. The lookahead planning makes the task ready so they CAN be performed. The week work plan expresses what WILL be done within the time plan. Comparing DID to WILL, tasks not completed can be identified and analysed in order to define countermeasures. The five levels of the LPS are illustrate in Figure 2.11 and briefly explain below.

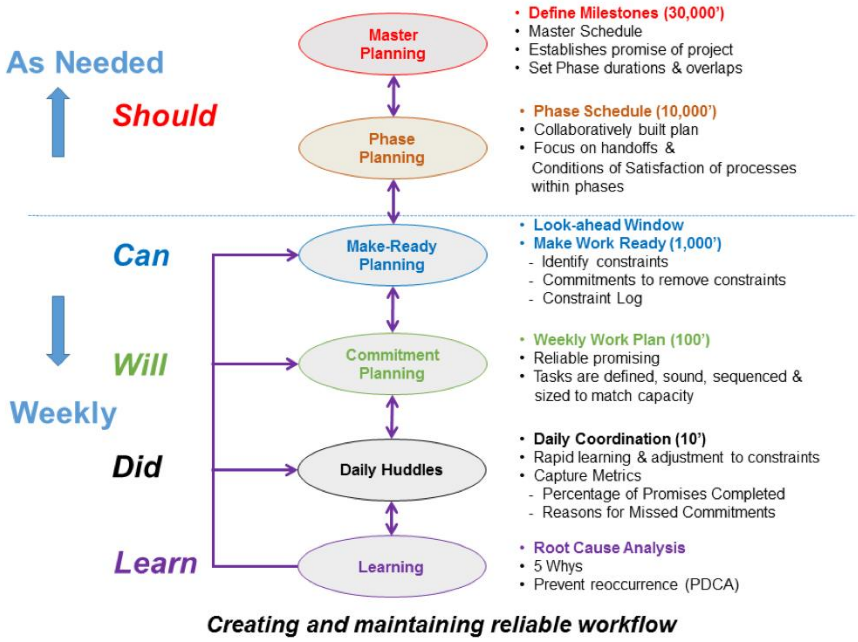


Figure 2.10: 5 Levels of the Last Planner System® – Lean construction Blog

Master Schedule (SHOULD)

The Master Schedule is usually produced during the front-end planning and covers all activities of the project. It helps to identify the key milestones of the project as well as overall project duration. The Master Schedule establishes the basis for the Reverse Phase Scheduling (RPS).

Phase Pull Scheduling (SHOULD)

The Phase Pull scheduling is a detailed schedule that covers each phase of work, from design to handover. The pull technique, also known as reverse phase scheduling, requires thinking 'with the end in mind', by working from target completion date backwards. Team planning requires all team members responsible for delivery of a milestone, to work together and develop the Pull Scheduling

Lookahead Planning (CAN)

The Lookahead is used to controlling the work flow of production planning within a time frame of 3 to 12 weeks, depending of the complexity of the project. The main goal of lookahead is to make the work ready to be executed by removing constraints, finding resources and developing operation's design. This process helps to eliminate potential variability and is the base of the weekly work plan.

Weekly Work Plan (WILL)

The weekly work plan (WWP) represents the last level of planning. It is also referred to as 'commitment planning' since at this stage, all the resources must be assigned in order for tasks to be performed. It is done by those who are directly responsible for production unit control, usually referred to as Last Planners (project engineer, supervisors, construction foreman). Only the work that can be done is promised by the last planner.

Learning and continuous Improvement (DID)

At the end of each week's plan period, all the assignments should be reviewed with the team to measure the planning reliability, analyse failure and learning in order to improve the next Weekly Work Plan. The methods used to measure performance are Percent Plan Complete (PPC). PPC is a basic measure of how well the planning system is working. It is based on the number of planned activities completed divided by the total number of plan activities expressed in percentage. PPC is a proportion of promises made and those delivered on time. The root cause analysis is part of the learning conversation and allows identification of the more common reasons for delay. By using the 5Whys technique, the true root of the problem can be identified, and countermeasures can be taken.

Research has shown the benefits of applying the LPS in the construction process (Fernandez-Solis et al., 2012; Mossman, 2015) including:

- increased work flow reliability,
- improved supply chain integration,
- reduced production duration,
- improved communication among project participants,
- support relationships,
- makes control more proactive,
- increase safety,
- eliminate waiting,
- enhancement of managerial practices in construction projects,
- knowledge expansion and learning among project teams.

2.6.7 Other Lean tools

Target Value Design: is a technique that offers the design team the opportunity to engage in the design conversation with both the client and the party who is will be delivering the service. Two elements drive the development of TVD: 1) design to the target cost rather than estimating the cost of the design , 2) design for what is constructible rather than evaluating the constructability of a design (Macomber, Howell, & Barberio, 2007).

Nine pillars create the conditions for successfully executing the target value design during the design process (Macomber, et al., 2007):

1. Engage deeply with the client to establish the target-value,
2. Lead the design effort for learning and innovation,
3. Design to a detailed estimate,
4. Collaboratively plan and re-plan the project,
5. Concurrently design the product and the process in design sets,
6. Design and detail in the sequence of the customer who will use it,

7. Work in small and diverse groups,
8. Work in a Big Room,
9. Conduct Retrospectives throughout the process.

Choosing by Advantage (CBA)

This is a collaborative and transparent type of multiple-criteria decision-making method developed by Jim Suhr. The aim of the CBA method is to help decision makers evaluate alternatives, both the advantages and disadvantages, and to understand the importance of all those differences. The most used CBA method is the Tabular Method, which is used to choose among two or more alternatives that are not of equal cost, rather, the one that fits best for the purpose. An example of CBA applied in the construction industry can be found in (Arroyo, Tommelein, & Ballard, 2013; Arroyo, Tommelein, Ballard, & Rumsey, 2016; Schöttle, Arroyo, & Haas Georgiev, 2017)

A3 Problem Solving

A3 Problem Solving is a technique that uses the size of an A3 sheet of paper to evaluate problems, making important decisions and making improvements in a visual and simple way. The A3 paper is divided into several sections that lead from the problem identification to the best solution (Seed, 2010):

1. Stating the background (Why is this a problem?)
2. Outlining the current situation
3. Identifying the desired future state (Goals)
4. Performing analysis - what are the steps to follow to achieve the goal
5. Proposing countermeasures or solutions
6. Developing an action plan for improvement (what, who, when) followed by (so, did it work?)
7. Capturing and analysing results (Follow-up)

2.6.8 Lean project delivery system

Ballard (2000) first introduced the idea of the Lean Project Delivery System in which the project's team assists the client to identify the objectives and work together to deliver the desirable outcome. According to Howell and Ballard (1998) by embracing the lean thinking philosophy, the new form of delivery system is able to produce significant improvement, especially on dynamic, uncertain and fast projects.

The Lean Project Delivery System consists of 11 modules, integrated and interconnected between five phases, starting from Project Definition, to Lean Design, to Lean Supply and finally Lean Assembly and Use (Ballard, 2008) as show in Figure 2.12.

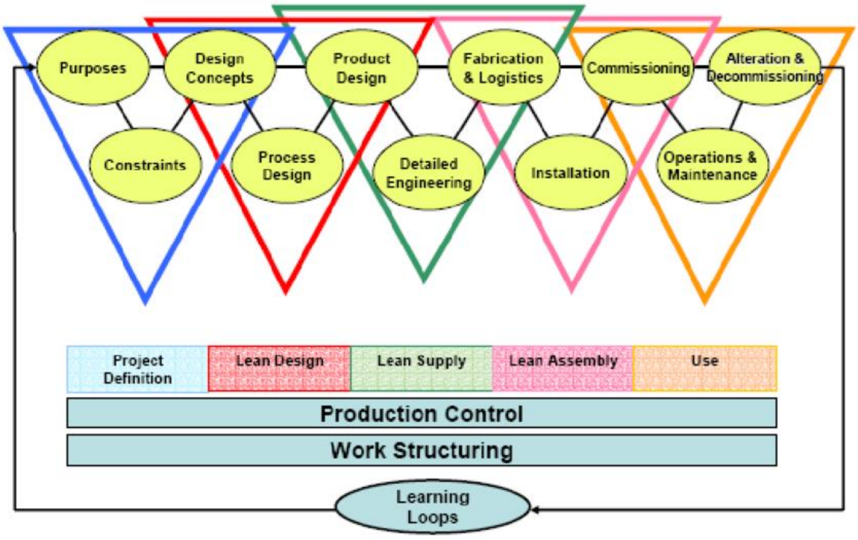


Figure 2.11: Lean Project Delivery System (Ballard, 2008)

Each project phase, represented by a triangle, contains three project steps. Each triangle overlaps with a step of the next triangle demonstrating the interconnection of the delivery system. Therefore, some steps are part of two project phases, which also means that each project phase has an impact on the following phase and is influenced by the previous phase. Decisions made in one phase, affect the next phases. The relationships and interdependencies between each project's phases – which are often ignored in the traditional project delivery – are well defined in the Lean project delivery system.

The first stage of the delivery system, namely Project Definition, aims to ensure the project goals are aligned between all members of the team in order to achieve customer satisfaction. Thus, what is expected (the end), how it will be provided (the means), and the constraints (location, time, cost, regulations) are made clear through conversation among the participants. These are all expressed through the Condition of Satisfaction (CoS). CoS is a decision-making guide developed between all parties. By signing the CoS, each team makes a reliable promise to one another and is responsible for delivering it.

The conversation between stakeholders continues during the second stage, called the Lean Design, where the team develops the design product on the basis of the conceptual design. The Lean Design phase transits into the Lean Supply stage. Starting from the product design, the team develops the detailed engineering necessary to fabricate and deliver both components and materials. During this stage concepts of logistic need to be applied to reduce the inventory and lead time. Information, components, and materials as well as tools, machines, and labours for installation continues to be delivered during the Lean Assembly phase. In this phase, construction activities are also performed following the 'just in time' principle of producing at the 'last responsible moment' to avoid waste in the form of change orders and rework. After installation the process ends with the commissioning and use of the facility, transitioning into Lean Use. Under this stage, information related to operation, maintenance, and decommissioning have to be tracked.

2.7 COLLABORATIVE CONTRACTING, BIM AND LEAN INTEGRATION

Collaborative contracting, BIM and Lean are relatively new construction trends and are leading towards a radical change of the construction industry. As shown above, all of them are conceptually independent of one to each other. However, it is widely supported that they can reach their full potential when they are used in a complementary way. Recent studies have shown the great benefits achieved when they are used simultaneously coupled, though their exploration is still in its early infancy.

Sacks, et al. (2010) first hypothesised the interaction between BIM and lean for improving construction. Through a matrix that juxtaposes BIM functionalities and Lean principles, they identified 56 possible distinct interactions during the design, preconstruction and construction phases. Among them, they found that 48 of the issues have been proved with documented evidence.

According to Olatunji (2011) by enhancing collaboration and information sharing, BIM can contribute to reducing non-value adding waste, which is the goal of the Lean management approach. BIM functionalities such as visualization, construction simulation and clash detection, can facilitate the application of the Last Planner System and assist in planning and controlled decision-making (Bhatla & Leite, 2012). At the same time, by achieving better understanding of the project tasks through visualisation and simulation, team members should be able make more reliable commitments during the planning.

Hamdi and Leite (2012) showed how the combination of Lean techniques and BIM during the construction stage resulted in $3 million of budgeted cost savings. The pull planning allowed identification of early conflicts and constraints, preventing the construction company from scheduled delays and time lost. BIM helped to visualize constructability and construction sequences, generate multiple construction plan alternatives and find potential solutions, becoming a rich source for the overall construction planning.

Tauriainen, Marttinen, Dave, and Koskela (2016) studied the relationship between Lean management and BIM to improve the design of construction projects. They conclude that several issues that may arise when BIM is used could be resolved by applying lean methods and techniques such as the big room, target value design, and the last planner system. The big room helped to facilitate information flow and communication between design team members. The target value design assisted the team to develop design solutions and get in-depth views for managing decision making. The Last Planner System helped project managers to develop and keep on time schedules and control the flow of input information in projects.

The Massachusetts Port Authority (Massport) is the first client driving the integration of a BIM and Lean managed project lifecycle (Massport, 2015). It developed a unified strategy for project success by using a set of Lean tools - such as TVD, set-based design, LPS, A3 problem solving and CBA - to support the different BIM uses. The overall Massport Lean and BIM integration strategy for both vertical and horizontal construction projects is illustrated in Figure 2.13

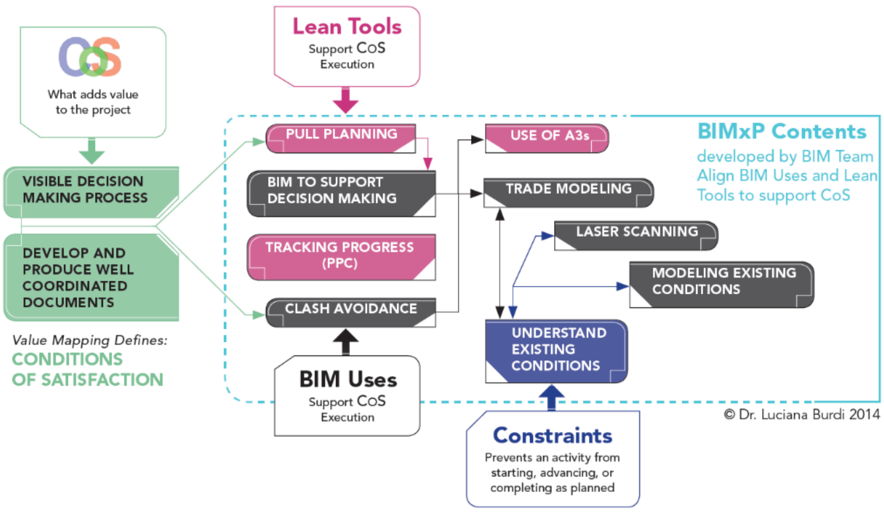


Figure 2.12: Massport BIM/Lean strategy (Massport, 2015)

BIM also supports the concept of IPD (Azhar, 2011). According to Ashcraft (2008), the best practices for complex projects strongly recommend the use of IPD methods and BIM.

Similarly, Becerik-Gerber and Kent (2010) believe that IPD creates a collaborative environment that facilitates the use of BIM within construction projects. By aligning the team's goals and incentivizing them to work together through a sharing risk and reward, IPD seeks to improve project outcomes by increasing process efficiency and minimizing errors. The authors showed a successful example of using an IPD model on a small commercial project supported by BIM.

Ilozor and Kelly (2012) conducted a conceptual study on the benefits of IPD and BIM integration and developed a BIM/IPD Integrated Model framework. The study takes into consideration two aspects: the benefits that BIM has already introduced into the business and the improvement that IPD promises to deliver.

Halttula, et al. (2015) defined IPD and project alliancing as relational project delivery arrangements and analysed the benefits derived by their use with BIM in order to solve issues arising from fragmented processes. Three key elements that characterized the relational project delivery arrangement were identified: integration, a mutual and single goal, early stakeholders' involvement. As well, three key elements of BIM were highlighted: comprehensive data storage, collaboration models and simulation. The study examined how the characteristic features can provide more benefits when they are used together, rather than used alone.

Regarding the contemporary use of Lean and collaborative contracting, Sutter Health, in Northern California, was the first major organization that developed the first relational contract, the Integrated Form of Agreement, which applied the principles and tools of Lean manufacturing in the construction environment (Mauck, Lichtig et al., 2009). These became famous as the Five Big Ideas (Mauck, Lichtig et al., 2009):

1) <u>Collaborate; really collaborate, throughout design, planning and execution.</u> 'Design is an iterative conversation; the choice of ends affects means, and available means affects ends.'

2) Increase relatedness among all project participants:

'Participants need to develop relationships founded on trust if they are to share their mistakes as learning opportunities for their project, and all the other projects.'

3) Project are networks of commitments:

'The work of leaders is bringing coherence to the network of commitments in the face of the uncertain future and co-creating the future with project participants. This contrasts with the common sense understanding that planning is predicting, managing is controlling, and leadership is setting direction.'

4) Optimize the project not the pieces:

'Pushing for high productivity at the task level may maximize local performance but it reduces the predictable release of work downstream, increases project durations, complicates coordination, and reduces trust.'

5) Tightly coupled action with learning:

'Continuous improvement of costs, schedule, and overall project value is possible when project performers learn in action. Work can be performed so that the performer gets immediate feedback on how well it matched the intended conditions of satisfaction.'

The 'Integrated Form of Agreement' (IFOA) was the base of the development of the first IPD contract, ConsensusDOC 300, developed to facilitate the use of Lean within an IPD agreement.

Canada's Integrated Project Delivery Alliance (IPDA) and the Lean Construction Institute (LCI) from the US, released in November 2016 the research report *Motivation and Means: How and Why Lean and IPD Lead to Success*. The report is a set of 9 case studies on projects with a range from $9.6M and $119M, which utilized a multiparty agreement and Lean design and construction technique. All projects were analysed in 24 areas across five major categories: Context, Legal and Commercial; Leadership and Management; Processes and Lean; Alignment and Goals; and Building Outcomes. Under the category Processes and Lean, the effective use of BIM was also analysed as a tool of collaboration. The overall finding shows that projects using Lean coupled with IPD achieved a more reliable outcome in term of time, cost and owner’s goal. In particular, team dynamic and integration, alignment of goals, and timely decision all strongly impact project performance.

2.8 SUMMARY

High levels of fragmentation, lack of communication and poor collaboration among stakeholders have characterized the construction sector for many years.

In light of this, BIM and Lean are considered the two major developments that are challenging existing silo mentalities and driving the industry towards more collaborative and integrated methods of working.

However, it is widely believed that they can only achieve their full potential when they are used in a contractual framework that supports a high level of collaboration and integration. In the light of this, collaborative contracting differs from other models by providing an environment useful for building a framework of collaboration, aligning project participants to commit to the same goals and incentivizing them to work as a single team, in a spirit of ‘we win, or we lose together’, changing the way people act, behave and interact with each other.

All of these three developments are in the relatively early stages of adoption, and several research studies have been undertaken to explore their potential benefits. Though they are different from each other, it is often claimed that significant advantages can be obtained if they are used in an integrated manner.

The preliminary framework below (Fig. 2.16) encapsulates the key features of collaborative contracting, BIM and Lean that came out from the literature, focusing on improving collaboration. While studies have proven the synergy when the three approaches are coupled, the literature lacks studies that consider the three integrated simultaneously. The theoretical framework has been built, believing that that their integration would enable a higher level of collaboration that would not only improve efficiency of the process but also encourage exploration of different approaches, methodologies, and techniques to optimize the whole process.

Indeed, the characteristics of collaborative contracting, both formal - such as the contract and commercial framework - and informal - such as a set of values to define culture and behaviour - should create the right environment to optimise collaborative working, facilitate the implementation of digital processes through BIM by addressing legal concerns and support the Lean management process by establishing a unique organisation that looks to the whole process, not to single parts. Likewise, the characteristics of BIM such as visualisation, simulation and clash checking, jointly with better levels of coordination, should enable the de-risk of projects and provide clarity and transparency in the process. This should result in encouraging clients to embrace the risk sharing framework and actively participate in the project. Lean management should provide a consistent approach to implement BIM throughout the project to ensure that the value for the client in term of digital goals is properly identified and understood among all project members and that they all work together to continually find ways to improve flow efficiency.

The aim of this research, therefore, is to explore how collaborative contracting enhances the effectiveness of BIM and Lean and, therefore, how a framework for collaborative contracting, which exploits the benefits of BIM processes integrated within the Lean environment, can be built.

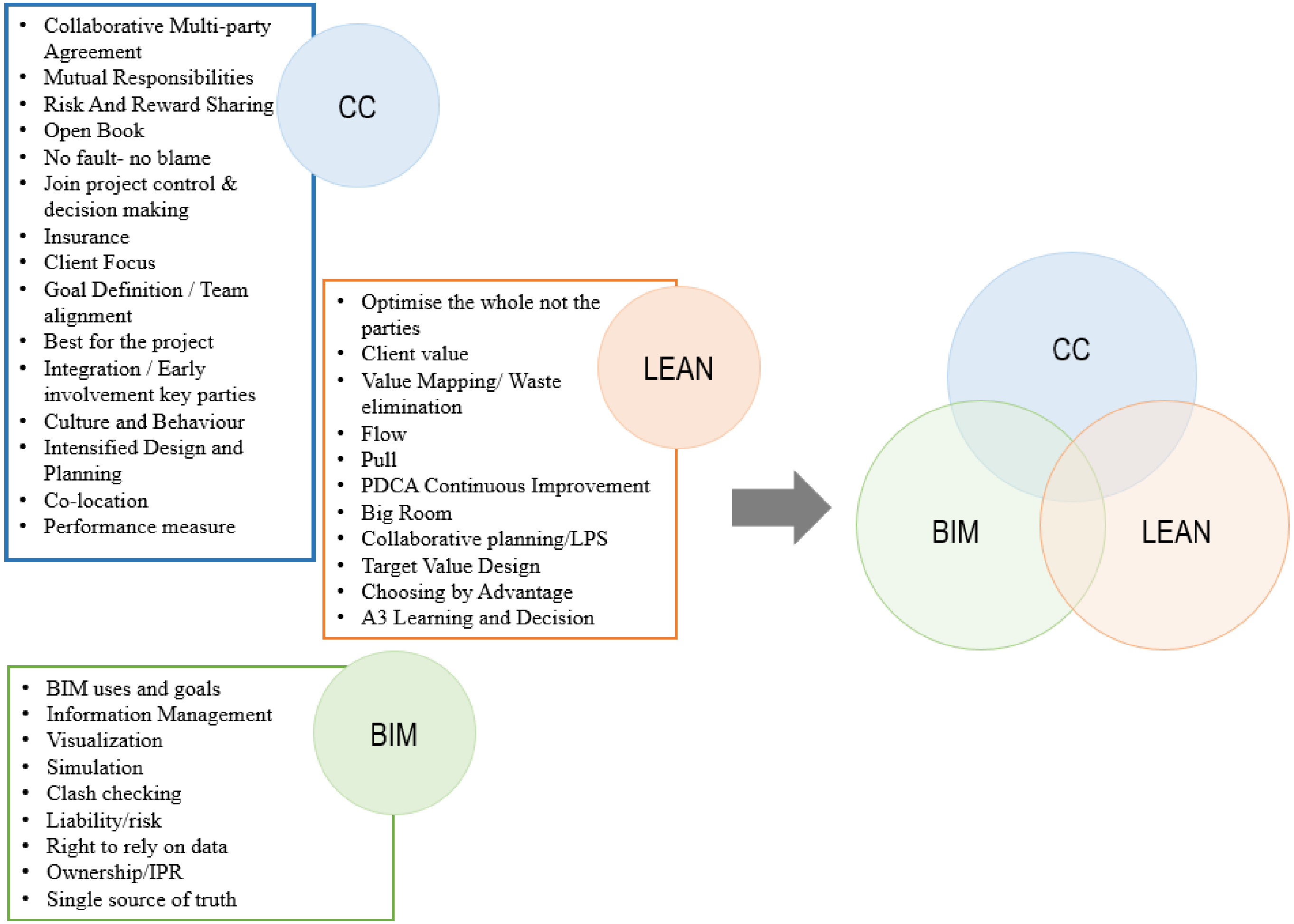


Figure 2.13: Research Preliminary Framework

Chapter 3: Research Design

3.1 INTRODUCTION

This chapter outlines the steps undertaken to design and execute this research, depicting the approach and procedures chosen for the data collection and data analysis to answer the research questions.

The research design is divided into three main stages, beginning with the first stage of research background, involving an exhaustive review of the literature. The second stage consisted of 43 semi-structured interviews as a main source of data collection with a concurrent data analysis completed by adopting a content analysis method. Finally, the last stage of this research involved four expert interviews as a method for confirmation of the proposed framework.

3.2 RESEARCH METHODLOGY

Research is often described as a journey of discovery from what is known to what is still unknown. Kothari (2004) defines research as 'an art of scientific investigation'. In the light of this, before starting any kind of research, it is essential for a researcher to clarify the most appropriate scientific procedure that will be followed, as it will provide a rigorous direction toward answering the research questions, thus achieving research objectives.

The research methodology defines the systematic strategy or plan of action that will lead the researcher to achieve certain goals in research (Crotty, 1998). In the study of construction management, two research approaches appear to dominate: the positivist approach and the interpretivist approach (Love, Holt, & Li, 2002). The positivism approach presumes that there are observable 'facts' that can be measured by direct observation. Positivism uses scientific methods, such as quantitative and experimental approaches, in which theory is deducted as a result of formulating and testing hypotheses (Love, et al., 2002). Conversely, the interpretive (inductive) approaches proceed from empirical findings, usually using a qualitative approach, to build a theory. This research uses inductive approaches through initial exploratory studies and semi-structured interviews as a strategy to data collection. The inductive qualitative method was chosen against the quantitative strategy to allow phenomena to emerge from participants. Indeed, while BIM has been widely applied by individual organisations in several construction projects around Australia, bringing the attention to the current limitation in procurements and contracts to enable an integrated process was quite a novel occurrence.

Therefore, to better understand the challenges that the industry is facing and to gain insight into the subject without limiting the scope of the research and the nature of participant's responses, it was important to give them voice. The semi-structured interview method was chosen because it drives toward an in-depth exploration of the phenomenon under study (Galletta, 2013).

Semi-structured interviews sit in the middle between structured and unstructured interview. This method allows for following a list of predetermined questions, ensuring that the complexity of the research topic is adequately explored (Galletta, 2013), meanwhile offering to participants the opportunity to explore issues they consider most important (Louise Barriball & While, 1994). For the researcher, semi-structured interview demands a degree of openness, a high level of curiosity and a willingness to accept fluidity (O'Leary, 2004). As well as the ability to adjust each interview to obtain accurate and complete data, the researcher needs to be able to adjust the interview questions to evoke the most relevant information to emerge while maintaining sufficient standardisation to secure validity and reliability (Louise Barriball & While, 1994).

The in-depth semi-structured interviews aimed to explore: 1) the contractual barriers to collaboration under conventional procurement models and how the barriers can be resolved by using collaborative contracting, 2) the challenges in adopting BIM for construction procurement in Australia, 3) how collaborative contracting can improve the effectiveness of BIM and Lean throughout the procurement process. The research questions, research objectives and the data collection method are presented in Table 3-1.

Table 3-1: Research Questions, Objectives, Data Collection Method

MAIN RESEARCH QUESTION		
How can we build a framework for collaborative contracting that exploits benefits of the integration of BIM and information management with Lean principles and tools?		
Research questions	**Research objectives**	**Data Collection Method**
What are the contractual barriers to collaboration under conventional procurement models and how can these be overcome using collaborative contracting?	Identify contractual barriers to collaboration under conventional procurement models. Analyse collaborative contracting methods and identify how the barriers can be resolved.	Literature Review In depth semi-structured interview
What are the challenges in adopting BIM in construction procurement in Australia?	Identify the challenges in adopting BIM for construction procurement in Australia.	In depth semi-structured interview
How can collaborative contracting enhance the effectiveness of BIM and Lean?	Identify how collaborative contracting can improve the effectiveness of BIM and Lean throughout the procurement process.	Literature Review In depth semi-structured interview

3.3 RESEARCH PROCESS

The research is divided into three main phases, starting with the background (Phase 1), followed by data collection and data analysis (Phase 2) and concluded with development and confirmation of the framework (Phase 3).

Phase 1 involves an exhaustive review of the literature. The purpose of Phase 1 was to achieve a better understanding on why collaborative procurements benefit from the use of BIM and Lean in comparison with conventional forms of procurements. This helped to define the most appropriate research design, the method of data collection and the participants' selection. Phase 2 is data collection and data analysis. Based on the literature and the previous related studies, 21 questions were developed and a pilot study with a BIM manager and a business manager, was performed to confirm the questions. Forty-three in-depth semi-structured interviews in Australia, Canada, the United States of America, and the United Kingdom were performed within four months. Interview data was immediately processed after each collection. The qualitative approach, such as interview in this research, is chosen as it allows a degree of freedom and flexibility (Soiferman, 2010). Indeed, based on the initial findings from the early interviews, the researcher was able to take the advantage in subsequent interviews to fill certain knowledge gaps or explore more in-depth on a specific argument.

All interviews were transcribed and analysed through content analysis using Nvivo software. Content analysis is a method used to extract thematic information from qualitative materials and then categorise the information into codes (Tharenou, Donohue, & Cooper, 2007). Based on the findings and literature review, a theoretical framework on BIM-based collaborative contracting that integrated BIM with Lean principles and tools was developed and confirmed with four experts in the field of BIM and business management. The whole design research process is shown in Figure 3.1.

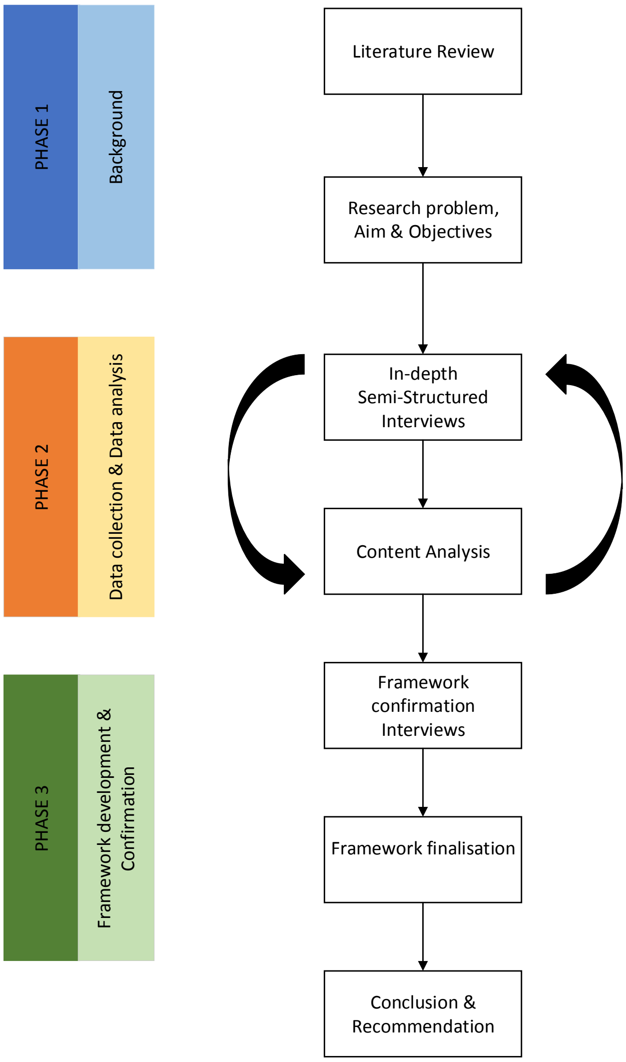


Figure 3.1: Research Process

3.3.1 Phase 1: Background

Phase 1 includes literature and exploratory studies through expert as a preliminary exploratory method to gain more insights into the relationship of collaborative contracting, BIM and Lean.

The exploratory studies helped the researcher to gain more insight into the relationship between collaborative contracting, Lean and BIM by interviewing leaders in the field, and 2) the application of Lean principles and tools as a strategy to improve construction project performance by being directly involved in the project.

The purpose of Phase 1 was to achieve a better understanding on why collaborative procurements benefit the use of BIM and Lean in comparison with other form of procurements.

The unstructured interviews and participant observations were intended to confirm the extracted information from the literature review as well as to get comprehensive information from actual practice (Saunders et al., 2012). The information gained helped to revisit and clarify the research problem and objectives, in order to better address the questions for the next stage of data collection.

Literature Review

In order to define the research questions and purpose of the studies, an extensive literature review was conducted. The literature review section in this research is divided into three main research themes: (1) Construction procurement models including conventional and collaborative systems, (2) Building Information Modelling and how its use affects procurements and contracts, and finally (3) Lean management as a philosophy and business strategy to manage the digital process.

The literature was the primary source of information, which enabled access to a deep level of knowledge into the three main topics, understanding the key features of each of them, as well as their synergy when they are applied together. The literature therefore provided evidence for the aim of this study and helped to underlay the existing problem that this work will address.

A combination of journal articles and conference papers was used to get a broad perspective of the current views of the topics. The databases and publishers that were searched include: ProQuest, Science Direct, American Society of Civil Engineers (ASCE), Emerald, Taylor & Francis Online, Scopus, and SpringerLink. Moreover, in order to pick up the industry's perspective on the three approaches, a document study was performed on a number of key governments and industry publications primarily around Australia, the United States of America and The United Kingdom.

Expert interview

Expert interviews were conducted for the exploratory study. In particular, the researcher needed to get a deep understanding of the implication of using Lean construction and BIM within collaborative delivery methods. Considering the limited use of best practices in Australia as discussed from page 31, the researcher had the opportunity to attend the Lean Construction Congress in Anaheim, Los Angeles, from the 16th to the 20th October 2017. The Lean Construction Institute Annual Congress is the most important event regarding Lean innovation, IPD and BIM implementation within the construction industry. During this time the researcher had the opportunity to get in contact with a number of experts in the field of Integrated Project Delivery, Lean construction and BIM. A total of five interviews of 30-45 minutes each were performed, discussing the current practices, benefits and contractual challenges of implementing BIM and several Lean principles and tools within both traditional and more innovative project delivery methods.

The interviewees included:

- Two representatives of the most advanced clients organisation in the integration of Integrated Project Delivery, Lean construction and BIM;
- One construction lawyer specialist in alternative project delivery and the use of technology and Lean in design and construction;
- One Lean construction consultant;
- One Lean construction coach and facilitator;
- Two worldwide well-known academic leaders in Lean and Integrated Project Delivery.

In addition, the researcher attended a full day workshop of Lean and BIM integration, the purpose of which was to illustrate how Lean is shaping BIM use in design and construction.

In particular how BIM capabilities can be maximized throughout the project lifecycle by utilizing Lean tools and methods for project development and management. The example came from the Massport, the first client driven integration of a BIM-centric and Lean managed project lifecycle (Massport, 2015).

3.3.2 Phase 2.1: Data Collection

This research used in-depth semi-structured interviews as a strategy for data collection. The semi-structured interviews allowed a degree of freedom and adaptability in getting the information from the interviewees (Gill, et al., 2008). The qualitative method intends to ensure, through a guided approach, that the same general areas of information are collected from each interviewee. However, depending on the specific context, questions may be omitted or added to better suit the experience of the interviewee or to deepen exploration of a topic (Saunders, Lewis, & Thornhill, 2009). The data collection, data analysis and interpretation require a more organic process if compared with the linear process of a quantitative method. It appears that all these three steps influence each other, working in a overlapping cycles (O'Leary, 2004). The following sections explain the selection process for the sample of participants and the procedure used to collect and analyse the data.

Procedure

The purpose of the interviews was to explore the following:

1) Identify the contractual barriers to collaboration under conventional procurement models and how the barriers can be resolved by using collaborative contracting;

2) Identify the challenges in adopting BIM for construction procurement in Australia;

3) Identify how collaborative contracting can improve the effectiveness of BIM and Lean throughout the procurement process.

The interview guide was composed of 21 questions divided into five parts preceded by a couple of questions for introduction including the interviewee’s years of experience in the construction industry, the current position cover and the year of experience in this position.

The interview questions were first piloted with three experts in Australia - an academic and two industry professionals - who helped to better clarify the industry awareness of BIM and collaborative contracting and therefore redefined some questions within the industry context.

The interviews were run in three rounds with a week break in between, to allow the researcher to begin analysing the data and better address the remaining interviews.

The five sections include:

Part 1 – Collaboration: Explores the human barriers to not collaborate and identified the key factors that lead to success or failure of collaborative projects.

Part 2 – Procurement: Investigates the differences between traditional delivery methods and more collaborative approaches.

Part 3 – BIM: Explores the impact of BIM on procurement and contracts, considering the challenges that experts face in construction projects.

Part 4 – Client: Analyses the client's role on driving the use of integrated collaborative approaches and technology.

Part 5 – Future Strategy: Asks for a future vision of project delivery and collaborative practices.

Table 3-2 below shows the interview guide. Interview questions are slightly varied depending on the interviewee's role and experience.

Table 3-2: Interview questions

PART 1	**COLLABORATION**
1	What do you perceive as barriers to effective collaboration? How can they be overcome?
2	What are the relevant factors to enhance team working and develop cooperation between team members? What tools and techniques can be used to foster team engagement?
3	Could you please tell me what has prevented you from becoming involved in, or using, (more) collaboration in projects during the past two years?
PART 2	**PROCURAMENT**
4	What are the contractual barriers to collaboration under traditional settings such as DBB and D&C? If yes, what are the main barriers?
5	Can behaviours be influenced by the contract? Does the contractual payment method fit to encouraging collaboration? Can collaboration work within conventional fixed-price contracts?

6	If you have delivered a project under collaborative contracting/IPD, which benefits did you experience in comparison with a more traditional approach?
7	Have you noticed any change in culture and behaviour when working under IPD/Alliancing? Have you seen any observable difference in those in the signatory pool compared to those outside of the pool?
8	Which type of behaviour and culture do you want on your project? How do you build on an environment of trust and transparency? How do the IPD principles flow down to the supply chain?
9	Why do you think the adversarial contracting model is still the one most used, even though experience tells us it is not the best? What stops industry moving to an integrated project model?
PART 3	**BIM IMPACT IN PROCUREMENT**
10	How can the choice of the project delivery method affect the way in which BIM is developed and information is exchanged? Can you see any limits of adopting BIM and a data-driver process under traditional contracts such as DBB and DC?
11	Do you think that the contracts and delivery methods used in Australia provide a necessary base to address BIM and more integrated practice or should they be revised to better accommodate changing practice?
12	How are BIM and data deliverables specified in the tender document?
13	How does collaborative working by using BIM affect the contractual relationships of parties? How are the role and responsibilities of each team member defined in relation to BIM during each project stage?
14	Does the contract clearly deal with liability and risk allocation in regard to BIM? If yes, how? If no, how do the parties develop a common understanding of their obligations and what they are entitled to?
15	It is argued that information in the model is not being properly shared due to concern over IP loss. Do you agree? Has the use of BIM changed your perceptions of data sharing?
16	How can collaborative contracts resolve potential legal issues arising when BIM is used?
17	To what extent was management of the asset and its operation and maintenance the driver in the use of BIM? How is the implementation of BIM impacting Facility Management?
PART 4	**CLIENT**
18	What are the client expectations when they ask for BIM in a project? If the client requires BIM but is not specific about what they expect, how do you resolve this? If a client doesn't have in house expertise, how should they leverage the use of BIM?
19	How do BIM and collaborative practices provide benefits for the client?
20	What should be the client role within the process?
PART 5	**FUTURE STRATEGY**

21	How can the use of BIM and collaborative contracting be fostered in future projects?

The interviewees who participated in this research study were all informed long before their participation to ensure they understood the aim of this research work, the goal of the interview section, how their responses would be used and their right to withdraw from the session before, during and within two weeks after the interviews. The participants were first contacted through LinkedIn and then emailed invitations to include information about this study, and a consent form was sent. The participants signed the Ethics Consent Form before the interviews to show their acknowledgement of the information about this study and also their consent to the voice recording of the interviews.

The duration of each of the interviews varied between 45 and 90 minutes and they were conducted face-to-face with the majority of the interviewees who were based in Brisbane, while ZOOM Video Conferencing was used as a powerful tool for conducting virtual meetings. ZOOM was chosen as a preferable option among other solutions for several reasons. First of all, Zoom automatically recorded both video and audio and saved text messages, which are all sent to the host through email as soon as the meeting ends. This is a significant advantage as the PC speaker audio quality is extremely high and clear, which makes it easier for the transcription process. It is also important to highlight that during the meeting the software allowed pausing or stopping the recording in case the interviewee would like to share sensitive information without these being recorded. Secondly, Zoom does not require the attendee to install any type of software, which means that participants are able to participate without losing time on downloading and registering tools. Indeed, an email, which is connected to the outlook calendar, provides a link to participate in the meeting via PC or smart phone leaving the interviewee free to choose their preferred medium. Last but not least, the Queensland University of Technology provided free solutions and assistance for students and staff. Although Zoom proved to be a very effective tool, the researcher found the face-to-face meetings to be more productive due to speed of establishing connection face to face with interviewees and the possibility to interact and communicate using examples and sketches.

Participants

A total number of 43 (Table 3-3) in-depth interviews were conducted from April 2018 to the end of July 2018 around Australia (33), Canada (1), the United Kingdom (3) and the United States of America (6). The number of interviewees and their expertise allowed collection of enough data to identify meaningful themes. In the initial interviews, something unique often came out and therefore further interviews were required to explore some key concepts, until interviews arrived at the stage where no value-adding information was provided anymore.

The majority of the interviews were conducted between experts in Australia and New Zealand, since the research focuses on the Australian context. The participants were identified through prominence in the literature review and then selected based on their role and expertise. The research's topic focuses on the strategic level rather than operational level, therefore experts whose roles are strategic and managerial were selected, such as BIM Director/manager, business manager and Lean consultant. In Australia, the term Digital Engineering (DE) is often used interchangeably with BIM, especially in the infrastructure space. Therefore, it is common to specify a role as a BIM 'slash DE' manager/director or leader.

Table 3-3: List of participants from Australia and New Zealand

N	Current role	Discipline Area	Years in industry	Years of experience current role
1	BIM/DE Director	Client	18	6
2	BIM/DE Leader	Engineering	23	10
3	Business Manager	Engineering	18	14
4	BIM Manager	Architecture	22	9
5	BIM/DE Director	Engineering	15	7
6	BIM Director	Engineering	15	8
7	BIM/DE Leader	Engineering	24	6
8	BIM Manager	Construction	30	10

9	BIM/DE Leader	Engineering	10	4
10	BIM Manager	Cost & Planning	35	11
11	BIM/DE Leader	Engineering	12	3
12	BIM Researcher	Independent research	24	14
13	BIM/Lean Consultant	Construction	10	4
14	Business Manager	Construction	18	18
15	BIM Lead	Engineering	14	4
16	BIM Researcher	Academia	20	4
17	Construction Lawyer	Law	23	23
18	BIM/DE Director	Client	46	2
19	BIM Manager	BIM Consulting	12	4
20	BIM Manager	Construction	22	11
21	BIM Manger	Construction	29	10
22	BIM Director	Architecture	16	16
23	BIM/DE Leader	Construction	6	3
24	Business Manager	Construction	24	6
25	Business Manager	Engineering	30	15
26	BIM Director	Client	30	2
27	BIM Manager	Design	35	11
28	BIM Manager	Planning	5	3
29	BIM Lead	Construction	32	3
30	Construction Lawyer	Engineering	11	3
31	Construction Lawyer	Law	15	15
32	Business Manager	Construction	22	10

33	Business Manager	Construction	15	10

Considering that the aim of the research is to improve the existing collaborative contracting framework, the best practices around the world were also studied. As emerged in the review of the literature, the United State of America and Canada are the countries leading in the use of collaborative contracting, referred to as Integrated Project Delivery (IPD), with BIM and Lean construction. Therefore, interviews were conducted also among American experts in that field. This helped to, first of all, understand the differences between the Australian collaborative contracting model, namely Alliancing contracting, and the American model, and how the two models can learn from each other. Secondly, this helped to understand from those experienced in being involved daily in IPD projects, what the challenges, as well as what the key factors are, to successfully work under collaborative contracting environments.

Likewise, three interviews were conducted in the United Kingdom with the aim of exploring the results of the first trial project that adopted the new procurement model called Integrated Project Insurance. The Dudley College project was particular interesting because it adopted BIM and information management processes following the UK PAS 1192 standards within the context of collaborative contracting. The UK PAS 1192 suite of standards has been used to develop the International BIM standard ISO 19650, which created a unified approach to BIM implementation and it may also be adopted in the Australian context. Therefore, the project is a good starting point to investigate the possibilities offered by using BIM within collaborative procurement systems. Table 3-4 reports the list of participants from Canada, UK and US.

Table 3-4: List of participants from Canada, UK, US

N	Current role	Discipline Area	Years in industry	Experience current role	Country
34	BIM/Lean consultant	Construction	31	4	US
35	Business Manager	Private client	17	11	US
36	Construction Lawyer	Law	32	18	US
37	BIM/Lean consultant	Construction	10	3	US

38	Construction Lawyer	Construction	18	4	US
39	BIM researcher	Academia	10	8	US
40	BIM/Lean consultant	Construction	11	7	Canada
41	BIM Manager	Architecture	18	5	UK
42	Business Manager	Consultant	20	5	UK
43	BIM Lead	Engineering	24	1	UK

3.3.3 Phase 2.2: Data Analysis

In the qualitative method, the process to move from raw data to the theoretical understanding is a cycle of interactive analysis. This study used the method presented by O'Leary (2004) as highlighted in Figure 3.2, to analyse qualitative material through content analysis.

The data analysis includes the information gathered during the 43 interviews as well as the data of the 2 interviews conducted during the testing phase.

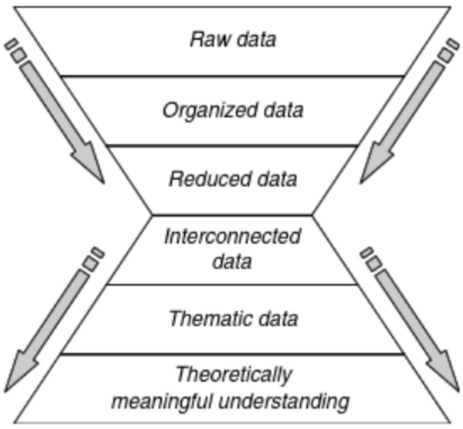


Figure 3.2: Working with qualitative data (O'Leary, 2004)

The first step was to list potential categories for exploration before reading the transcriptions.

Four groups were created in accordance with the sections presented in the interview guide:

- Collaboration,
- Delivery Method,
- BIM,
- Client.

The second step required getting a big picture of the whole data, by reading through all transcriptions several times and taking notes. In this first stage, no software was used, only papers and a set of coloured markers. The objective of this stage was to look at the data as an overarching story (O'Leary, 2004).

The next step of the analysis required taking a line-by-line examination of all data in order to build sub-categories of the main groups. All the interviews were transcribed to ensure that no information was lost along the process. This was a very useful aspect because patterns that were neglected at first, were then reconsidered as they emerged as the interviews proceeded.

Both open and pre-defined codes that were previously identified in the literature were used. For this step, Nvivo software was used to facilitate the process. Nvivo allowed efficient searching of words and to perform thematic analyses with faster and more accurate coding than traditional paper-based process. At the end of the first round of coding, four main groups with 106 categories (including sub-categories) were created (see Table 3-5)

Table 3-5: Number of coding in first round

GROUP NAME	NUMBER OF CODING
Collaboration	47
Delivery Method	26
BIM	33
Client	4
TOT	**106**

The next step was to look for patterns and interconnections among codes.

For example, the group called ‘client’ was removed and all codings were merged within the existing sub-category of group ‘BIM’ as well as in the group ‘Contract and

Procurement' created by merging the previous two groups 'Delivery Methods' and 'Collaboration'.

The processes of reducing and merging codes and categories was extensive due the large amount of data collected. However, the map started to become clearer and more understandable, evolving from an incoherent mass of code into a more consistent and structured set of data.

The four initial groups merged into three main groups:

1) Contractual barriers to collaboration;
2) Characteristics of collaborative contracting;
3) BIM adoption in procurement.

Phase 3: Development and Confirmation of the Framework

Based on the research findings, this research developed a collaborative contracting framework, which was confirmed through expert interviews. As the collaborative contracting framework combines the integration of BIM and data-centric processes with Lean principles and tools, as discussed previously the experts were selected based on the following criteria:

1. Have a suitable knowledge of collaborative contracting as well as BIM processes.
2. Understand Lean key features and principles
3. Be a representative of either client, design consultants or contractor.

Four experts who were interviewed in Phase 2 were contacted to confirm the framework through an individual interview. During the interview, the BIM-based collaborative contracting framework was adjusted, improved and confirmed.

3.4 ETHICS AND LIMITATIONS

The anonymity and confidentiality of each participant of this research is protected. All participants' personal identities cannot be identified by their response.

All the ethical issues related to this research are addressed according to the Queensland University of Technology's Research Ethics and Integrity Units. The Ethics Application for this research has been approved on 12th of September 2017 under the Human-Low Risk Ethics Category, with an approval number of

1700000633. This ethics approval is valid until 12th of September 2019, subject to receipt of satisfactory progress reports.

3.5 SUMMARY

The overall research objective of this study was to investigate how the existing collaborative contracting framework could be improved through BIM and Lean management practices to increase their adoption and resolve current industry inefficiency.

The literature review and exploratory studies were conducted initially to address the research aim and objectives. The research then uses a qualitative research methodology strategy based on an in-depth semi-structured interview as a primary source of data collection. Forty-three interviews were performed, recorded and transcribed. The information gathered during the interviews was analysed using content analysis strategy. Nvivo software was used to support the data analysis process. The collaborative contracting framework was developed, confirmed and refined based on feedback from the BIM experts. Next, Chapter 4 presents the research findings and discussion and Chapter 5 discusses the collaborative contracting framework.

Chapter 4: Findings and Discussions

4.1 INTRODUCTION

This chapter presents and discusses the findings from the interviews. The analysis of the data was performed using qualitative content analysis, which enables development of specified categories that are continuously revised and refined in an interactive, feedback-loop process to ensure credibility and usefulness (Drisko & Maschi, 2015). The findings are grouped into the following three categories:

1) Contractual barriers to collaboration
2) Challenges and characteristics of collaborative contracting
3) BIM adoption in construction procurement

Figure 4.1 below provides an overview of the outcome of the analysis.

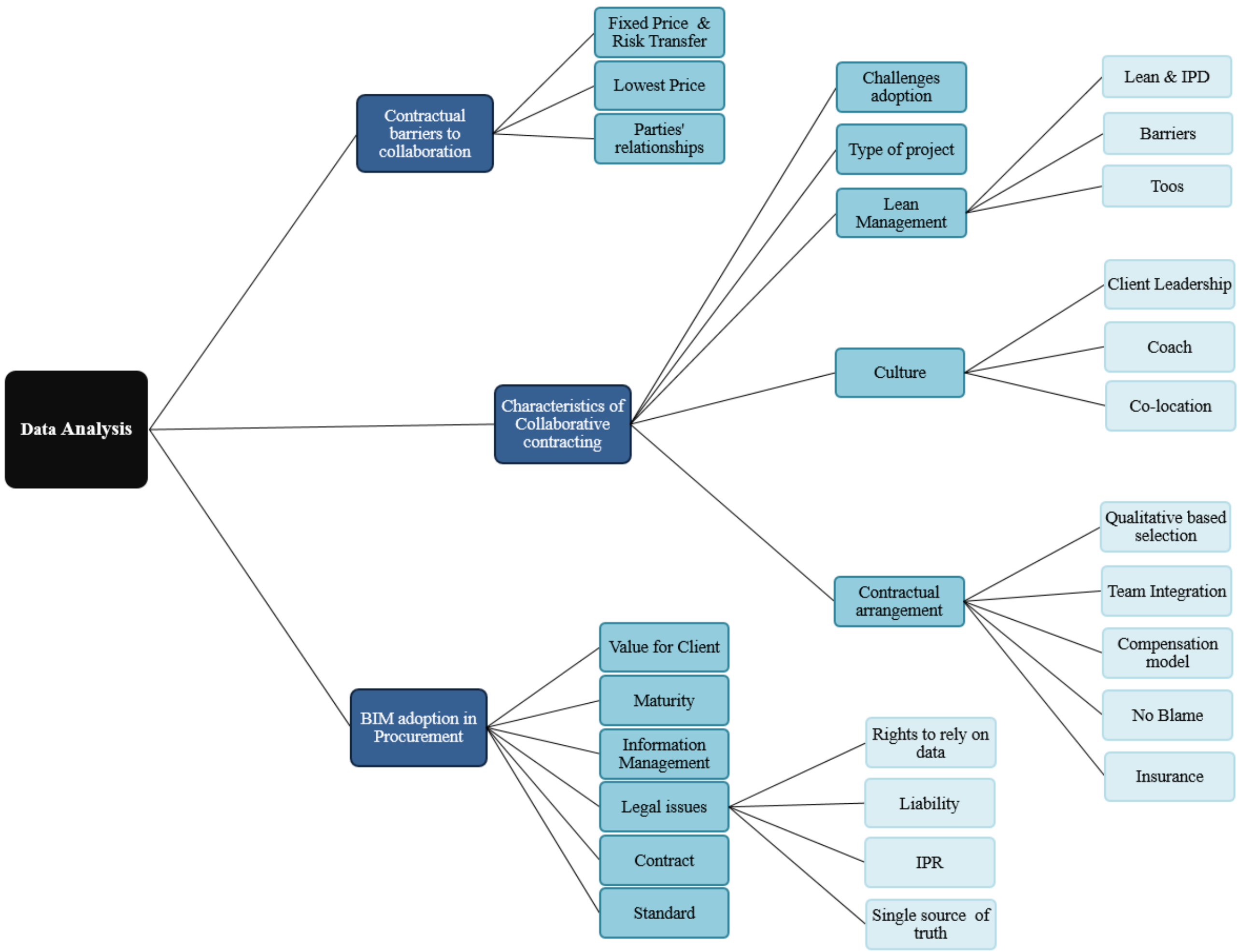


Figure 4.1: Hierarchy representation of codes and sub-category of code

4.2 CONTRACTUAL BARRIERS TO COLLABORATION

4.2.1 Fixed Price and Risk Transfer

From interviewee responses it appeared that the preferable option of many client organisations still involves standard forms of contracts and delivery methods. The majority of projects are still delivered under fixed price Construction-Only or Design & Construct contracts.

It was asked of the interviewees, how contracts can drive collaborative behaviour. A few participants believe that it is people's attitudes as much as the organisational culture that are the drivers for collaboration, rather than the contract itself. According to interviewee 10:

'It's totally about the people; it's entirely about the people - but it's also about organisations. There are some organisations that have a history of working together and people within that, when they think about those companies working together, they'll feel warm and they'll talk about it with a level of success.'

Likewise, interviewee 6, a BIM manager for an engineering firm, believes that under traditional types of contracts, the collaborative behaviour among parties is not often guaranteed, but it can be facilitated if parties have built trust through past work experience together.

'If you get a trusted partner that often you've worked with before, and saying hey we want to do a greater level of collaboration, we want to do some advanced construction scheduling or coordination or whatever it is, but it's not a contractual deliverable that will only happen in a D&C environment if the parties decide to play nice. Otherwise, they'll just go, nah, I'm going to use some drawings. Good luck with that. So, it's very key and it comes down to the aptitude and attitude of the parties involved or often the individuals involved within the parties that have the remit to be able to make those calls.'

On the other hand, there are interviewees who believe that the behaviour of project parties and their willingness to collaborate is indeed affected by the contract or at least influenced in some way. For example, interviewee 9 stated:

'I often say that collaboration it is culture aspect not contract. But I firmly believe that you need that contract as a foundation, and you can put it aside after that, but you need that there to keep people accountable to push in the right direction.'

Indeed, two aspects seem to influence most people's attitude to collaboration: the payment method and the risk allocation. As stated by the interviewee 30, *'the parameters in which you assume the risk for the project are going to affect your behaviour'.* Interviewee 7 also believes that *'within the framework of a hard dollar contract, there is clearly defined allocation of risk and responsibility and that really sets the limits of collaboration.'* Likewise, interviewee 25 believes that the commercial framework drives the relationship among a project's parties.

'It can work with a fixed-price contract, and usually does if the contract goes well, because people wish to enhance their reputation. The problem occurs if the project doesn't go well - people have to protect their commercial interests, so the collaboration breaks down. It's as simple as that. If it goes well, you know, you can do anything you like. If it doesn't go well, the commercial and legal model will determine how difficult that relationship become.'

The commercial arrangement addresses the interest of a single party, allocating risk and responsibilities to each of the project participants. As a consequence, people are going to behave in a more risk-averse way to protect their commercial interests: '*where people protect their own interest - whether their financial interest or their position on a project or their position within a business, rather than getting the right outcome for the project' [interviewee 3].* Therefore, parties are not adding value to other parties and to the overall project: '*Each party is solely focused on delivering value to themselves; they're not incentivised to deliver value to anyone else but themselves' [interviewee 14].* When things start to go wrong, rather than working collaboratively to overcome the problem, the adversarial attitude of traditional contracts is to blame the other party for the problem, which will likewise try to blame yet other parties, and so on.

This approach may also obstruct innovation, performing only the 'minimum-necessary' that it is required, even when a different option could deliver a better result. Interviewee 5, a BIM/DE director in an engineering firm, claimed: '*If somebody is on a fixed price and they have signed up to deliver A, then you are only going to get A, even if they think that B, C, or D might be a better option'.*

Under this scenario, it has been pointed out that the best outcome for a client is therefore highly unlikely to be achieved since the effort is placed to just optimise locally rather than trying to optimise the whole process:

‘We are getting paid to stay in our box, make sure that our box performs and not care about the rest, and it has been proven again and again, if you only improve the parts, you don't necessarily improve the whole. You need to improve everything systemically to get to those better outcomes [interviewee 13].’

According to interviewee 24, an engineering business manager, there are many types of procurement models that should improve collaboration, such as design and construct, construction management, and early contractor involvement contracts, however the problem lies in the appropriate level of risk taken on by the head contractor.

According to interviewee 21, a BIM manager in a construction company, the client’s tendency is also to push out the risk to the contractor: *‘whether it's manageable or not instead of the risk being managed by the stakeholder that is best placed to manage that risk, including the client’.* The main reason for that has been attributed to the fact that clients have always perceived value *‘as being passing as much risk as possible onto the contractor’*, as reported by interviewee 19, whose role is BIM manger in a BIM consulting firm. According to interviewee 30, a construction lawyer for an engineering firm, *‘clients use this approach because they are comfortable with it*’. For instance, the risk associated with the ground condition is often taken by the contractor, even if they are not able to price and manage. If something unforeseen has occurred because the scoping was insufficient, the contractor is then faced with all of the extra cost.

An example reported by interviewee 1, who is a BIM director within a client organisation, outlines the difficulties that may arise in a project when the risk transfer mechanism is used: *‘The job cost about $2.1 billion, but there's a further roughly $1 billion claim now against the government, because there were a few aspects, which, with so many utility providers, utility owners had to have their utilities relocated. So, I think that's an example of where-- it was a D&C contract, like a fixed dollar contract. I think, to me, that highlights how it's just challenging to try and push too much risk onto the supply chain.’*

Governments in Australia have started realizing that the fixed price, lump sum contracts are not delivering what was expected but rather, often end up being disputed. For this reason it seems they are moving away from traditional procurement toward a more collaborative relationship with contractor and the supply chain (NSW Government, 2018).

4.2.2 Lowest price tendering

Greater consideration needs to be given to the selection of the team, which is assembled at the project planning stage. It seems from the interviews that the lowest price bid does not establish which team is the best placed to deliver the project but rather it focuses most just on the party who submitted the lowest price. As stated by interviewee 27, a BIM manager in an architectural firm: *'most clients prefer the lowest price knowing that there'll be heaps of variations that come in and they'll be changing every time that something changes. Whereas there might be someone else whose base price is slightly higher, but the value is far greater because over that time they can accommodate the changes, they've got flexible systems.'*

Moreover, lowest price tendering does not lead to great innovation but rather often favours the price at the expense of quality. In a similar opinion as the above, interviewee 2, a BIM leader in an engineering firm, stated: '*In a majority of cases, it comes down to affordability and it comes down to cost, but having a focus on cost doesn't give you the right outcomes in all those other areas.'*

Moreover, it has been argued that parties who contracted at the lowest price, which forces more aggressive competition and reduces their margins to secure the new contract, have the tendency to act right from the beginning with the claim and blame mentality in order to recover their profit. Interviewee 13 stated:

'At the moment the binding process is very much focused on the lowest price, and you almost have to hope for changes and claims that you make a margin at all. So, that isn't going to lead towards great collaboration'.

As a result, the final cost does not match the initial tender cost. The study conducted by Odgers, Rowsell, Thomas, and Ward (2011) suggests that collaborative projects are 15% more likely to be completed on time and 44% more likely to be completed within budget than those led by traditional routes such as lowest price tendering.

4.2.3 Parties' relationships

One of the key characteristics that often leads to poor outcome is the lack of a holistic view by all project participants over the whole project life cycle of the asset that they are going to design and build. Indeed, the linear and sequential approach of engaging parties under traditional delivery methods is rarely able to provide the best project solution: *'all the stakeholders get appointed differently along the project timeline; it is hard to say what the best solution is from the start because you do not have all those other people input' [interviewee 4].* The way in which the contracts are built, with a huge gap between designer, contractor and subcontractors, represents a missed piece of collaboration in which a lot of knowledge and information is lost. '*The sub-trades have really amazing knowledge on how they do their work, and it is not captured many times on the design side of life,'* stated interviewee 39, a BIM consultant and researcher.

Conversely, several constructability issues, which are complicated and expensive to fix if left in the late construction stage, could be potentially resolved by overlapping different stages and involving the contractor and main suppliers at the earliest phase of the design. This approach requires major effort, time and cost at the early stage of the design in comparison to the traditional method. However, due to the higher level of design completion, the initial effort will then be repaid by less effort and risk during the construction phase, as mentioned by interviewee 33, a business manager in a construction firm:

'If you brought in the trades earlier on to look at the project and integrated them into the process, you would have way fewer - you'd have to spend more money upfront to get the right things going, but you spend it and at the same time you shorten the cycle of delivering the documents that are more quality, higher quality in terms of perfection.'

Although, a few designers showed they are concerned with the idea of the early engagement of the contactor in the initial stages of the design due to a lack of a common goal and vision between the two parties. Indeed, where consultants struggle the most is to make sure that the architectural intent is still maintained through the process when a contractor is engaged early, as has been highlighted by an architect – interviewee 22: '*The best design outcome might be a concrete building, but they* *(contractor) might suggest against it because they can do blockwork better, so you end up with this tug-of-war. I still think that there's benefit in having some silos.'*

Designers have the perception that having the contractor on board early does not necessarily drive to a better outcome in term of quality of final product since the contractor's decisions are driven merely by cost. For example, according to interviewee 11, an engineer consultant, contractor's attitude is driven only by cost: *'essentially they want to build the things as cheaply as possible and go to the next one'*. Interviewee 4, a BIM manager for an architectural firm, believes that right now not much value and reward come back to the designer due to the adversarial set-up of the current contract model: *'it's quite adversarial right now, the way the contract is set up, because as soon as the builder gets on board the designer's almost scared that, what are you doing to my design?'*. The same interviewee highlighted the different approaches to the design when collaborative contracting is used: *'if it was an IPD-type contract with that shared risk reward it would be, "let's work together to work out how we build it quicker and still maintain your design intent, and we'll share whatever reward we get from that", and I think that's the difference between IPD and the D&C'*.

These challenges are aligned with the study of Sødal, Lædre, Svalestuen, and Lohne (2014) on assessing the advantages and disadvantages for the design team when the contractor is involved in the early phases of design. They found that consultants typically perceived the contractor's attitude to have a distinct focus on cost and time and for this reason some consultants prefer the traditional silo design, believing that quality will be better maintained.

Moreover, when the interest of the parties is not aligned, the relationship between consultants and contractor do not appear to be always driven by principles of collaboration, open communication, and trust. Although the contractor is on board early this does not necessarily drive the expected collaborative behaviour. This seems to be true when the contractor is the party most likely to assume the lead position once the contract is signed. Interviewee 7, an engineering BIM/DE leader, believes that *'in a D&C environment consultants are sort of bullied, I mean, they are bullied when they move into a contractor environment'*.

The same dynamics have been reported by interviewee 5, also a BIM director in an engineering firm:

'You can have the contractor at the table and it's still quite an adversarial setup. Some contractors are still driven by dollar and risk allocation and they'll just try and re-built their authority on that process'.

Indeed, under Design & Construct the designer is still a sub-consultant of the general contractor: *'they do not have a shared risk and reward structure between them, so it really changes things when the main designers and builder are literally a collective enterprise [interviewee 34]'.* The hierarchic relationship between designer and contractor has also been emphasized by interviewee 35, a client business manager: *'So the design team is not brought up at the same level or at the same table and you don't have the same sort of representation or voice in the process as you do under IPD.'*

In light of this, interviewees 12, 28, 32 suggested that a collaborative solution between client, the delivery team and the supplier would be the preferable route to deliver the better outcome. As stated by interviewee 8, *'if all agree what they're trying to achieve and they reach a common agreement and goal for that, then they're able to drive a better solution'.*

Importantly, collaborative contracting enables the highest level of collaboration and integration because the key participants are engaged from the earliest practicable moment and they are all involved in the decision making. Additionally, parties are all aligned and committed to the best for the project behaviour and there is no space to blame each other. According to interviewee 7 - an engineering consultant - *'collaboration needs to be driven by a design-led process with the client and everybody involved in knowing what is important to everybody else, and to understand everybody else's perspective'.*

Under other types of models, more effort needs to be expended to achieve a similar outcome. In this case, setting goals, establishing incentive systems and reward structures could be beneficial.

4.3 CHALLENGES AND CHARACTERISTICS OF COLLABORATIVE CONTRACTING

4.3.1 Current challenges to collaborative contracting adoption

Collaborative contracting is often criticized for being too expensive and hard to quantify if it delivers value for money, as team selection is not based upon a competitive process but by using non-price criteria. In this regard, a few comments have been reported by interviewees in favour of collaborative contracting against traditional methods. According to interviewee 24, a business manager in a construction company:

'People have been maligned in terms of that they're too expensive, mainly because people are just looking at the cost of the delivery methods for that particular thing. But they are forgetting in other contracts, all the other work that got to the point to generate the design and all the other requirements around it should be included in the price of delivering that project, and the fact that the project may not actually deliver what the customer wants either.'

Similar considerations have been reported by a Lean/BIM consultant - interviewee 37:

'People have to be careful thinking about total final cost versus front cost, and so in some of these more traditional procurement models, you get a fixed cost, but when you factor in all of the external costs with change orders and claims costs and litigation costs and all those things, your final cost may not be quite as competitive as you thought it would be.'

Interviewees 34 and 38 consider contingency another important issue that the clients should contemplate when they are choosing the most appropriate delivery method. Contingencies typically refer to costs that are held to deal with unknown risk associated with a project. According to interviewee 34, a client business manager:

'There's always going to be the risk of contingency being more than people think it should be. But what you have in IPD that you don't always have in other methods is, you have more transparency and you have the ability for the owner to be much more deeply involved in the cost exercises and reviewing cost estimates and being part of the core group or project management team, to be involved in all those discussions. So, it's much harder to hide things from the owner when you're in an IPD open-book, you know, fully transparent culture and set of practices'.

Same considerations were presented by a construction lawyer, interviewee 38:

'IPD tries to address the problem of stacked contingency. So, in IPD, the team will have a pooled contingency that's shared among the team to use, instead of each party holding their own contingencies. The sum of everyone's conservative estimates -

when you add it up, I'd guess, you know, seven or eight or nine times out of ten, it's going to be more contingency than if you did the other approach. So, the owner ends up paying more than they would've needed to. That to me seems like also a big idea in favour of moving away from traditional project delivery compensation method'.

Many government clients often use some hybrid form of alliancing, and IPD, which partially incorporates the above characteristics. However, while in the US the regulation and law can preclude entering into a multi-party contract with profit and risk sharing, in Australia there are no such restrictions. Nevertheless, clients do not feel comfortable to share the risks and embrace a no-blame concept, as was pointed out by three construction lawyers, interviewees 17, 30, 31. According to interviewee 30, *'Clients think risk management is risk transfer and they turn alliances into these risk transfer contracts, which they're not meant to be, they're meant to be about risk sharing'*.'

Interviewee 17 believes that*: "The no-blame is fundamental, if you want the high level of collaboration that an alliance can deliver, because as soon as the parties can blame one another to try and recover their loss - well, then that's what they will do. And as soon as you can be blamed if you make a mistake, then you'll start taking steps to protect your legal position'.*

This has been emphasised also by interviewee 31: *'The no-blame framework is extremely important, and that's the stuff that's hard to communicate to people who just think, oh, you stuffed up so you should pay for it. It's like, well, someone stuffed up, but we should figure out how to fix it rather than figuring out who stuffed up and who to sue'.*

The hybrid forms, therefore, are not necessarily going to deliver as good a value as the pure forms, where parties are free to be innovative without fear of being sued as soon as problems start arising. Interviewee 30 is very clear on this: '*if you want to get the advantages of alliancing, you have to take the stuff that seems scary or risky - because it's a structure, it's built a certain way, it's built with a governance framework, it's built with best-for-project and mutual sharing of risk, which allows you to share the downside and the upside, and it allows innovation and creativity and all the good things you want in a project*.'

The challenge, therefore, seems to be educating the client about the benefits that they can get from a collaborative approach: *'convincing them that risk sharing means these things and it actually gives you a better value-for-money outcome, because you avoid disputes, you avoid massive problems, and you create an environment where people can get on with the job and actually solve problems rather than positioning to make sure they don't get sued for the problem.'*

Key characteristics that are required to establish the ideal environment for collaborative contracting also emerged from the interview findings. To do so, both alliancing and IPD are taken into consideration, outlining the difference and similarities between these two approaches in terms of commercial agreement as well as project culture. In particular, IPD differs from alliancing by deploying Lean principles in the management of the project. By using Lean management tools and setting the behaviours required with them, interviewees 33, 35, 37, 39 believe that it enables the building of a strong project culture based on collaboration, open communication, mutual respect and a common goal. Paragraph 4.3.3 outlines the benefits of using Lean management within a collaborative contracting project.

4.3.2 Type of project

Collaborative contracting can be used in any type of infrastructure project as well as vertical project. In the building sector they are used mostly in a number of healthcare facilities, commercial and educational buildings. In the infrastructure projects they are being predominantly used in civil as well as transport infrastructure projects including road, railways, airport, pipeline, tunnel, and bridge projects.

Generally, they are the preferable procurements choice when projects are complex, scope of work is unclear, risk is significantly uncertain, the timeframe is short and community and stakeholder interest are critical. In the building sector, when a project presents very complicated functions and systems that need to be integrated as well as the need for aesthetic space, collaborative contracting is considered the best solution. In this regard, the US experience in IPD has highlighted how collaborative contracting can deliver successful high performing buildings.

Regarding the dimension of the projects, generally speaking collaborative contracting has been used in projects ranging from \$2 million to \$1billion and more. In Australia, collaborative contracting has been predominantly used in large projects with project costs in the range of \$100m to up a billion, while the majority of IPD stay on the range between US\$15m and US\$200m with some exceptions.

Collaborative contracting requires more effort and time to stipulate the agreement and build an integrated team. Therefore, clients usually use traditional forms of contracts for small projects because the effort and additional cost needed for a collaborative delivery method is not justifiable for such small projects. However, based on their own experience, interviewees 34, a business manager in a client's organisation leader in IPD projects in the American construction market, stated that if the client and the team already have experience on IPD, this type of contract can be used for the smallest projects starting from US\$5 million, while for inexperienced clients US\$20 million is considered a good place to start as the job is not as long *'because you're going to make a lot of mistakes the first time through, so you want a job that finished relatively quickly so you can learn and start over.'*

4.3.3 Contractual arrangement

Team Composition

Collaborative contracting adopts a quality/capability tender selection process. The team is not selected based on price but rather, is chosen based on competence and ability to collaborate, which allows each project member to be aligned with the project goals. The advantage has been highlighted by a construction lawyer, interviewee 17: *'With the alliancing contracts, there's a much bigger focus put on the non-cost items. And I think as a result that does lift the industry, and it gives the different parties - whether the contractor or the consultant - give them an insight into how each other operates and the various drivers and the goals that each party will have, and then allows you to take them into consideration and actually get a common set of goals and drivers for a project that you're all working towards'.*

Interviewee 25, a business manager in an engineering firm, reported the experience during a tendering process within the collaborative contracting framework:

'It was a qualifications-based selection process with some competition on margins and rates and things like that. So, there are two parts to that competition - but

in reality, what dominated in the end was the quality of the people and the methodology for that part of the work. So, we had an interview and a workshop, and another team had an interview and a workshop, and they compared the attributes of the people involved in the interviews and workshops along with their assessments of their background through the CVs, to see which the preferred team to work with was'.

Interviewee 42, a business manager for a client organisation, outlined the key point of the team selection under collaborative contracting. The focus is to find not the best individual people, but rather to select the people who have the ability to work together, as reported: '*We're not going to be appointing the successful architect, the successful structural engineer, and the successful constructor individually; what we're going to be doing is forming an alliance, we have to form a judgement as to who will be the best to work with, who to form the alliance with.'*

Interviewee 36 also believes that how people's personalities and their ways relate to each other is a key factor in order to assemble a high performance team: *'Under collaborative contracting the composition of the team is your most important asset. You can have a really good company, but you get some people on your project that just aren't of the right mindset: they're not very collaborative, they might be sort of old-school in their approach to construction, finger pointing and blaming, that kind of thing, and the project just won't go well. Personality really matters, I guess what I'm saying is, your ability to work together with other people. That's probably the biggest factor in whether an IPD project succeeds or not.'*

The goal of team selection is to involve project participants that are engaged and aligned with the project' culture. The biggest factor is not selecting an organisation on the bases of their credentials but selecting the best combination of key individuals within each organisation to build a cohesive team. There are several processes that can be used during the selection stage. The traditional mechanism is around workshops and interviews, which are considered good opportunities to assess the core team's ability to work together and not the individual company. In some cases, it can happen that the client provides to the potential team sample problems to resolve in real time to demonstrate their ability to work collaboratively.

Some clients also use psychometric tests and similar tools to secure the best combination of personalities within a team. For example, interviewee 35 uses the Patrick Lencioni Tools, "5 dynamics of a Team" where through 15 questions, a survey gives a score on trust, conflict, accountability, commitment, results. Another tool cited by interviewee 34 is the Myers-Briggs Type Indicator used for psychological assessments.

Team Integration

The collaborative contracting agreement is a multi-party agreement, which includes the client, the design consultants and the general contractor. The agreement brings all the parties under the same rules and contract conditions. As stated by interviewee 39, the contract plays a key role to set the foundation for building the team and the project culture: *"you need the contract there to keep people accountable to push in the right direction".*

The key point of collaborative contracting is having all people that can influence the project sit around the table, to quote interviewee 32, a construction business manager , *"the best thing is when they're all sitting at the table together, because then they're all involved in the joint decision-making and they're all involved in the management of the project."*

However, while under IPD, interviewees 34 and 39 reported that in addition to the client, architect, and contractor, key participants commonly include engineers and trade subcontractors - such as mechanical, electrical and plumbing designers and contractors and depending of the project, also structural steel, framers, and curtain wall contractors - alliancing rarely includes other participants outside the three main parties: *'seem to focus on the client, designer and contractor relationship rather really encapsulate a whole range of parties to the project' [interviewee 16].* Indeed, this is one of the main points where alliancing should be improved, according to interviewee 1, a BIM/DE director in a client 'organisation:

'The designers, the engineers, the consultants may or may not be part of the actual alliance contract. They might just be contracted to deliver design services to the alliance, but they're not part of the pain-gain type incentive pool. I think that's probably where it could get better. It would be probably within everyone's interest to have certainly some of the specialist subcontractors be part of that as well, to have a seat at the table.'

From a designer perspective, interviewee 4 highlights the benefits that could be obtained by an early involvement of sub-consultant and sub-contractors:

'It'd be much more productive and interesting if we could have that end supplier or subcontractor, or sub-consultant, or whoever they are - having some sort of feedback loop to the designers, so as the design process goes along they are collecting the knowledge of the people fabricating and installing whatever it is to mitigate that kind of information mishandling or double handling or reviewing at a later stage.'

The same view was emphasised by an engineer consultant, interviewee 6:

'I think when you're going to get the real benefit is when you get that supply chain informing the design processes to the selection of products and procedures and methodologies that they know work, from their experience'.

Interviewee 43, a BIM leader in a UK engineering firm, enthusiastically reported their experience in working in a collaborative contracting type of model with early integration of key suppliers:

'Some of the suppliers were really excited with the fact that at least they were having a role to play, they would have a role to play in influencing the design, and they were coming out of their shells and they were being brilliant.'

Typically, in IPD projects, key consultants and suppliers are added to the core team at the time their contribution can affect the project goal as the project progress. They might all sign the IPD contracts or alternatively, clients, designer and contractor sign the IPD contracts and the other parties are typically subcontracted under one of the primary signatories under the same business terms and have their profit at risk. The choice then depends on the client; their past experience and its relationship with the trades. However, regardless of the approach selected, IPD emphasizes more than Alliancing, the importance of extending the core team by including key consults and suppliers, *'as their knowledge impacts the design and therefore it is necessary that these parties cooperate for the project to progress smoothly [interviewee 38]'.*

Compensation and incentive system

One of the main features of collaborative contracting is the commercial and risk allocation framework. Under collaborative contracting, the risks are not allocated to different parties but rather they are shared through the gain share/ pain share model among parties. The commercial arrangement is designed to align the team and drive 'the best for the project' behaviour, ensuring that the client's goal is achieved. According to a construction lawyer, interviewee 38: '*this approach motivates the team* *members to come up with innovative solutions that do not interest only one discipline but encompass all those firms that are involved in the project*'. As a consequence, *'everybody is much more aligned to kind of optimise the whole project as opposed to their one little piece',* stated interviewee 34, a BIM/Lean consultant for a construction company.

All the parties that signed the collaborative contracting agreement will either win or lose together, *'savings for any company on the job gets paid out as shared savings to every company on the job' [interviewee 35]*. They create a virtual organisation that shares goals and values and '*all the people that have put profit at risk are in the circle of love. They're all tied together and so they're not going to act self-interested as much - because whatever they do, if it hurts somebody else that's in that circle it's going to hurt them as well, they're going to get hit the same way [interviewee 35]'.*

A collaborative contracting model should consider as key participants not only the client, designer, and contractors but rather all the parties whose contribution is critical to the success of the project. For instance, interviewee 43, a BIM manager in a consulting engineering firm, brought attention to suppliers and their important contribution at the early stage of the project: *'The suppliers have enormous knowledge and they should influence the design. So, the collaborative culture and the integrated approach goes as fast as we can make it down the supply chain, as soon as we can make decisions as to who we're going to have on board. Once they are on board, they can give all their wisdom without worrying it's going to be given to the competition.'*

In this regard, an issue this study identified is the importance of defining a strategy to establish which companies will need to be a part of the gain/pain model and which companies will be outside. The majority of the interviewees that have worked under collaborative contracting reported a difference in behaviour and culture between parties whose profit was in the risk and reward compensation model to participants engaged with the traditional contractual arrangement on the fixed price bases.

Indeed, interviewee 23, BIM leader in a construction firm, believed that the people within the compensation model *"are more relaxed and more willing to share information and less worried about getting it wrong"*. While participants outside the compensation model tend to act for their own interest, as mentioned by interviewee 17, a construction lawyer: *'Absolutely, that would be evident in the way subcontractors to the alliance would behave, because often the alliance would enter into a traditional* *fixed-price conventional contract with the subcontractor. And so, the subcontractor, having agreed on a scope and a price, is looking to do the bare minimum to meet its obligations so it can maximise its profit, and if there's some problem the subcontractor is motivated to adopt a position that minimises its costs rather than adopting a position that minimises the cost of solving the problem to the owner'.*

Therefore, careful consideration needs to be taken to identify the key parties on the top of the client, main designer, and contractor that will be part of the commercial framework. *'You have to think very carefully who you would put on a fixed price,'* interviewee 41 stated. It has been suggested that the compensation model should be extended to all key parties who have a significant impact on the project outcome and their behaviour needs to be guided. The key party may be the one whose work needs close collaboration with other parties, or the one whose service provides a significant portion of the project cost in the duration of the project.

As commented by a construction lawyer, interviewee 36, '*the whole idea of collaborative contracting is protecting risk, is managing risk, so things that are risky you should want to bring inside of the risk pool*.' Interviewee 25, a business manager in an engineering company, provided a clear example in this regard: '*You're going to build a railway line or building on old landfill, okay, and you've got a specialist contractor in there who's going to treat the old landfill - the dump, you know, waste management facility. And you don't really know what's in the ground, and you don't really know what contaminants are there and whatever - and so you're going to quarantine that risk with a performance-based subcontract to deal with that. But I wouldn't include the supplier who's going to supply the asphalt or the railway lines or the electrical wiring or whatever, because that's not a risk item, it's a transaction that is well-defined'.*

Depending on the dimension of the project, many parties could be involved in a single major multi-party contract, which then makes harder the work for the board. The option could be to have a structure of governance where there is a head board and then sub-boards that are dealing with different issues: "*you've got an alliance, that's a head contract; we would just have sub-alliances dealing with that one subcontractor, and we would call it back-to-backing the contract. So, the contract terms would be very similar and the risk-reward regimes would be very similar, but in that sub-alliance it is just related to the work that that subcontractor is doing' [interviewee 25].*

The second important point is to incentivize the parties outside of the pool to share the same project's goal and value and align them with the type of culture expected under collaborative contracting. For instance, according to a construction lawyer, interviewee 38, this could be useful in establishing a performance incentive structure to pay the subcontractors, thus encouraging them to work to the overall objective.

No-blame culture

Collaborative contracting is also built around the 'no blame' culture, which is a cultural aspect that parties try to enact through the on-boarding process and establishing a team culture. Parties cannot seek redress and cannot sue: *'it eliminates finger-pointing - because all the people that have put profit at risk, there's no benefit in finger-pointing [interviewee 35]'.* The contract is developed to not allow a win/lose approach, the type of behaviour is described in an example provided by interviewee 17, a construction lawyer: *'hey look guys, we've got a problem here, there's a hole in the boat and we're sinking, we'd better work cooperatively to find a solution before we all sink.'*.

According to interviewee 43 the no-blame framework *'only works if there is a good insurance regime.'* Indeed, the idea of collaborative contracting is that the insurance is there to respond to a loss being suffered by the integrated team, and if the insurer could then sue the team member who did the wrong thing, then that would undermine the whole 'no blame' concept.

Insurance

Under collaborative contracting, it is very important to get the insurance right. The basic principle is to have an insurance regime that protects everyone equally so that everyone can focus on doing the job in the first place and if a problem arises, focusing on getting the right outcome.

From the legal side, according to interviewee 43, a BIM leader in an engineering firm in the UK, *'the no blame framework only works if there is a good insurance regime*'. The involvement of several parties in the design phase should result in a collective responsibility rather than allocate responsibilities only to the design professional. Collaborative contracting usually has a project-specific insurance policy that creates an umbrella for the whole team, which has been described by interviewee 42, a business manager for a consultant firm in the UK.

‘So, if there is a design error, you don't have proof that the person was at fault, just that the error occurred. The insurance covers it regardless of whose fault it is, so let's get on with the job. Where if it's normal Professional Indemnity insurance, you would say: “designer, you stuffed up, we're going to sue you” and the PI will come in to cover. And so that drives totally different behaviour and outcome.’

In the UK ,a new insurance scheme called ‘Insurance Backed Alliancing’ was developed to encourage more collaborative models of procurement and project delivery (Integrate Project Initiatives Ltd, 2014). The insurance policy developed by the brokers Griffiths & Armour, covers all parties for all risk, including third party liability, delay in project completion, cost overrun and also latent defects for 12 years. The policy allows for a no-blame, no-claim structure where the percentage share taken of the gain is equal to that of the pain. Dudley College is the first project delivered with IPI. To give an idea, on a £10 million project (~ $18 million) about half a million pounds would be the excess, £2 million (~ $3.6 million) would be the insurer's indemnity, so it's only if it reaches about £12.5 million (~ $22.5 million) that the client would start to pay, apart from his share of the pain share, of course. However, only projects in the £10 - £25m (~ $18 - $45 million) range are currently suitable to make the level of cover viable. Thus, the issue remains that only a few insurers are offering cover for cost overrun and this cover still has low limits. Interviewees 42 maintained that to increase the adoption of collaborative contracting, the insurers should gain confidence and prepare themselves to innovate and invest in skills to offer reasonable levels of cover as a key element.

4.3.4 Lean management

Relationships between lean and IPD

Collaborative contracting represents a drastic cultural shift in the construction industry. They require all the input from designers, constructors, trades, and suppliers to help clients understand their needs and select the best solution to translate the needs in the outcome. As opposed to the master-servant relationship, which has characterised the industry for many years, the collaborative contracting requires creation of a work environment where people feel free to express their full potential.

The parties are not involved just to provide the means to accomplish what the client is thought to need, but rather to come in with their own ideas and bring the best of themselves to the project. It is about collaborative effort that involves trust. According to interviewee 34, a BIM and Lean consultant: ‘*an employee in all levels needs to feel psychological safety to make mistakes, take chances, and move forward with something that doesn't really work’*.

IPD is often referred to as Lean Integrated Project Delivery to show the strong relationship between the contracting method and the implementation of Lean principles in the management of the project. An expert in IPD, interviewee 37, stated that the use of Lean is fundamental to achieve the benefit of collaborative contracting since just setting up an alignment contract does not guarantee that people will change their traditional mindset: *‘if you have a party who is by culture risk-averse, they don't necessarily know how to work together, so things like pull planning and weekly work planning and tracking PPC and variances, culturally it's a big shift’*.

Therefore, while the contract aligns the team financially and acts as an accelerator to the ability to collaborate: ‘*It really forces them to stay, even when hard conversations happen [interviewee 35]’*. The Lean principles and tools provide ‘*the means to effective collaboration [interviewee 35]’*. Interviewee 13 described Lean as *‘a completely novel concept about including everybody, considering your supplier as your client’*.

Barriers

Lean principles and tools can be used also under any construction delivery methods, however, the benefits can be limited by the contractual relationship among parties:

‘When you're transferring risk onto trades in contractors, you can set values and you can try to do Lean on these jobs and I think it will help them significantly, but you're never going to take it completely out with the way the contract's built’ [interviewee 39].

According to interviewee 35 the effective adoption of Lean depends on the level of team integration and therefore, some procurement models can obstruct its adoption*:*

'While Lean really can help drive the collaboration into the project, it's hard to use on a strictly traditional project because you don't put it out to the contractor until everything's designed. So, you're missing that whole front end during design, of having all that collaboration during design to eliminate, you know, build conflicts, bad design - not the most optimal design because you don't have all the different disciplines interacting and coming up with ideas. But in IPD, you can engage in all that same stuff because you procure your team together early.'

One of the main principles of Lean IPD is to *'optimise the whole, not the parts [interviewee 14]',* which means that all the parties are aligned and work together to achieve a certain outcome. This approach is opposite to just optimising a part of the process *'that will de-optimize the process as a whole [interviewee 14]'.* By bringing all the key members - client, designer, contractors, trade contractors, and suppliers - together from the start to define options, evaluate alternatives and find a solution, IPD allows for clearly defining the value for the client and set the team toward that outcome.

Lean tools

Interviewees 34, 35, 36 and 37 mentioned several Lean tools that are used during the design stage to find the 'fit for purpose' solution: including the target value design, set based-design, and choosing by advantages. The BIM model supports this process by providing high-quality design and faster analysis of the design alternative to fulfil the client requirements. As reported by interviewee 34, '*all those tools are based on the idea that you're creating and understanding objectives of the teams and what they're there to do and define those very clearly*'. Therefore, the integrated scenario of BIM and Lean tools during the design development *'considerably helps the teams to navigate that process [interviewee 38]'.*

The use of Lean principles and tools are often required within the IPD contract. Moreover, to ensure the same level of engagement with the parties outside the IPD core team, the contract with sub-trades also often states that they will need to participate and be engaged during the last planner system planning: '*you will be doing last planner system planning, you will attend meetings and participate in the pull* *planning, weekly work planning [interviewee 40]'.* Having the contract with the sub-trades, which states that they are going to apply lean tools as well, helps to create a sense of awareness to enter in the project *'with a different mind. On other jobs guys can just say, sorry, we're coming in to do our work - you know, they can do that because it's not in the contract' [interviewee 40].*

One of the most powerful elements of IPD during the design process is the target value design (TVD). It is a collaborative design process used to prepare a validation study and it involves all parties including designers, builders, suppliers, estimators, and clients. It embodies the five Lean thinking principles, starting from identifying value for the client/customer, followed by the value stream map and successively promoting flow and finally promoting pull. During the TVD process, several Lean tools such as set-based design, A3 problem solving and pull planning are used.

The principles of Lean are to deliver value to the customer while eliminating waste. In this regard, the most interesting factor of Lean is the way in which it looks at the customer and how to deliver value. The customer is no longer only the end client but everyone who needs a previous work done in order to start their own activities. Lean practitioners believe that is the game changer.

'The way that's made its way into the design space is really interesting. It has a slightly different view of who the customer is, and how we deliver value - it's not just the very end-user client, it is whoever you hand off your work to. If I'm an architect and I hand my design to the structural engineer, the structural engineer now is my customer and I need to provide value, not only to the building owner but also to the structural engineer. So that process forces sort of a different lens on how we walk through and what is valuable versus what is wasteful, in terms of how we work with our colleagues."

The Last Planner System (LPS), is another pillar of Lean construction and IPD projects: *'it's a tremendous approach to getting this sort of collaborative process and commitment-based planning'*, interviewee 13 stated. It can be used both during the design and construction. During the construction phase, the LPS focuses on improving workflow as well as plan reliability. It is developed in four levels of planning steps: master schedule, phase pull scheduling, lookahead planning, and weekly work plan or commitment planning. The IPD creates the best environment for the LPS since it involves all parties, including suppliers in the development of the planning stage, to open up the conversation between the people that actually are performing the job: *"In IPD projects all the team is engaged in the planning process, including subcontractors. Everybody introduces themselves by their role on the project, not by their company and works together to define a more reliable planning. Team performance is measured through the percentage of task completed, if you hit that date you're doing okay on the schedule; if you set steel a month later than that, you're behind schedule. And this check is done weekly to align with the rest of the projects' [interviewee 34].*

During the design, the Last Planner System is carried through in a slightly different way, since there is not the same ability to forecast as precisely as happened during construction. As explained by interviewee 38:

'*The design it's more iterative, so you don't have the ability to forecast as precisely how long it will take to do something. So usually, it gets into more about, what is the information or what is the deliverable that needs to be handed off? And that can support a well-defined BIM strategy'*.

4.3.5 Project Culture

To ensure collaborative contracting succeeds the cultural aspects are essential and a big effort is needed to ensure that the culture is aligned among all teams.

According to interviewee 3, a construction business manager, the actual key to the success of the model is the background work that happens with the team *'the alignment of the teams and basically that working together actually gives the outcome rather than the financial incentive.'*

However, to build that culture into a high-performance team a lot of work needs to be done. *'You can't let it happen by accident, you actually have to plan for that'* interviewee 31 stated. According to interviewee 17: *'more effort needs to be put into the front end. Now, when you look at the stages of team building - the forming, the storming, the norming and the performing - and acknowledging that that takes a certain amount of time. People are not acknowledging that the more you leave the team to itself, the longer it's going to take.'*

In this regard, three key factors have been found that help to establish and drive the culture: 1) client leadership, 2) the involvement of a facilitator and 3) co-locating the team.

Client leadership

According to the majority of the interviewees, the client plays a critical role in the success of a collaborative contracting project. The client's vision, commitment, and support to undertake this type of delivery method are critical to ensuring that all people are on board with the same level of involvement: '*if they've got a particular interest, it's going to flow through down the rest of the entities [interviewee 25, engineering business manager]*'. For many people it may be the first experience on a collaborative contracting project and the top-down approach is essential to drive the cultural change: *'the client needs to lead the behavioural change and to do that, needs to show a high level of commitment [interviewee 14, construction business manager]'.* According to interviewee 26, a BIM director in a client's organisation: '*Clients need to be very forceful and enthusiastic in demanding more integration and collaboration'.*

The client's project manager role and attitude are also critical to the success of the project, as stated by interviewee 37: *'he/she needs to be transparent, to ask uncomfortable questions, to really dig and make sure that no stone was left uncovered. As opposed to being more of the laid back, you know, 'you tell me that everything is good and I'll trust you that everything is good', and it's sort of trust on a handshake and not trust in transparency.*"

In this regard, it has been pointed out that some project managers may not have previous experience in collaborative contracting principles and tools, and therefore the risk is that they will assume the traditional behaviour, which is against the collaborative attitude required in collaborative contracting. Therefore, coaching sessions and training need to be put in place to ensure that project managers have the sophistication to lead a collaborative contracting project, and the knowledge to use the Lean tools, such as the last planner.

Coach/Facilitator

A coach or facilitator is considered extremely important by many experts involved in collaborative contracting. The facilitator provides an essential role in training and guiding the team, particularly unexperienced teams, through the process, especially during the front end to align the team and make all parties feel that they belong to a unique organisation and not anymore to a single company. Based on their own experience in collaborative contracting projects, interviewee 30 believes that:

'The facilitator has a really important role to make sure everyone has the right mindset, because it's a new way of working for a lot of people, and so that the alliance can form its own unique culture. So, you can get the same brands but people who've never worked together before, and you can have the same problem. And that's why the facilitator and that cultural piece is so important, to be able to get them to be a cohesive team.'

Likewise, interviewee 13 considers that *'a facilitator is essential to build the collaborative team behaviour necessary for a collaborative and integrated project'* however they also added the importance of having tools and processes to maintain the culture and really check regularly '*through surveys or interviews that you still have the culture that you want to have in the project'*.

Interviewee 6 reported their experience of being coached*:*

'So, the coaching - a good coach - and that team-building exercise, I always thought it was a bit of fluff, but now I see it as being a very, very important and valuable exercise. We all started really caring about each other and it completely changed the dynamic.'

Interviewee 41, a BIM manager in an architectural firm, was involved for the first time in a collaborative contracting project as well as the rest of the team and they found the role of the facilitator paramount for starting the transformative journey required from this type of model.

'It was extremely important on the first project, because, you know, we really didn't know what we were doing - so having that guidance there and that sort of voice there to question what we were doing, why we were doing it in a certain way, was really important, otherwise it never would have succeeded. If you're doing something so entirely different like that, you need that facilitation there to guide you through the project.'

Another important argument was made by interviewee 41, who sees the role of the facilitator as an essential element to enable insurers to gain confidence in this new procurement system. Indeed, new types of insurance models are emerging in support of the collaborative working environment, however for the insurers, *'the biggest risk is if people start falling out, so it's absolutely essential to avoid disputes arising and the facilitator by providing regular report to them, helps to build the trust and confidence'*.

The facilitator is a third party that is engaged for an initial workshop and follow-up during the project. In particular, this is if presence is required when new participants are coming into the project or when any reinforcement in positive and collaborative behaviour is needed.

Some client organisations have started having a permanent role of a coach whose role is to facilitate from day one, the creation of the team. In an IPD project, it is preferable that the coach/facilitator has exceptional interpersonal and communication skills, and knowledge on lean principles and tools to help build a thriving culture.

Co-location

Co-location is considered among participants as an incredible means to foster collaboration through greater team integration by physically collocating the client, designers, engineers, and contractors. According to the experience of interviewee 25, a business manager in a consulting engineering firm, '*we couldn't achieve what we're doing without co-location, it drives what's best for project mentality'*. The same concept was expressed by interviewee 20, a construction BIM manager, who perceived significant benefits out of co-location, especially on big and complex projects that required the integration of several systems. Likewise, interviewee 5, a design consultant BIM director, considers co-location as an essential approach for creating the type of environment and culture that drives a successful outcome:

'I'm a big fan of co-location, people sitting in the one room and what's best for project mentality. And that's why the big construction projects work quite well: because people are in on it for three or four years and they're working for the project, not for their individual companies. So, breaking down that silo mentality, that's because I'm the architect I'm only going to do the architectural, or because I'm the engineer I'm only going to do my engineering, and you guys can figure out how to coordinate and make sure it actually works together. So, I think, yeah, that co-location would certainly help.'

Therefore, co-location allows a project team's coordination to be very effective, reducing the time for informed decision-making, enhancing productivity while reducing waste of reworking, all of which makes co-location an important Lean tool.

The benefits are stated by interviewee 33: *'The key is eliminating rework by co-location. Why I say that is because co-location means you're going to be able to reach across the partition and say, "what do you think about this idea?" versus sending out an RFI. And really, in that world where you would send a document, the problem is you're not face-to-face and you can't get the subtleties - it eliminates a lot of the subtleties of making good decisions'.*

4.4 BIM ADOPTION IN CONSTRUCTION PROCUREMENT

4.4.1 BIM value for client

Within the Australian market, to date, there are many contractors that have developed internal BIM procedures and frameworks without the client requiring them to do so, and they are educating the consultants they appointed to do the same, as reported by interviewees 8,20,23,29, BIM managers in different construction companies. Likewise, BIM is used by many consultants who have a BIM process in place for their own advantage, assisting their sub-consultants to become capable, as mentioned by the majority of the designer and engineer consultants interviewed. However, this approach is self-driven by individual organisations, which utilises BIM and information management to de-risk and optimise their own work.

So, what should be the client's role in driving BIM and more integrate practices? While some interviewees believe the client's role should be passive. Here reported is the quote of interviewee 7: *'I think they should be passive. I think that being very prescriptive will get them to an outcome that they may not use and may never understand'.* The majority stated that the client plays a significant role in driving innovation and therefore their role should be active. As stated by interviewee 15: *'I think the client needs to be active in a sense of defining what they want to be delivered, and knows how they want it to be delivered, then they should absolutely encourage that. And I think the more involved the client is, then the better the outcome, because the team will be more informed and they'll have a much better understanding of what the client wants to achieve'.* Interviewee 4 claimed that working in a project where the client doesn't believe in it *"that's hard"*.

According to the interviewees, the value of BIM/DE to the client is strictly linked to the type of client and the activities they need to perform. Indeed, according to engineering BIM manager interviewee 15, *'the value varies depending on the client, and there's value in a capital delivery stage - so, reducing errors and variations and things and essentially improving delivery. And then the second value is around the operational stage - so, just being able to have that complete set of asset information handed across to them'.*

During the design and construction stage, the BIM model helps to *'really accelerate the communication, as well as improves collaboration and transparency of the project [interviewee 33, business manager construction firm]'.* Transparency is considered the main advantage since it enables the client to better understand the risk of the project and understand how the project is progressing. This has been highlighted by interviewee 23, a BIM/DE leader in a construction company: *'clients very quickly understand what we are trying to communicate, and they very quickly understand where the risk is and if they're actually prepared to take that risk themselves. Because a lot of the times, a lot of these design meetings or program meetings that we have are to communicate risk and to essentially ask the client to take that risk or to ask the client to price the risk'.* According to interviewee 6, a BIM director in an engineering firm, the visualisation and simulation aspect enabled through the model have the power to better engage the client and raise the conversation to another level: *'they can begin to say, "oh, well I didn't know it was this late," or, "I didn't see this", or, "I didn't understand that," or, "this thing I need now - oh, I could put such and such a thing here, I didn't think about that before".'*

For a client who is not engaged in the operation and maintenance of the asset, they are more interested in the benefits they can get during the delivery of the project in terms of high quality of the project as well as certainty and reliability in time and cost. They may require the use of BIM for operation and maintenance, but they will not specify its requirement. An example of a PPP project was reported by interviewee 11 who also highlighted how the client's value is aligned with the procurement strategy: *"The consortium who are building it also have to operate for the first 50 years, so the client just wants to know that this information is being managed but really they don't care until the 50 years when returning back to them, and even then they might reengage the same operator to keep running it. So, the contract where it is* *required to deliver Cobie, the Navisworks model, and IFC model and they just want to know that is ticking over, they are doing things well, but they are not necessarily interesting to specify'.*

Alternatively, clients who hold and need to manage the assets will also have interest in clearly specifying the information for their asset management purpose, and therefore they are encouraged to actively take part in the conversation: *'I think client role is critical, because, it is their money at the end of the day. It is really important they drive it particularly if they want to do the operation side' [interviewee 11].* Interviewee 6 also emphasized the importance of an active client for the asset management purpose*, 'it's much more helpful to the entire project if they are involved from an earlier stage, particularly from an ongoing asset management, facility management kind of perspective - that's where the real value lies – and say, this is how we need the thing to perform for the life of the project, this is the information that we need to run the asset, these are the things we really care about'.*

However, without defining the purpose of why BIM is used and aligning it with the project goals, according to interviewee 5, the value of BIM for the client is debatable and often not realised: *'because that will be realised by the contractor or will be realised by the design team, but if the client's not ready for a digital deliverable, then the value to them isn't probably there'*. To cite interviewee 12, an independent BIM researcher and consultant: '*if there is no defined purpose to start with, there are no defined deliverables, and based on these deliverables there are no requirements - then it's difficult to measure whether a BIM project succeeded or not'.*

Interviewee 26, the BIM director in a client's organisation highlights that one of the biggest difficulties is the scepticism among a client's stakeholders to undertake change from traditional work practices because *'that's the way we've always done it'.* As a BIM consultant, interviewee 19 reported:

'on the client side one of the biggest problems I am having at the moment is politics or internally between people […] The people are what I'm finding are the biggest barrier at the moment […] because people are unaware of the technology and how it works, they're very quick to stomp on that process or push it away or say "we're not doing that" etc, where then you have to sit down and you have to explain from start to finish the process for them to come on board and be collaborative'.

To achieve the level of awareness within the whole client's organisation, the discussion needs to arise at the strategic level rather than at the technical group, involving all the stakeholders, who traditionally are not engaged at the beginning of the project, as reported by interviewee 1, BIM/De director in one of the main client's organisation:

'Clients need to have a strong vision, I'd say that's the most important, and they need to be able to articulate that clearly. They can't just communicate on a technical level, they have to have a clear message which resonates with people. […] So, it means that we're not just a technical group coming up with technical stuff, but also coming up with business outcomes.'

According to interviewee 26: *'There needs to be a recognition that behaviours have to change'.* In this regard, interviewee 4 believes that *'the education piece is huge to drive the change'.* The same concepts have been stressed by interviewee 12: "*Clients need to be educated in order to understand that the benefits of digital means, to make their business more efficient, save money, increase value, which makes the process more Lean and extends the life of the information to be used from design to construction to operation'.*

Finally, it has been argued that the journey toward a digital transformation will also require changing the way projects have been procured. To quote a client's representative, interviewee 26: ;*The procurement process needs to become more agile, to recognise the continuous evolving status of an asset after being construct, it should be continuing the asset delivery through the time of demolition'*. The conversation needs to 'start with the end in mind' and the 'end' to no longer coincides with the construction completion but will be extended until the end of the asset lifecycle, continued interviewee 26:

'So, it's changing the way we have the conversation - what is this asset going to look like in 20 years' time? How are we going to maintain it? How are we going to operate it? How are we going to effectively embrace the opportunities of digitisation that technology advances, that our understanding of the asset over that period will improve the way we deliver it? If you start with that endpoint, we can then look at those elements all the way back in to when we first think of the asset. So, instead of handing it over, it's a continuum.'

4.4.2 BIM Maturity

To take full advantage and maximise efficiencies in capital and operational outcomes, it is fundamental that clients clearly define the project BIM goals by specifying the model's uses and the information requirement to be delivered.

The initial point towards a successful BIM journey is asking the right question at the start of the project in order to clearly document the project's goal and collect the 'information' related topics that the stakeholders believe will give them the most benefits. It has been recommended that inexperienced clients appoint a BIM advisor to facilitate these discussions and enable clients to make informed decisions towards the expected BIM goals. Moreover, in cases where the model will be used for operation and management purposes, the operator needs to take part in the conversation right from the beginning, advised interviewee 11: '*just getting in the operator to define what defines for information and handover and getting this information to be structured in some way'.* Indeed, the operator or the facility manager, is the only person that can provide advice on how to design the asset thinking with the mind of who will actually operate the asset and therefore they are considered a key party to add value during the early design development.

During the initial stages, the client with the help of consultants or advisors should identify the BIM Uses that will deliver the highest value during the project planning, design, construction and operation phases. A BIM Use is defined by Kreider and Messner (2013) as 'a method of applying Building Information Modelling during a facility's lifecycle to achieve one or more specific objectives.'. For instance, model-based existing conditions, cost-estimating, clash avoidance, and detection, etc. Several guides have been developed that define several BIM uses – such as the PENN State BIM Project Execution Planning Guide, the NATSPEC BIM guide, Massport Authority BIM Guide to cite some - and can be used to address the client's needs.

The BIM Uses, therefore, define the end purpose and should be captured in the BIM execution plan together with the defining BIM deliverable, the communication procedure, the technology, and the work planning.

According to interviewee 15:

'I think that the BIM brief document or the employer's information requirements document should form part of the contract. And that then defines what should be

delivered and who should deliver it, and that will then contractually tie the different parties into working collaboratively to deliver the information.'

However, the reality is often very different. Two major issues arose from the interviewees: first, whether the client is ready to clearly specify their requirements and second, whether the industry is ready to provide the information required by the clients.

On one hand, there is a high level of frustration among both consultants and contractors due to the inability of clients to clearly address their BIM requirements and expected deliverables, with lack of indication of how information will flow down in the construction process. A contractor BIM manager, interviewee 8, said: *'the scope that they write is their own interpretation and because of that it is very variable. Very variable indeed, and sometimes very naïve -which gives you the understanding that they do not know what they are asking for, and so they do not actually know the cost implication of asking for it'.* The purpose behind BIM/DE being required seems to be missed, as stated by interview 9 *'Clients very rarely specify the uses of BIM that they want to use on their project'.*

Typically, in tender and contract documents, there is just a blank statement saying '*we want BIM'*, '*we want LOD 500*', '*we are not sure what we want so just give us everything*'. More and more often, overseas standards such the UK PAS 1192 are quoted during tender in the form of '*we want BIM Level 2*' or '*we want PAS 1192*' without discussing and agreeing what this actually means in terms of deliverables, role, and responsibilities. Therefore, issues can arise due to ambiguity in what a client is actually asking: *'people are specifying compliance with a standard that they've never read or actually know how to apply - so, it's potentially dangerous [interviewee 20]'.*

Interestingly in this regard, in the recent 'Winfield Rock Report: overcoming the legal and contractual barriers of BIM' (Winfield & Rock, 2018) published by UK BIM Alliance, the two authors found that among 44 UK BIM experts interviewed, '*no two people gave the same response'* when they were asked to provide a definition of BIM Level 2. With this is mind, even more, consideration should be taken when overseas terminology and standards are used within a market where they were not developed.

Thus, merely requiring BIM on a project does not lead to success if the client's goal for the project is not clearly set and BIM requirements do not correlate to achieve those goals (NIBS, 2016). Without a clear BIM scoping there is a great chance that clients will either get an under-delivered or over-delivered model, as stated by an architect BIM manager – interviewee 22:

'If the model is under-delivered, the client will not get the data that may have wanted or they will get variations and claim because of the change of the scope of the contract. If the model is over-delivered, it is wasteful, and the client is going to pay a lot extra for that information that they never needed.'

This approach can be incredibly onerous for clients in terms of collecting data for the sake of data without having a mindful consideration of what they actually need and want and are therefore willing to pay for.

If they want to carry out the model into operations, clients need to add more value as the project goes through the process to get a more refined BIM model. The client cannot just think, *'okay, now I have this BIM model, I could just take it into operations and maintenance and so on and so forth',* as it has been highlighted by interviewee 23. The initial BIM model is usually not necessarily refined enough for operations and maintenance. They are general, and unless they are contracted for this purpose, the client needs to know that they would be paying more for more value. Most importantly, the client needs to be ready for the digital deliverable and for managing the whole-life asset management data, otherwise, they may pay for such outcomes that they will never be able to implement.

From another perspective, the second issue that arose from the interviews is whether the industry is ready to provide the handover deliverables, and information required by the client. Indeed, a few sophisticated clients have started to understand the value of data-driven processes and are demanding data for their asset lifecycle operational strategy to be linked to their facility management system. By having in-house expertise or appointing external BIM consultants, they publish tenders, in which their BIM requirements and information deliverables are very rich and detailed. Under this scenario, however, the situation seems to be reversed, with participants concerned about the insufficient level of understanding and skills of the industry, as mentioned by interviewee 11: *'I think that will start became more apparent; the client will start saying "ok this is way I want this information, not just I want some BIM fence". But I do not think the designers and the contractors understand how much worker that is* *going to be, in particular some of that information that is untypically provided at that stage of the project, it is typically at handover when you give them that information.'*

Few examples have been reported showing the difficulties of both consultants and contractors complaining about the client requirements. Without really understanding what the client is requiring and the amount of data needed to be produced, they may accept jobs that can potentially hurt them, reported interviewee 6. One example has been reported by interviewee 11:

'*the client was advised by a BIM consultant, who defined the information needed to put in the model, and YY did not really understand what that was and said "yeah we can do this", and now they are still putting into the data and losing a lot of money, because is so onerous, there is a lot of effort, and they did not know what all these really meant at the time, and now it is in the contract and the client asked where it was, and the BIM consultant is going into a model which doesn't work, they need to fix it, and it is not just one model but 500 models.'*

In conclusion, BIM requirements need to be aligned with the client's project goals. At the early stage, the BIM uses that will add value to the project need to be carefully analysed and specified. They should represent the client desired outcome for BIM being used in the project. This approach could also help the client to evaluate the BIM capabilities of bidders. In this regard, it has been suggested to add in the procurement team that will interview the bidder during the tender process, and an information manager that can address the questions regarding the tenderer capabilities against the BIM requirements. What usually happens is that the BIM team can provide questions to the procurement team to ask to tender, however rarely are they sitting with the procurement team and asking the questions specifically to tender. Critical, therefore, becomes the role of the information manager (in-house or appointed consultant) who serves clients by coordinating stakeholders and progressing through the necessary levels of detail and information during the procurement process. The information manager's role should be expanded across procurement, design, construction and also be accountable for how that information gets back to operation.

4.4.3 Information management flow in traditional and collaborative contracts

The choice of the procurement strategy affects the way in which the model is developed and information is exchanged (NIBS, 2016). Therefore, it is very important that the decision to use separate, integrated or relationship-based contracts is aligned with the purpose of BIM being used. This needs to be determined at the initial stage of the project to allow BIM implementation to be properly structured and managed. BIM and Information management can be used in any type of delivery method. However, when deciding the procurement strategy, the client should take into consideration that the different types of contracts will affect the contractual relationships and responsibilities among different parties and thus, the way information will flow and be shared among parties.

Under the traditional delivery method, consultant and contractor sign two separate agreements with the client at different project stages. Therefore, two separate BIM briefs need to be developed by the client to address the needs of both design and construction. This process requires careful coordination among the two contracts to make sure that they are aligned between what the client is telling the consultant in the design agreement and what the client is telling the general contractor in the construction agreement.

Moreover, in the case in which the client is not specific with the requirements, one of the main challenges for the consultants is to address the information that the contractor will need during the construction stage due to the lack of knowledge on constructability. As reported by an architect, interviewee 22: '*I think the challenge is actually identifying, "what information do contractors need to build a building?" and identifying that against how we currently produce information and then making how we produce information change to align exactly with how a builder will work'.*

As a consequence, from the constructor's perspective, the work done by the consultant may lack useful information and therefore the process generates zero value. According to interviewee 27: *'What usually does happen is that the designers create the model in a way that suits their purposes. And often when the contractor takes that model to use for construction purposes, they find so many issues with it that they virtually start from scratch.'*

More efficiency can be achieved if the client is able to communicate their requirements to one entity. However, in the case of Design-Construct, the client will have a contract with the contractor and the consultants will be appointed by the contractor. Therefore, it is the responsibility of the contractor to align the client's project goals with the consultant, and to make sure that the consultants understand what needs to be delivered.

Moreover, after tender, the client has less control during the development of the design and construction phases since they are no longer actively involved in the project. Depending on the needs of the client, this approach may not be advantageous if the client is responsible for the management of the asset. Under this scenario, if the client has not effectively communicated expected model deliverables and information requirements, the handover as-built model can fail to match the client expectation, which can lead either to a missed opportunity for the client or to the need to pay extra money to obtain what was not clearly defined from the outset.

From a project information flow point-of-view, it seems that traditional delivery methods present a few drawbacks in the transmission of the model and information due to the different stages in which parties are appointed. This promotes the creation of waste such as re-work, duplication of information, inconsistency in data and terminology among others. Interviewee 5 believes that: *‘procurement routes like design-bid-build and design-build promotes this sort of chaos and information waste that we have on projects, because you develop information to a certain point and then somebody else might come on board and then that's scrapped and then they have to start again and re-develop it’.*

Conversely, the integrated collaborative contractual framework, where the key stakeholders are engaged as a unique team from the early stage of the design under handover is considered the best scenario for BIM as information can flow without bottlenecks, creating value-adding from one model used to the next, reducing the amount of waste that is usually created through the different stages of conventional delivery methods. Interviewee 12 emphasized the benefits of information flow under collaborative contracting as: *‘from an information management perspective, the more alliancing the better. And the reason for that is, for information to flow between parties, it needs to have less roadblocks, less gates to go through, less checking mechanisms preventing workflows. In traditional contracts, there is no real attention given to information flow or digital information flow*’.

When the client, designers, engineers, contractor, and main suppliers together agree right from the beginning how the models will be developed and constructed as well as establishing which information will be needed at each key decision point, this should ensure that information will flow more smoothly avoiding loss, conflicts, inconsistency or omission of data. Indeed, under collaborative contracting, a long time is spent in the planning phase, where the parties are all in the same room under the same hat and have the time to plan the project '*and that is what BIM is about as well, it is about that initial planning strategy of information throughout the project. So, everything you plan is with the end in mind, and there with you while you're planning it - you're planning it collaboratively' [interviewee 41].*

This approach allows optimisation of all the processes by mapping the value of BIM through the value stream and defining why, what, when and by whom information needs to be developed to achieve specific BIM uses, meanwhile eliminating any step that does not deliver value. It should guarantee that only the information needed is actually created and delivered at the time they are expected to avoid any over-production or under-production of information.

4.4.4 Legal issues

Rights to rely on the model and data embedded in the model

To date, one of the main challenges that people face with the effective use of the model and information embedded in it, is related to the validation of this information. Indeed, a BIM process should involve the exchange of models and information among various project participants providing the rights to rely on the data transmitted. In reality, a number of disclaimers are used by the consultants or engineering firms when transmitting the model, to be absolved of any liability due to errors or omissions in their digital data once the model is not anymore in their control, for instance: *'here is our model but don't blame us if it's wrong [interviewee 4]'.* Most disclaimers state that the accuracy of such data cannot be guaranteed. By stating that there is no guarantee that the model is accurate, the transmitting party does not create any value to the receiving party as the model needs to be recreated from the start while the model transmitted becomes unusual. The intent of reaching full collaboration with BIM is actually obstructed by BIM model disclaimers and risk management, as shown by this quote of interviewee 15:

'So, they will create a three-dimensional model but they will basically say that it is an issue for information only, and you have to rely on two-dimensional drawings. And again, I think that comes back to the whole risk thing and the fact that we are

exposed. Because we do not do as much as we should have been doing because of the low costs, low fees'.

Interviewee 2 described the inefficiency of the process taking as an example using the model to perform cost estimating:

'So, a quantity surveyor would love to use the models to inform their cost estimate. But more often than not, they get given a big disclaimer that says "you can't use our models" - and the reason they get that disclaimer is because consultants are scared that the QS will just press the 5D button and just take everything that's in the model as gospel, and won't allow for anything that's not modelled. The reality is the QS is still responsible for the cost estimate, whether they do it using paper or whether they do it using the model, and therefore the responsibilities with current deliverables - or current procurement models, anyway - are still basically the same as they always were.'

However, the major evidence of inefficiency of this approach is shown during the tender stage. It seems that the current practice among clients is to use disclaimers in the models that go to tender: '*you can take the model but you're using at your own risk [interviewee 4]*' or '*say there's no warranty or guarantee that the information provided in this tender is correct or is the most suitable design or is fit for purpose or anything [interviewee 1]'*.

In particular, under the traditional delivery method, the client is responsible for the design produced by the consultants that passes to the contractor during tender. Clients do not want to bear the risk of inaccurate or missed information, therefore they issue the model as information-only while the contract documents legally governing the work of contractors continue to be two-dimensional plans and specifications. This has been emphasised by interviewee 1, a BIM director in a client's organisation: '*the reason why we have disclaimers in our contracts, is that we don't want to guarantee it's correct, is because - just say there's something wrong with that information. It means that we pass the risk onto the tenderers to do their own work to make sure that the design's okay. If we said, yep, we stand behind this design and you can use it if there's something wrong with it, then we would be liable for paying any damages'.*

This approach, however, may raise issues regarding inconsistency and conflicts between the information provided in the model with the information in the 2D drawing.

Moreover, contractors need to spend a lot of time and cost to rebuild the model to ensure they and their subcontractors can rely on it.

Potential benefits of using BIM in tendering process

By providing a trustful BIM model as a bid document to the contractor, clients could potentially obtain a more reliable price during the tender process, which should reduce variation during the construction stage, as stated by interviewee 34, a BIM advisor: '*client would be able to manage much more accurately the actual risk of overbidding or adding contingencies to cover that risk'*.

Likewise, from an architect's point-of-view - interviewee 22- , several benefits could be potentially achieved by providing the model during tender: *'it would be used to de-risk the scope right at the start of the job so that everybody knows exactly what is required and has a better understanding of the key risks that exist in a shorter period of time, so it's a more efficient way of getting to a scope upon which you would then tender'*.

Indeed, considering the short time of the bidding process, the efficient use of a reliable model could allow the contractor a better and faster understanding of the complexity of the project. Meanwhile the estimator could obtain more accurate quantity take-off by automatically extracting quantity to better calculate the price during the tender, which will also drastically reduce the time on estimates. These ideas are expressed by another architect, interviewee 4:

'you give the model to a builder with some confidence and then you'll get a whole different level of outcome - they should, and I say should, because you kind of envisage it - hopefully be able to price it more accurately, be less likely to miss things, and then hopefully have the opportunity to identify a more efficient way of planning and scheduling and construction in a safe manner, because it's very challenging to do so when you're doing it from a set of drawings and a fixed specification if you can actually walk around the model and see how you can put the thing together. Preliminaries are the really big cost, and on-site cost every day is where builders lose a lot of money, so if you can actually give them that information, then you're going to get better outcomes anyway.'

Data validation and re-use of information

To date, the validation and re-use of the information is the biggest obstacle of a full adoption of BIM. Information is created at single phases and it is not really built up to the next phase. There is a lot of recreation of information at each stage along the way, and therefore the current legal challenge for the client is to address how information can be purchased for one stage and reused in the next stage. Looking at international best practices, many of these issues have been resolved by using protocol/addendum, and making each party responsible for errors in its contribution. The AIA E203 states, ‘Parties shall develop, share, use and rely upon the Model in accordance with the Authorized Uses identified in the Modelling Protocols’. The E203 requires participants to specify for each ‘Model Elements’ the Level of Development (LOD) (specific minimum content requirements), the party responsible to the development of the model element (Model element Author) and the associate permitted uses. A similar approach is taken in the UK CIC Protocol, stating that the project team member shall have no liability for any purpose other than the Permitted Purpose. Therefore, the use of the model and information beyond the purpose for which they were created, is the sole risk of the user. As has been highlighted by Udom (2012), it is important that the protocol limits the liability of parties to a scope consistent with their fees and insurable rights without eroding the responsibility for inaccurate contributions.

At the present moment, the deliverable under the contract is still a set of drawings and that is what consultants and contractors are getting paid on. The client should contract the consultants with clear BIM requirements and pay the fee for the model deliverable, from which they want an outcome. Consultants should also be granted more time to set a proper model-based project. The validation process in the BIM scope is the key part of the collaborative BIM process since the model needs to be validated against the BIM requirements stated in the BIM Brief or EIR. This process can be done through Quality Assurance (QA) and Quality Control (QC) software, such as Solibri Model Checker and Autodesk Navisworks. Moreover, as long as the transmitting party explicitly states their intention of the model, these issues around disclaimers should not occur. As reported by interviewee 4, within their internal process, what they do is to say: *‘here is this and it is used for that, great - if you wanna use it for anything, don't come back to us, we don't care, it's not our problem, because it wasn't intended for that use’.* Similar approaches should be taken by the clients during the tender process, allowing the model to be part of the contract document and qualify the data to be reused for the intent for which they have been created: *'it is important to sort-of define expectations on how the others are going to reuse that information downstream to make the process work' [interviewee 38].*

Liability

It has been argued that for the collective responsibilities between parties, as well as avoiding disputes, that distinguished collaborative contracting from other forms of contracts, enables participants to be more willing to accept the model as a contract document and to agree that all of the key participants have the right to rely on the accuracy of the model. The potential liability barriers that may arise under traditional contracts are therefore overcome by a collaborative framework that allocates all parties under the same umbrella. To quote interviewee 42, reporting the UK experience on a project delivered under collaborative contracting: '*There's no liability. Everyone was working on the same BIM platform. And the suppliers, the supply chain, they all were able to work on it and they were all circulated with all the different updates that were going on. So, one single platform and nobody could be held liable - unless it was fraud, as I say if they wilfully blew the thing up that would have been not a good thing to do. But no, they were all able to work on it as a virtual company. We had no problems whatsoever'.*

Additionally, the dispute resolution process with the 'no blame' regime should ensure that parties will hardly recourse to adversarial procedures from any problem coming out from the use of the model (Circo, 2014). While still important to sort out what the responsibilities are, there is more flexibility for the team to deal with an issue that may arise rather than recur to legal action. This has also been stressed by interviewee 17: *' if there's a mistake in the model, under an alliance the parties have agreed, 'well, it's a no-blame regime' - so the fact that one of the participants entered inaccurate data into the model - well, you can't sue the participant for that, but all of the participants are going to be losing a margin - losing their gain share or having an increase in pain share liability - whilst ever-additional costs are being incurred in doing the rework as a result of the error in the model, and so everyone is motivated to solve that problem in the most efficient way possible. It's in the interests of the owner, the injured party, the wrong-doing party and then all of the other innocents who are also participants, who are not involved in the error or the consequences of the error -*

it's in the interests of all of them to come up with a solution that maximises the financial outcome for everyone'.

Another example has been reported by interviewee 21:

'So, under a traditional arrangement, I want people to accept responsibility for putting the information in on time when they should have, and I want to be able to sue them if I suffer loss because they were late putting in their information and that's delayed me and caused me additional cost. But under an alliance, even though I don't have those rights of recovery, I know that everybody is motivated to put their information in on time, to make it as accurate as possible - they've all got strong incentives to do that because they're all going to be sharing my pay in the event they don't. So, I think all of the participants will be more comfortable with that sort of a risk allocation and won't insist on their counterparties actually warranting the accuracy or the timeliness of the information.'

Different outcomes can be encountered when the interests of parties are not aligned and the commercial framework clearly allocates risk and responsibilities to each member. Interviewee 29 discussed their difficulties encountered when BIM is used in a PPP and joint venture project:

'you've got a joint venture with the design partners and architect partners, so they're part of a group but they've still got different legal contracts between each other. That's not a good thing. And in our digital space it's almost like there are more things trying to stop you doing work than helping you do work. So even in the BIM team I've got people that are from XX, I've got people from YY, I've got people from ZZ and then sometimes there's friction between the two, because someone wants a role, someone else wants that role. Sometimes we've got more XX people than YY people, they're not happy about that. When you win the project these companies actually bid against each other. And that creates factions, division and it creates an environment of me versus you versus them. And there's a lot of legal issues there, some cannot see the models from this one and vice versa, because there are IP issues, this one ends up suing this one, and it's not good'.

The example reported by interviewee 20 instead, outlined how under conventional contracts, collaboration breaks down as soon as things start not going well. The project was procured under conventional models, which enable early collaboration; all parties were co-located and they were working and sharing their models on a common server. Everything was going well until *'they got a little antagonistic and split it between two servers to protect they interest'*. The commercial framework, therefore, determined how difficult the relationship became and the impact that it had on the project, where each party was trying to protect their financial interest as opposed to acting for the best of the project interest.

Rather, the collaborative contracting framework does not allow the team to be antagonistic, everyone wears the same hat. Therefore, situations like the one described above are very unlikely to occur. People work for the best of the project rather than becoming antagonistic and pointing the finger. The contractual arrangement motivates them to work collaboratively to find a solution: '*the pain-gain share - that's your incentive, everybody's got the same goal, you're all in it together, you either all succeed together or you all fail together. So that's a massive driver behind it - everything you do is best for the project and that's what you're constantly thinking about during the project - you think, right, I've got to do this, is it best for project?' [interviewee 41].* It has also been argued that the pain-gain mechanism should also provide a good solution for sharing the pain of any reworks associated with unresolved clashes that tend to delay and increase the costs of the project.

Common Data Environment

The Common Data Environment (CDE) as specified in the PAS 1192 (BSI, 2013) is a single-source of information to collect and manage project information, in a form of modelling as well as a conventional data format of the multi-disciplinary team during the whole duration of the project. A CDE could be a project server, extranet, file-based retrieval system or cloud-based software. All participants in a project should be provided with codes to allow them access to the CDE, which is then used to share and access information, allowing the project to function and progress according to four distinct phases which are Work in Progress (WIP); Shared; Published Documentation; and Archive. Data within a CDE is finely granulated and structured to be easily re-used (BSI, 2013).

A few interviewees 5 and 17 also pointed attention to the first BIM issue that reached the court in the UK, the recent case regarding Trant Engineering Ltd v. Mott MacDonald Ltd (2017). Winfield and Rock (2018) report the case: Trant Engineering Ltd was appointed to the UK Ministry of Defence to construct a new power station in the Falkland Islands. Trant engaged Mott MacDonald during the period to provide design services and act as a BIM coordinator. Following a dispute regarding services and fees, Mott MacDonald denied Trant access to the CDE, which was in this case ‘ProjectWise’. This action effectively brought the project to a break with Trant applying for an interim injunction that Mott MacDonald should provide access to ProjectWise to Trant. The Technology and Construction Court granted the injunction and ordered Mott MacDonald to give the access on the basis that there were serious questions to be tried, that damages would not be an adequate remedy and that there was a high degree of assurance that Trant was entitled to the data that was reposited in ProjectWise.

This case outlines the importance of negotiating early between those involved in a BIM-enabled project regarding which party should host, coordinate, control and allow the access to the CDE. However, it emerged that often, contracts lack clear definitions of these types of responsibilities. In the light of this, according to Winfield and Rock (2018) the contract, or a BIM protocol, should specify that the parties are adequately protected and the data contained in the CDE will not be used as a tool in a bi-party dispute.

Considering which party should host the CDE, an interviewee observed that if every participant needs access to the BIM model in order to perform their obligations, they will want ‘the right to access’, to be documented and clear. However, that is not possible if only one party has the contractual arrangement with the site provider, unless they provide back-to-back licenses to everybody else. In the light of this, under a collaborative contracting model it would not be in the interests of any of the alliance participants to turn off the access for one participant and create problems with that participant, because those problems will then turn into problems for the project, and everyone will share in the pain of the problem, according to interviewees 27 ad 42.

Intellectual property rights

Finally, consideration has been given to the intellectual property rights and ownership of the model. Some argued that the concerns related to Intellectual property and ownership have been overcome by clients holding the intellectual property as a result of paying for a service: *‘I am paying for it - therefore it's mine. I'll have the intellectual - I hold the copyright, it's my intellectual property, you transition to me [interviewee 8].’* Therefore, by owning the information clients are entitled to do *'whatever they want with it' [interview 22].* To others, interviewees 10 and 15, the intellectual property should remain with the author who then grants a license to the client and the other participants to use it in the project.

The multi-party nature and no-blame regime of collaborative contracting could simplify the discussion by avoiding the creation of a branch of intellectual property right and sharing the risk of infringing third party intellectual property:

'all of the participants are parties to the one agreement, so the intellectual property licenses can all be documented in the one document and there's no need for the owner, and the head contractor and subcontractors and whatnot further down the chain, to include in every contract these sort of back-to-back intellectual property licenses and indemnities and makes sure it all flows through and works, so that simplifies that piece immensely [interviewee 17].'

The synergy between collaborative contracting and BIM has been summarized by interviewee 42: *'Collaborative contracting is about mitigating risk, it's about reducing waste, it's about being agile and that's really what BIM's about, but from an information sort of point-of-view. That's why the two go really well together.*'

4.4.5 Standardised BIM contract

At present in Australia, there are no published standard forms of contracts, neither protocol nor addendum, written to incorporate BIM and to address potential legal issues.

The current practice is to incorporate the BIM Execution Plan within the contract, making the BEP a contractual document. However, this approach raises some concerns regarding the effective legality of the BIM Execution Plan. Indeed, the BEP is considered a live document and as such it is constantly evolving: *'that it's always gonna continually revise, and that to expect updates, I don't think the legal fraternity would accept that'.* According to interviewee 5*the BIM execution plan is really how you're going to do it when you're going to do it - the protocol should be, what are you asking me to deliver? So, the BIM execution plan is a living document and it evolves the project, the contract can't evolve'.*

Therefore, while some believe that in addition to the BEP, an addendum or protocol should be developed and incorporated into the contract to address the legal issues not present in the BEP, others think that the standard contract should be revised to address these issues.

To some, the protocol is considered a good first step to address role, responsibilities, and obligations of parties in regard to the development of the model and information embedded in it, as has been emphasized by interviewee 6:

"I think they are a very positive thing in saying, here's a contract and here's an addendum, and this addendum says x y and z is required on the project, I think, yeah, that's a great first step."

The UK CIC BIM protocol, US AIA E203:2013 and ConsenusDOC300:2016 have been named several times among this study's participants as a good starting point that Australia should learn from and adapt within the Australian context. These documents do not change contractual relationships among parties, however they address important issues regarding the development of the models and information such as the intellectual property rights, the ownership of the model, the risk allocated to the use of the models, the permitted use, etc. For the addendum/protocol to have a contractual effect, it is essential that it is clearly expressed in the contract and not only referred to. For instance, the AIA B101-2017 Owner-Architect Agreement contains a clause in which it is specifically addressed that parties will need to use the AIA E203 'Building Information Modelling and Digital Data Exhibit', to establish the protocols for the development, use, transmission, and exchange of digital data.

On the other hand, however, there are those who believe that '*it is not good enough to simply bolt the BIM protocol [interviewee 17]'* and see the protocols as *'just the simplest way to do it, but that doesn't address the actual issues on the ground' [interviewee 10].* Moreover, they have also outlined the problems of inconsistency that can arise when the protocol is used with the contract due to the misalignment between the protocol and the terms of the contracts as well as the different terminology that the two documents might use. This has been stressed by interviewee 17:

'It's impossible to come up with a BIM protocol that can be bolted onto every form of contract being used in the industry and for it to be internally consistent. If each of those participants has also signed up to a conventional contract - either with the owner or the head contractor or whoever it is in the chain - and that conventional contract deals with intellectual property licenses and indemnities and liabilities for

information provided to others differently, then you've got this inconsistency in your contractual arrangements.'

Therefore, others believe that rather than develop a protocol or stand-alone contract, the current standard form of contract should be adapted and improved by integrating BIM and information management process, as has been emphasised by interviewee 24: *'There is no need for having a special BIM contract, the existing contract should be redrafted with the technology in mind. I think the design and construct Australian standard contract should be redrafted to do that, and also alliance contract should be redrafted'.*

In conclusion, the BIM protocols could be a good first step to start addressing the legal aspect of BIM, however, the next necessary step will require the adaptation of the current standard form of contract with the new data-centric process.

4.4.6 BIM standard

In Australia, there are not specific standards developed to implement BIM. NATSPEC published a set of BIM guidelines and relative documents, such as the BIM management plan and the Project BIM brief, both of which are used, but not widely.

Indeed, interviewees reported that the BIM standard mostly used is the UK standards PAS 1192:2013 Part 2-3. What emerged indeed, is that PAS 1192 Part 2 and 3 *'are increasingly being used by some government agencies as a basis for the implementation of BIM/DE [interviewee 15]'.* For instance, the Department of Transport and Main Roads in Queensland utilises the NATSPEC national BIM Guide for the documentation process and the UK PAS 1192 as a framework for the information management process. Transport for NSW is developing a strategic digital engineering framework adapting the principles of PAS 1192 Part 2 to drive a consistent client-led approach.

Some participants pointed out that at the end of the year the international standards ISO 19650 Part 1 and Part 2 are expected to be available, which will largely be based on the UK standard PAS 1192. The ISO 19650 is considered a welcome development that will push the industry to embrace the digital transformation and provide everyone with a common understanding, according to interviewee 12:

'It could be easier to convince people. Meaning some people who are still not convinced, let's say - so it will be easier to say, look, this is ISO standards. Doesn't

matter if you're convinced or not, you can just say - that's it, you have to do it, and then you can force the discussion. So, ISO helps in that direction. Doesn't make people innovative, it just forces them to stop being reluctant. That's it. That's all it can do. They can still be reluctant, but to a less degree than before."

However, it has also been claimed that *'it must become an Australian standard before it has really an impact here [interviewee 12]'* which is aligned with another participant who applauds the ISO but believes that *'there still might be some work to be done in seeing how those standards apply more generally and pervasively throughout the Australian industry [interviewee 16]'*. Other participants point out their concerns regarding how prescriptive this is and, *'I have heard criticism about how prescriptive they are and how challenging they can be in terms of define kind of xyz, rather focusing on the outcome that needs to be achieved' [interviewee 32].*

Overall, when asked about the need for BIM standards for Australia there was a general consensus that there is a need to develop Australian standards for future Australian construction projects. Participants agreed that a standard is needed in order to provide and unify a framework for the industry and resolve the current uncertainty and ambiguity around terminology and information management processes. They expected that the Australian construction industry will adopt the ISO 19650, however, work will be needed in order to effectively adapt the international standard to the Australian market.

4.5 KEY FINDINGS

The main findings are summarized below.

Contractual barriers to collaboration in Australian construction procurement

- Conventional procurement models, such as construction-only and design and construct are the preferable option among Australian client organisations.
- The selection process is based on the lowest price bid which only focuses on the party who submitted the lowest price rather than establishing which team is most capable to deliver the project.

- The fixed price framework favours 'the minimum necessary' behaviour to the detriment of innovation. Parties are not encouraged to perform more than what was required even when a different option could deliver a better result.
- In the fixed price lump sum contract, there is clearly defined allocation of risk and responsibility, which sets the limits of collaboration. When things start not going well, rather than working collaboratively to overcome the problem, the parties have to protect their own interest. The adversarial attitude sees one party blaming another for the problem who then try to blame another party, and so on.
- In procurement models that promote early contractor engagement, such as Design & Construct, the commercial interest of the design consultant and main contractor is not aligned. Although the contractor is on board earlier, this does not necessarily drive the expected collaborative behaviour. The design team is a sub-consultant of the main contractor and therefore it may not have the same sort of representation in the process. It can still be an adversarial setup where contractors try to re-build their authority in that process. Different results are obtained if the parties share past successful working relationships that helped to build trust.
- In procurement models that promote early contractor engagement, the consultant and main contractor may lack common goals and vision. From the consultant's point of view, the contractor decisions focus primarily on cost and time rather than quality. This seems to be the reason why they prefer the traditional silo design, believing that quality will be better maintained. A different scenario might be obtained if the parties have successful past experience of working together that helped to build trust.
- Setting goals, establishing performance incentive systems and reward structures could be beneficial to increase the level of collaboration.

The use of BIM in Australian Construction Procurement

- BIM in Australia is predominantly used as a self-driven approach by individual organisations which utilise BIM and information management to de-risk and optimise their own work. However, the number of clients demanding BIM in their projects is increasing drastically.

- Clint’s stakeholders are still sceptical to undertake change from traditional ways of working. The discussion needs to be shifted from a technical to a strategic level. Effort needs to be allocated to educate clients on the benefits of digital means.
- The value for the client is strictly linked to the activities they need to perform. Clients who are not engaged in the operation and maintenance of the asset are more interested in the benefits that BIM can offer during delivery of the project in terms of the high quality of the project, as well as certainty and reliability in time and cost. Clients who hold and need to manage their assets have interest on clearly specifying the information for their asset management purpose, and therefore they are encouraged to actively take part in the conversation from the beginning. Therefore, this scenario favours procurement models that require an active engagement by the asset owner.
- Most clients lack clarity in articulation of a project’s goals and expectations. The project often lacks a clear BIM brief that addresses the client and stakeholder’s requirements. Typically seen in tender and contract documents, there is simply a blank statement saying, ‘*we want BIM’* or ‘*we want LOD 500*’ or quoting an overseas standard ‘*we want BIM Level 2*’ or ’*we want PAS 1192*’. This approach can be incredibly onerous for clients in terms of collecting data for the sake of data, without having a mindful consideration of what they actually need and want and therefore are willing to pay for.
- If a client does not have in-house experts, they are strongly encouraged to appoint a BIM advisor or Information manager whose role is to understand the client’s needs and translate them into a digital strategy.
- The workflow of information is wasteful and inefficient under a conventional procurement system. Due to the different stages in which parties are appointed a few bottlenecks are created that obstruct the transmission of the models and information, creating waste in the process such as re-work, duplication of information, inconsistency in data and terminology among others.
- Under conventional procurements, a client shall prepare two BIM brief/ EIR, one for the appointment of the design and one for the appointment of the contractor. Therefore, client’s need to make sure that the BIM brief/EIR

prepared for the consultant in the design agreement is aligned with what they are telling the general contractor in the construction agreement to avoid possible conflicts.

- If the client does not clearly communicate the BIM scope to the design team in the initial BIM brief, there is a high possibility that the documentation goes out for tender without having been properly defined. As a consequence, the BIM model made by the consultants may lack useful information from the construction perspective and therefore the design models do not add value to the contractor who needs to start from scratch.
- The cross-firm collaboration expected to be obtained from a free exchange of electronic data is significantly obstructed by a number of disclaimers that are used by the consultants or engineering firms when transmitting the models to the receiving party. The transmitting party uses disclaimers to be absolved of any liability due to errors or omissions in their digital data once the model is not anymore in their control, which as a consequence, eliminates the right for the receiving party to rely in the information. For instance, design information that could support cost analysis is often omitted or disclaimed in the model to minimize designer liability exposure. Therefore, the current contract model, related compensation and risk allocation framework do not encourage collaboration.
- Likewise, clients do not want to assume the risk of inaccurate or missed information in the model. To avoid such responsibility, they issue the BIM model to be read as ‘information-only’ while the contract documents legally governing the work continue to be two-dimensional plans and specifications of information. The tendering process is still the missed opportunity for the successful implantation of BIM.
- The tendering process could be drastically optimised by providing a trustful BIM model as part of the bid documentation. The model helps to de-risk the scope right from the beginning, and evaluates different design solutions, allowing the client to obtain a more reliable price. Clients would be able to manage much more accurately the actual risk of overbidding or adding contingencies to cover that risk.

- At present there are no published standard forms of contracts, neither protocol nor addendum, written to address potential legal issues that may arise when BIM and digital processes are used. While the development of a BIM protocol could be a good first step, the current standard forms of contracts need to be revised to accommodate the new data-centric processes.
- Australia lacks standards developed to implement BIM. Participants from this study expect that the Australian construction industry will adopt the ISO 19650, however, work will be needed in order to address the international standard for the Australian market.

BIM and Collaborative Contracting

- While in Australia collaborative contracting has been predominantly used in large, complex, high risk civil projects with project costs ranging from $100 million up to $1 billion, experience from the US and UK has outlined the benefits of using collaborative contracting to deliver successful high performing building projects that stay in the range between US$15 million (~$20m) and US$200 million (~$275m) with some exceptions. In this case, collaborative contracting was adopted to deliver a building project with very complicated functions and systems that needed to integrated, such as hospital, commercial and education building.
- Clients need to be educated about the benefits that they can obtain by using collaborative contracting. To get the maximum advantage of collaborative contracting, clients need to embrace risk sharing and no- blame concepts. They are fundamental to achieving the level of collaboration that this type of contract can deliver. The team is commercially aligned in an environment that eliminates litigation.
- Hybrid forms of collaborative contracting do not deliver as good a value as the pure forms, since parties are not completely free to innovate without fear of being sued as soon as problems start arising.
- The agreement needs to be signed between at least the client-design consultant and main contractor(s). However, it is highly recommended to incorporate all the parties of the supply chain, whose contributions affect the success of the project by significantly influencing the scope of work and on costs. These

parties can also sign the main contract or sign a sub-contract but be included in the commercial arrangement under the risk and reward regime.

- The commercial arrangement is designed to align the team and drive ‘the best for the project’ behaviour, ensuring that the client goals are achieved. However, it has been pointed out that parties outside the sharing regime and contracted on a fixed price basis, demonstrated different culture and behaviour to the parties in the regime. Therefore, it is important to define a strategy to establish which parties should be part of the risk and reward regime and which should be outside.
- Parties outside the risk/reward mechanism should be incentivised through a performance inventive structure that encourages them to work on the overall project and share the same project goals.
- Establishing the team’s value and culture is essential for collaborative contracting to succeed. The agreement plays an important role, however, the actual key to success is the background work that happens with the team to ensure that the culture is aligned with all project teams. Client leadership, the involvement of a coach/facilitator, and team co-location are the three main aspects that emerged from the interviews to establish and drive the team’s culture. The team alignment period helps to clearly define each party’s role and responsibilities.
- The US experience in collaborative contracting (IPD) has shown the benefit of using Lean principles and tools to help teams to effectively work together. Indeed, Lean principles and tools provide the means to effective collaboration.
- The Lean driver is to optimise the whole not the parts, which means that all parties need to work together to deliver a customer’s goals. The value for the client needs to be clearly defined and the team needs to be set up toward that outcome.
- Collaborative contracting adopts a qualification-based selection process where teams are chosen based on competence and ability to collaborate. The selection process consists of a series of interviews and workshops to assist in reviewing the team’s capabilities and performance and usually involves team

development and coaching. Sometimes, clients may ask the team to work together on a sample project to demonstrate their ability to collaborate.

- From an information management perspective, collaborative contracting allows a Lean workflow of information. The information flows between parties with less roadblocks, less gates to go through and less checking mechanisms that prevent the workflow. The parties are engaged even before the contract is awarded to work collaboratively and to present the best solution for delivering the client's digital goals and the best digital information flow strategy. Lean tools and principles can be used to set the strategy to having focus on the end goal.
- The Client information manager or BIM advisor prepares only one BIM brief/EIR as part of the bid documentation, which will help the parties to understand the client expectations in terms of BIM. During the election process, the client information manager or BIM advisor can assess the team's capability to satisfy the client's digital requirements.
- In the selection process, the team works together with the client's team and has time to ask questions to better understand and define the scope of work. During this period the team also prepares the initial BIM management plan to demonstrate how they will set up their BIM strategy.
- Under collaborative contracting, a lot of time is spent in the front end of the project where teams have time to plan and align with the project goals. The effectiveness of a digital strategy depends on how well it was planned. The planning phase is pivotal to prepare a proper BIM implementation. The collaborative environment offered by collaborative contracting allows the integrated team to work together planning and mapping the BIM strategy to achieve a common goal. The multi-party contract and the commercial framework build a virtual organisation, which removes the traditional constraints where each firm tries to pursue its own goals and objectives.
- Several Lean tools can be used during the design stage to find the 'fit for purpose' solution and assist the teams in the development of the best project solution, including the target value design, set based-design, and choose by advantage. The integrated scenario of BIM and Lean tools during the design

development help the teams to navigate during the design process in a more effective and efficient way.

- The contract and the risk/reward mechanism assist with overcoming some legal concerns with BIM. The no-blame culture is a pillar of collaborative contracting, in that parties cannot seek redress and cannot sue other parties. It promotes the win/win approach. Therefore, parties are more willing to work together and agree that all the integrated teams have the right to rely on the accuracy of the model and information transmitted. If an error is found in the model, all the teams will work to fix the problem.
- The insurance regime needs to support the no-blame culture. For instance, the involvement of several parties in the design phase should result in a collective responsibility rather than allocate responsibilities only to the design professional. A project-specific insurance policy that creates an umbrella, instead of Professional Indemnity Insurance, for the whole team is needed.
- The pain-gain mechanism provides a good solution for sharing the pain of any reworks associated with unresolved clashes that tend to delay and increase the costs of the project.
- Since all participants are part of a single agreement, the intellectual property licenses can all be included in one document, avoiding the creation of a branch of intellectual property right, with parties also sharing the risk of infringing third party intellectual property.

4.5.1 Summary

This chapter discussed the findings from the 43 interviews. The interview's aim was twofold. Firstly, to understand the current contractual barriers in the current Australian procurement models to enhance collaboration and support the use of BIM and advanced technologies. Second, to investigate how the main features of collaborative contracting can support and foster the adoption of BIM.

Four main barriers have been found that obstruct collaboration and limit integration among project's team members: fixed price contract, risk transfer mechanism, the lowest price selection and parties' relationships. While there was a general consensus that an organisational cultural change is needed to enhance the ability of parties to trust each other, there was also a strong belief among interviewees that the type of contract and the commercial framework, influence and affect project team behaviour. If the commercial framework is not aligned among the project teams and there is a fear of being sued as soon as problems start arising, it is hard to believe that parties will work in spirit of cooperation, collaboration and integration. As mentioned from interviewees the commercial framework determines how difficult the relationship becomes as soon as a project starts going bad.

These aspects not only impact the way parties relate to each other but also in the way they communicate and share project information. While BIM is often cited as a new paradigm to enhance collaboration, the findings confirmed that without the right commercial and legal framework that support the integration among different project organisations, the effectiveness of information management using BIM is minimised. Indeed, the data validation and re-use of information among parties is the biggest obstacle to a full adoption of BIM. The way in which the BIM model is developed, and information created, shared, and managed among parties lacks efficiency. Quite often the information is created at single phases and it is not really built up to the next phase. This is because parties do not want to bear the risk of any error or omission in their digital data once the model is not anymore in their control.

Under this scenario it also becomes hard to monitor and check if the client digital requirements are achieved along the process. Therefore, client organisations that want to mandate the use of BIM and information management within their projects should consider leaving behind contracting forms that promote adversarial attitude and poor information sharing, if they wish to obtain the full benefit from a digital strategy. Indeed, it is pivotal to develop a holistic approach that takes into consideration the whole project and no single phases.

Collaborative contracting provides the contractual framework that facilitates the adoption of BIM and changes the way parties interact and look to each other. The risk-sharing regime jointly with the blame culture and supported by the right insurance that protects the interest of everyone equally, are fundamental in taking advantage that these types of contract can be offered. Therefore, clients should be educated about the advantage of using the pure form of collaborative contracting against the hybrid form and have the same ‘skin in the game’ in order to work collaboratively to achieve project goals.

In Australia, it seems that this type of contract is reserved for large, complex and high risk projects because they require additional investment in the outline and a high level of client engagement. However, apart from a client's reluctance to be so exposed, it seems that there is not a real reason for limiting the use of collaborative contracting only to big projects, as shown by the best practices in the United States and United Kingdom, where collaborative contracting has successfully been used to deliver relatively smaller building projects.

In addition, the current contracting framework in Australia is still not aligned with the progress made by technology and the digital age. An alliancing model does not mandate the use of BIM and digital process. However, while this does not prevent BIM from being used in projects, the way it is applied may be inconsistent from project to project, since no framework has been developed to integrate the two strategies and the respective processes and roles.

The American experience on collaborative contracting, namely IPD, brought attention to the use of Lean management as an approach to manage projects by focusing on delivering value by continuously improving efficiency. To accomplish this, a set of Lean tools are often used both during design and construction to support better decision making. However, less focus was given to the Lean value principles such as the Womack and Jones's five Lean principles as well as the PDCA cycle of continuous improvement, both considered essential to begin a Lean approach. Too often, focus is given to tools without understanding the philosophy behind the use of such tools. The Lean approach, rather, could be used to assure consistency in the strategy and in the way processes are developed, including BIM and information management processes.

Chapter 5: Framework

5.1 INTRODUCTION

This chapter presents the BIM-based collaborative contracting framework developed from this research. The framework has been created by merging the findings from initial exploratory interviews with the from the semi-structured interviews as well as industry best practices, reports and standards. The aim of the framework is to provide clarity and consistency on the digital strategy process to assist clients navigate within the new environment.

The proposed framework is based on existing collaborative contracting models and it shows, within five stages, how to leverage digital practices and information management along the project life cycle. It has been developed by using Lean principles and tools in support to the digital strategy to ensure that the BIM model and the information embedded into it are created to deliver value to the client along with the project progress, by eliminating waste and superfluous work. In addition, the framework also highlighted the role and responsibilities of each key project stakeholder and their levels of engagement within the process.

The chapter first presents the feedback and comments received by four experts - who also participated in the Phase 2 semi-structured interview - to confirm the framework. Subsequently, a detailed description of the 5 stages of the framework is presented.

5.2 CONFIRMATION OF THE FRAMEWORK

The framework has been reviewed and confirmed through four expert interviews, one for each of the main phase of project development:

- Client/Government agency
- BIM advisor
- Design/Engineering
- Construction

The experts, who also participated in the Phase 2 semi-structured interview, were selected for their knowledge on collaborative contracting and digital practices.

Considering the exploratory nature of the study, four interviews were considered a reasonable number in order to collect a good and different range of opinions and feedbacks without making the analysis difficult. It has been recommended that future research should focus on validating the framework and therefore an in-depth analysis will need to be carried out.

The experts' profile is illustrated in Table 5-1.

Table 5-1: Experts Profile

N	Current role	Discipline Area	Years in industry	Experience current role
1	Industry Director	Design & Engineering	30	15
2	BIM/DE Lead	Government Agency	46	2
3	BIM Manager	Construction	22	9
4	BIM Advisor	BIM consultant	12	4

The framework was sent in advance to the four experts, allowing them time to become familiar with the work and think of possible adjustment.

Each interview took approximately an hour. They were all performed via ZOOM with a shared screen. The session was divided in two parts:

Part 1 – Framework Review

Part 2 – Framework Confirmation with the above 4 questions

At each interview, each proposed adjustment was recorded and discussed with the other experts. At the end of the interview round, based on feedback received, the collaborative contracting framework was revised, and important adjustments were made. The table below summarizes the comments received from the interviewees.

Is the framework appropriate and relevant to the construction industry needs?	
Interviewee 1	Yes, it is. The elements of the framework are the best way to deliver projects. Sometimes the client will have a lot of expertise in the delivery of those sorts of projects, and they'll have asset managers and BIM people and engineers and whatever else. And sometimes the client won't have those people at all. So that creates a different scenario for what input the different parties need to have along the way. And in that instance sometimes the client will set up a contract that is design, construct and operate for 30 years - a facility - so that the client doesn't need to have people with the expertise to maintain that facility for the 30 years. So, it sort of shifts the boundary between where the expertise needs to be.
Interviewee 2	I think it's there. What you put together here is a very good document that does that, it melds the two trends. And I think the three levels of decision points, certainly clear and relevant, it is important to show the involvement of all the three level of leaderships.
Interviewee 3	Yes, definitely. The framework is appropriate, relevant and aligned with the industry needs. We still need to educate our supplier - there is a big piece of work that need to be done to create a digital supply chain and receive reliable data from them.
Interviewee 4	Yes, I completely agree with all of that. It what we are starting to see happening in industry now with a few projects be procured under an alliance contracting model mandating the full adoption of BIM following the international standard. Unfortunate, a great number of infrastructure projects are still delivered using traditional model, reducing the benefits coming from digitalisation.
What are the merits and worth of the framework for improving collaborative practices?	
Interviewee 1	The framework addresses the need of the industry to start thinking about digital engineering, collaborative contracting and Lean practices to be competitive in the market. It is clearly articulate, and it provide a guidance for clients to move from an adversarial behaviour with the support of today technologies and new business processes.
Interviewee 2	The framework simply and clearly explains a process that needs to be followed in a digital space combining it with the Lean principles. It educates people about what they need to do, so I think that's good. The collaborative contracting trying to bring some of the information upstream earlier into the design process rather than leaving it to some of the back end that we do see in construction, which is where that cost then really does start to escalate. So, the more we can do through the early design phases and collaborating in that space, the better off we'll be.

Interviewee 3	It's just embracing everything that is Lean. If you're going to embrace Lean, then you get all the benefits that Lean offers in the BIM environment. I often see piece of work on how to implement BIM in the construction projects, interesting here is the connection with lean as a key to improve productivity. Lean is all about waste identification and reduction, and BIM is the technology to achieve so.
Interviewee 4	The framework encourages a cultural change in our industry to drive quality, innovation and value for money. Th risk-sharing mechanism recognised that not all risks can be fully assessing and need to be managed collaboratively. The technology is also very advanced and can help us on assessing and reducing in ground risk. We need to embrace a culture of collaboration. In term of BIM, this means sharing the data and information with other project parties without seeing them as competitor. At the end of the day we all work to deliver the project and achieve client's expectation.
Does the framework need adjustment or revision for necessary improvement?	
Interviewee 1	The framework is a good base, but it may need to be modified depending on the project and the client. For example, one of the main factors in regards of how often the PMT and TLT are involved is the dimension of the project. If the schematic design last is two months, they might be fortnightly meetings; if it's twelve months, they might be something else. So, if it's a little project, it's likely to be a shorter period; if it's a big project, it might take twelve months. Certainly, the Project Implementation Team (PIT) meeting, will occur more often than Project Management Team (PMT) meetings, which will occur more often than Project Leadership Team (PLT) meetings, will occur more often than these. So typically, PIT would be weekly meetings; PMT would be fortnightly; and PLT would be monthly.
Interviewee 2	I think you've got it right. Important to bring the facilities manager in early in the process and particularly when trying to bring lean into it, you bring the facilities manager in early into the process so that people understand what his requirements are. May not necessarily need to be there along the way - maybe some of the project management meetings just to make sure they are on track, but it will be a deliverable at the end of the process that goes through to the facilities manager.
Interviewee 3	Identifying some of the challenges that we'll face within industry to move to a framework like this. And making sure that that engagement has to commence

	from the start and a clear scope of work is defined; even though it's an alliance agreement, there still needs to be very clear scope for each party within that alliance. Also, the role of a BIM advisor needs to be written as important as employing any of those other actors in the process. I think that it needs to be in their face from day one about the value of having that person on the team.
Interviewee 4	The framework provides a comprehensive overview of the process. However, scalability has to be something to consider in this framework. The scalability of something that's very small versus something that's very large, it will differ slightly before you've even started on that first part of strategy. There's a lot more work involved in forming a consortia and putting a bid in as a consortia than there is an individual just tendering for one piece of the work. So, this on a smaller scale, if you're going to use that model, who pays for those consortia to put together their bids, for example? Where there is a selection of three - or it is narrowed down to three - then the government actually pay for all three to put bids together, or they may well have contributed to some of that, or it may well be at risk. But on a large project, the lead of the consortia may say, well I'm going to choose to put in however many millions of dollars to invest in this because the reward is obviously chosen. But on a small project, balancing the amount of money that you're going to put upfront without knowing whether you're going to win the work, versus having a team of key stakeholders that the client's going to choose from day one without having to be competitive about it. There's a balance, if that makes sense.
What direction should the framework take in the future?	
Interviewee 1	Full integration of BIM collaborative contracting lane. It is important to clearly address the three levels of decision; they need to be well-defined. Some projects get into trouble when people at this PLT level start taking decisions at the PMT level. They get too involved in the detail of the project, and that dis-empowers these people. They no longer feel as though they can make decisions. They depend on these people all the time. So, it's really important for this board to ask for the recommendations of the management team before making a decision, otherwise they end up making all the decisions. Whereas if the PMT, if they're not making recommendations, they haven't thought about resolution of the issues. So, it's very important to have clear distinction.

Interviewee 2	At the current stage I think the framework already addresses important points. At strategic level, it provides a good overview of the process. Next step could be trying to write every step of the process in detail. I also would suggest extending the framework to clarify the capabilities that the supply chain need to develop in term of BIM and information delivery and their role in the process. The supply chain will not be involved from the key stakeholder strategy meeting from day one, so the guys for example that are fabricating the steel or providing the ductwork, they will not be on board at that stage, yet they will be employed by the builder. But what is the requirement on those guys? Because at the moment within industry, the supply chain is used an excuse for why you do not do really work with BIM. So, is there an education piece there required for the supply chain, or is that the contractor's responsibility to make sure that he is only employing people that adhere to this framework? This is something that need to be considered.
Interviewee 3	I think it covers enough to cover what will happen in the next five or so years anyway. The only other thing in terms of direction in the future would be more so along the asset management side or FM side, where we have a much better understanding of the standard way of handing over that data. At the moment we just focus on capital delivery, however the real value of BIM is the operational level. The big value of collaborative contracting is that allow all key players including the asset manager to be engage from day one defining their requirements and need. This is a massive change form traditional way of working. We need to start to think better with the end in mind.
Interviewee 4	It should be used to educate the various stakeholders. And incentivise the adoption of collaborative contracting. It could be used as a based to develop standard form of alliancing contracting.

Table 5-2: Framework confirmation

5.3 BIM-BASED COLLABORATIVE CONTRACTING FRAMEWORK

The revised BIM-based collaborative contracting framework is presented below. Figure 5.1 describes the BIM-based collaborative contracting process, articulating the framework in five linear stages:

Stage 1 - Strategy: it is a catalyst stage to ensure that the client requirements and digital goals are correctly specified within the Exchange Information Requirement

(EIR) document as part of the Request for Proposal documentation. Less experienced clients, with no in-house expertise, should consider appointing a BIM advisor to assist the client and stakeholders to specify their needs, define the digital strategy and make sure that all these work during the projects.

Stage 2 - Selection process: provide information regarding the process that needs to be used to select the team. The team selection is based on qualification and the team is chosen based on their ability to collaborate as well as their digital capabilities. The team needs to prepare an initial BIM Management Plan (BMP) in response to the client EIR demonstrating their knowledge, capabilities and strategy to satisfy the client's digital requirements.

Stage 3 - Contract negotiations: Describe the legal key features that the client and the selected proponent need to address during the contract negotiation to ensure the effectiveness of the procurement strategy. The section also presents the organisational structure, defining the role and responsibilities of each key project stakeholder, and the culture required under the collaborative procurement approach.

Stage 4: Lean Design and Construction: describe the integration between Lean principles and tools with the BIM process. The five Lean principles – value, plan, flow, pull and perfection – support the information management process to ensure that the BIM uses to achieve the projects goals are defined and understood by all project team. Once the team is aligned with the goals, the process is mapped to define the input and output of each of the BIM uses. The flow stage defined the information flow for each project milestone. To ensure efficiency in the flow, the process is pulled. The pull stage requires working from a target backwards to maximise the flow and determine what each task in the process requires from the one before it. The final step is persuading perfection; this is the last step of the cycle where the learning generated by the entire process can be integrated in order to complete the information exchange, adjust the goal, review the plan or add value to the solution.

The plan-do-check-act cycle is a continuous loop that needs to be used during both the design and construction phase. The 'Plan' stage follows the above approach of the 5 Lean principles. The 'Do' stage is when the plan is implemented and executed. The 'Check' stage corresponds to a specific gateway, where information delivered needs to be checked against the requirements and decisions needed to be taken. Finally, the ‘Act’ stage corresponds to the perfection on the five Lean principles presented above.

Stage 5 - Operation and Maintains: the end of the project no longer coincides with the construction completion, but it needs to be extended until the end of the asset lifecycle. The procurement process needs to become more agile, recognise the continuous evolving status of an asset after being constructed through the time of demolition.

Fig 5.2 illustrates the relationship between the parties that contribute to the design and the parties that take part in the key decision. The blue circles show the parties involved in the design contribution, while the stars show the parties involved in the decision-making process. Thus, the figure illustrates that the parties involved in the decision-making points are not the only ones who are contributing to the design. This is the key aspect of collaborative contracting, get the right people on-board at the time that their decisions can influence the success.

Figure 5.3 depicts the process of information deliverable to support key decision points. The core-team will establish the information requirements (EIR) that will flow down as it cascades to the non-core party who will then pull it up as information and model deliverables to the project information model. The digital deliverables created by the core-team as well as the non-core team will pass through all three decision points and are checked against the client’s EIR before adding it into the project information model (PIM)

BIM-BASED COLLABORATIVE CONTRACTING FRAMEWORK

STAGE 1

Strategy

Client duty:

- Identify Key Stakeholders and End Users
- Involve asset manager /operator/FM
- Appoint BIM/DE advisor if needed

⬇

- Together define:
  - Initial project scope
  - KRA/initial performance expectation
  - BIM/DE goals aligned with project goals, clarify ***WHY*** and ***WHAT***.
  - Establish initial BIM Uses
  - Initial client's exchange information requirement (CEIR) contains the asset information strategy.

STAGE 2

Team selection

Qualitative-based selection:

- Interview
- Workshop

Assessment

- Financial
- Behaviour and collaborative working.
- Digital
  - Past experience
  - Pre-Contract BIM Management Plan (BMP) to assess the team's understanding and capabilities to respond to the client/key stakeholders/end users/ asset managers expectations. Ask ***HOW***

STAGE 3

Contract Negotiation

- Multi-party Contract (at minimum client, lead consultants, main contractor, key supplier(s)
- Risk/Reward Pool (Core-Design Consultants, Contractor(s), Core-Service Contractor(s)
- No fault-No blame
- Joint decision making
- Integrated Insurance

Team Establishment

- PLT: Project Leadership Team
- PMT: Project Management Team
  - Project Manager
  - Information Manager (client)
  - Asset manager
- PIT: Project Implementation Team
  - BIM manager(s)
  - Cost
  - Core-Design Consultants
  - Contractor(s)
  - Core-Service Contractor(s)

Co-location

Foundation workshop → Coach/Facilitator knowledge in team and process improvement
Develop the Culture: Mutual trust, Respect, Open Communication

STAGE 4

Schematic Design + Design development

Plan

The PIT developed team BIM Management Plan:

❖ Apply Lean Principles:

1) **VALUE:** Start with the End in Mind. Define BIM/DE Uses to achieve project goals. For each project's milestones. Ask: ***WHY*** and ***WHAT***.
2) **PLAN:** BIM/DE uses mapping at each project's milestone and integrated with the delivery schedule. Define the Responsible Party for each BIM uses. Ask: ***WHEN*** and ***BY WHO***. Identify INPUT and OUTPUT.
3) **FLOW:** Define Information Exchange for each project's milestone stages. Ask: ***WHAT***, ***WHEN*** and ***BY WHO***, (Level of Information need ISO 19650).
4) **PULL:** Select the milestone to pull. Work from a target backwards to maximise the flow and determine what each task in the process requires from the one before it. The customer is whoever the work is handed off to, ask: what is the information needs to be handed off for the next task start? →Conversation among transmitting and receiving parties. Identify the information requirement from non-core team parties for each decision points that they need to pull upward.
5) **PERFECTION:** establish Quality Assurance (QA) and Quality Control(QC) of the model and information embedded for continuous improvement

Common Data Environment ISO 19650

Big Room

Do

Model-discipline (s)
PDF & Open Docs
Cobie Data

Set-based Design

Target Value Design

Choosing by Advantage

Check

- At each decision point check the information delivered against the requirements.
- Ensure information against what is needed to start the next stage is available
- QA/QC

The decision point can be:
- Internal among (PIT)
- External (Team to supplier)
- Client decision points

Big Room

Act

- Review the plan
- Revised client requirements
- Add value to the solution

A3 Problem Solving

Big Room

Plus/Delta Continuous Improvement

Collaborative planning/Last Planner System Design

Develop the Target Outturn Cost

Coaching sessions repeated with regularity to reinforce collaborative behaviour and help new participants to quickly align with the team value.

STAGE 4

STAGE 5

Complete design development

Construction Documentation

Construction

O&M

- Focus to continuously adding value to the project through the 5 Lean principles: Value, Value Stream Mapping, Flow, Pull, Perfection
- Interactive loop process: Plan-Do-Check-Act
- QA/QC
- Involvement of the right people at the right time
- Develop the EIR and agree to the BIM Protocol with the NON-core design consultants and non-core contractors when is needed

Model-discipline (s)
PDF & Open Docs
Cobie Data

Validation as built content in the model

Integrated FM system with BIM

Keep the maintenance of the model update

PLAN-DO-CHECK-ACT LOOP

Collaborative planning/Last Planner System Design & Construction integration 4D BIM

Big Room

Coaching sessions repeat with regularity to reinforce collaborative behaviour and help new participants to quickly align with the team value.

Figure 5.1: Design Contributions and Decision Points

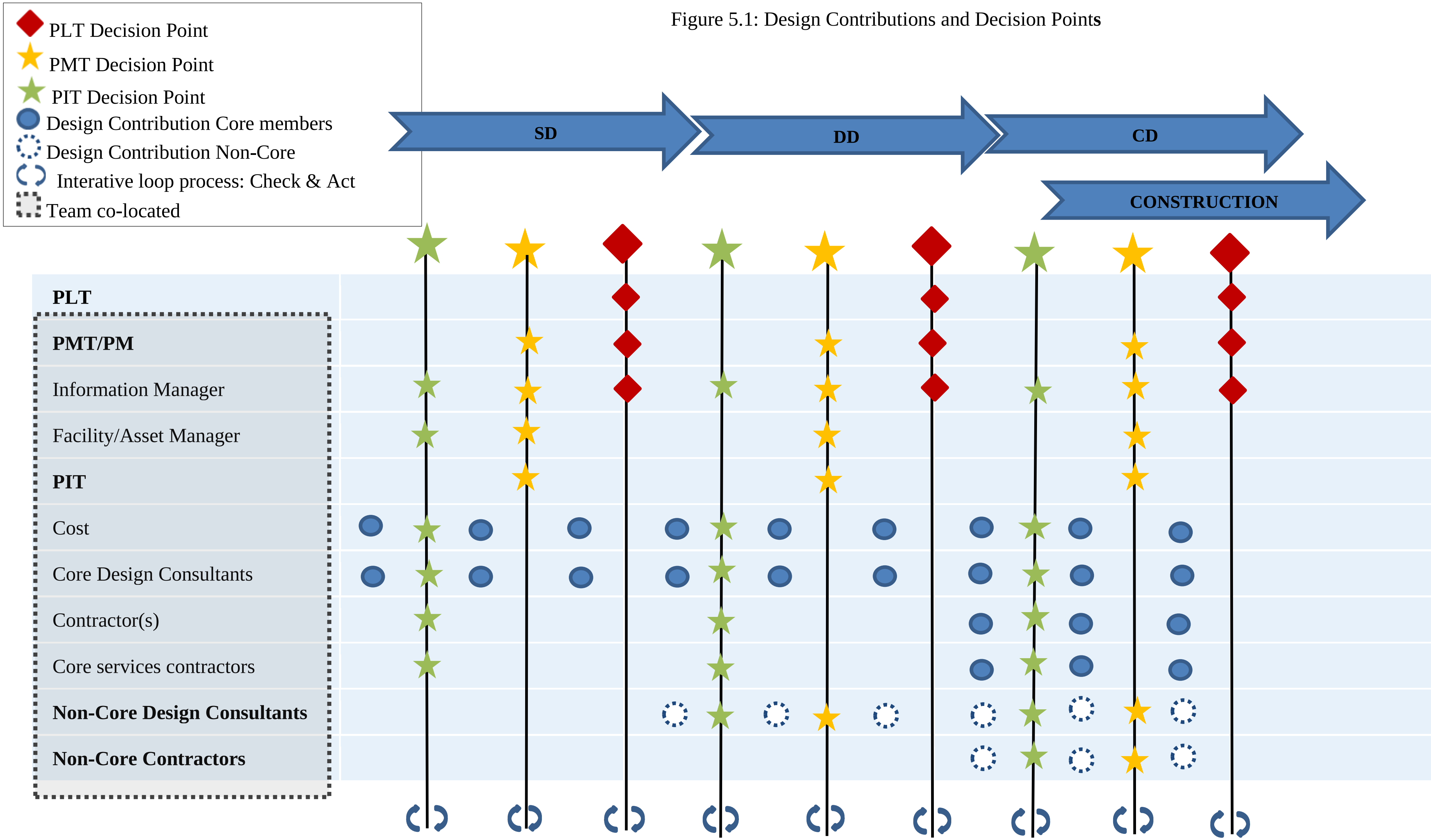
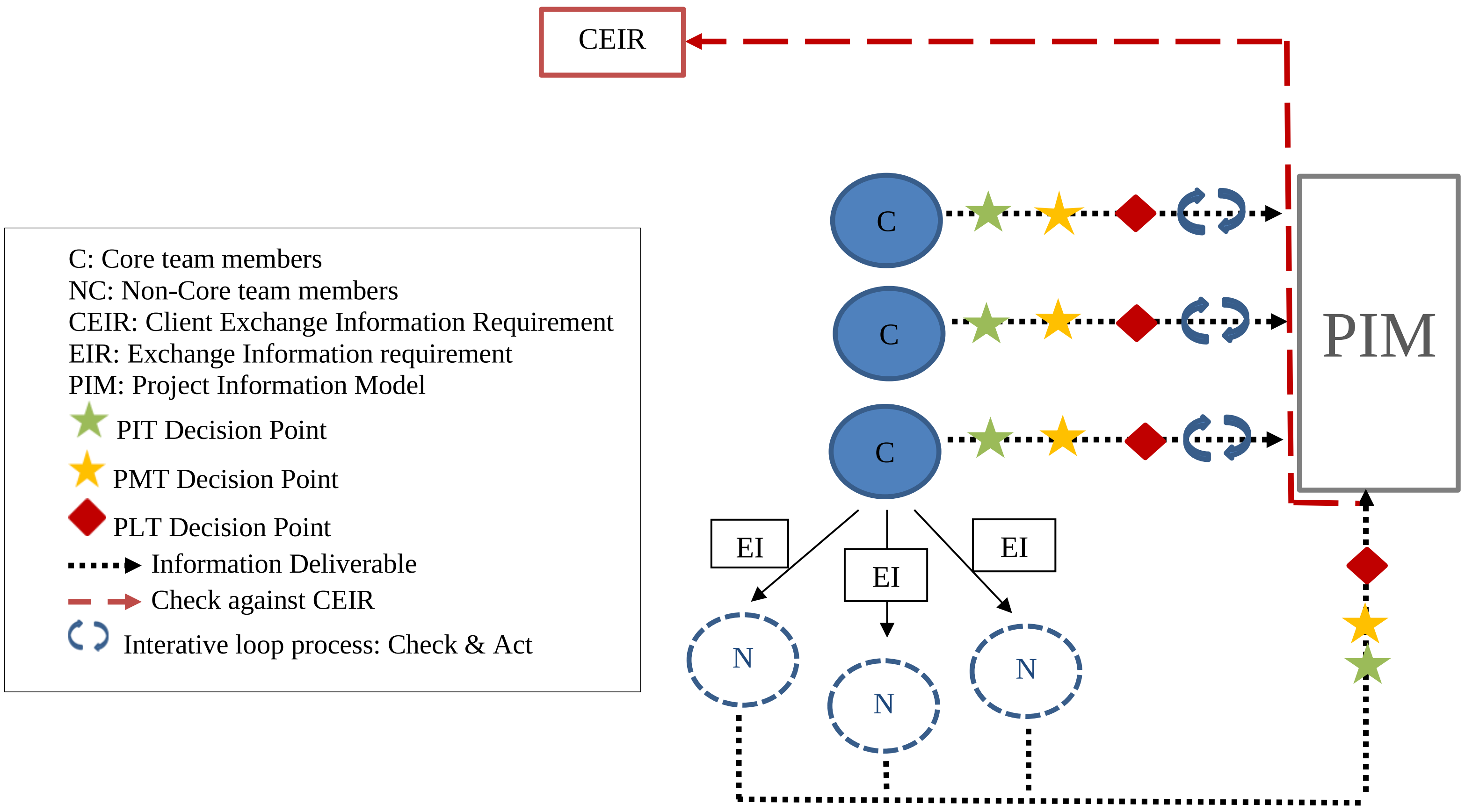


Figure 5.2: Process of Information Deliverables to Support Key Decision Points



5.3.1 General terms

Below is a list of terms used in the framework.

- Client: to refer to individual or organisation procuring and commissioning a built asset and issuing the contract.
- Client Exchange Information Requirement: information required by the client in relation to the appointment with the selected proponent
- Exchange Information Requirement (EIR): information required by the core-team in relation to an appointment with a non-core team.
- Contractor: organisation that carries out construction works. It is assumed the contractor is the organisation that also performs the construction programming.
- Core-consultant(s): professionals that provide services during concept design, design development, documentation and contract administration. e.g. architect, cost consultant, service engineer, structural engineer, etc.
- Core-services contractor: individual or organisation responsible for the installation, operation and monitoring of the technical services including mechanical, electrical and public health systems.
- Non-core design consultants: professionals appointed by the PIT that provide services related to a specific task of the design e.g. lighting engineer, landscape architect.
- Non-core service contractor: a person who is hired by the PIT to perform a specific task as part of the overall project. They are normally paid for services provided to the project in fixed-price bases.
- PIM: Project Information Model relating to the delivery phase.

5.3.2 Stage 1: Strategy

The first step for the client is to establish the organisational needs and the purpose relative to the characteristics of the project. The key stakeholders and users must be identified, in particular, those who are part of the strategic decision making, in order to define their objectives and expectations. The client needs to clearly explain the purpose of a collaborative engagement, the nature of the relationship, and the expected behaviour. The collaborative contracting approach requires a change in the ways of thinking and working, therefore it is important that all stakeholders understand their commitment to the process, the principles and project culture, and where and how their contribution will make a difference.

Less experienced clients, with no in-house expertise, should consider appointing the Information manager to pull together the digital strategy and make sure that all work during the projects. Clients, stakeholders, together with the Information manager should, first of all, state the client's intent for requiring information deliverables, including the aspects of the assets that are intended to be managed. To do so, the Model Uses which collate the information requirements that need to be delivered in – or embedded within – the BIM models need to be identified.

The Model Uses are 'the intended or expected project deliverables from generating, collaborating-on and linking models to external databases' (BIM Dictionary, 2016). As stated by Succar, Saleeb, and Sher (2016) *'the term Model Use is not exclusive to the construction industry and can be applied to Geographic Information Systems (GIS - e.g. Urban Modelling), Product Lifecycle Management (PLM - e.g. Sheet Metal Cutting) and similar information systems'*. Several Model Uses lists are currently available including the PENN State BIM Project Execution Planning Guide (2011) and Massport BIM Guidelines (2015) with respectively 25 and 51 well-defined BIM uses. This work suggests the use of the Model Use Table developed by the BIM Excellence (2016) which comprises three categories of Model Use: 52 General Model Uses and 72 Domain Model Uses, and Custom Model Uses are all very well structured and defined. To identify the Model Uses for the project, the 'Implementation Task List' can be adopted as a valuable tool to demonstrate the practical applicability of each model use (Succar, et al., 2016)

Once the Model Uses have been defined, they need to be embedded within the Client Exchange Information Requirement (EIR) (ISO, 2018a). The client EIR is a pre-tender document and it sets out the information to be delivered, standards and process that the Project Implementation Team should adopt during the project delivery process (Scottish Futures Trust). The core content of the EIR is typically divided in three categories of requirements:

I. Technical

   - Software Platforms

- Data Exchange Format
- Co-ordinates
- Level of Information
- Training

II. Management

- Standards
- Stakeholder roles and responsibilities
- Planning the work and data segregation
- Security
- Coordination and clash detection process
- Collaboration process
- Model review meetings
- Health and safety and construction design management
- System performance constraints
- Compliance plan
- Delivery strategy for asset information

III. Commercial

- Timing of data drops
- Clients strategic purpose
- Defined BIM/project deliverables
- BIM-specific competence assessment

In cases in which the facility will be also managed, it is highly recommended to involve the operator right from the beginning to capture the operator information requirement, also defined as Asset Information Requirement (AIR). The AIR outlines the information that the client/operator requires within the BIM model in order to manage their facility/assets after handover and it should be used to inform the development of client EIR (ISO, 2018a). To date, the majority of the asset owners seem to be quite backward with an archaic asset hierarchy and data structures. Therefore, the BIM manager also needs to educate the asset owners and lead them during the digital transformation, understanding their needs to be able to deliver a solution suitable for the ongoing management of their assets.

Inexperienced clients might also choose to develop the EIR after the selection process in order to get the input from the team. That can be particularly reasonable in small projects where the cost for an external advisor may not be justifiable. However, this approach could be risky for both the proponent and clients. For the proponents, they will bid without knowing exactly what is required from them in terms of model and information deliverables, for the clients, it will preclude them from selecting the team based on their capability to respond to the EIR.

The role of the Information Manager is extremely important since they need to assist the client and stakeholders in:

- Defining their requirements to develop the client Exchange Information Requirement (EIR),
- During the tender process to evaluate the digital expertise of the proponent,
- During the whole process, checking that the BIM deliverables are in compliance with the client requirement.

Collaborative contracting differs from traditional contracting since the key parties are selected at the beginning of the process when the scope of work is not fully prescribed. Therefore, it is expected that the initial EIR does not mandate exactly ‘what to do’ and ‘how to do it’ but rather it limits in its specifications and grows over time once the team has been assembled following the project’s progress. The initial EIR should be a kind of guideline that gives to the bidders an understanding of what the expectations are and goals that need to be achieved. Hence, the client’s EIR should be incorporated into the tender documentation as part of Request for Proposal relating to BIM, enabling the proponents to come back with their own solution producing an initial BIM Execution Plan in response (PAS 1192).

One of the main advantages of collaborative contracting is the initial degree of flexibility, which allows proponents to make change and comes with innovative and creative solutions. Each of the proponents, therefore, will work hard to submit their best solution and this will ensure the taxpayer that the best solution for the project will come out.

In preparing the Request for Proposal (RFP) clients must also define the initial Key Results Area (KRAs), sometimes referred to as “critical success factors” and Key Performance Indicators (KPIs). The KRA identify what the customer’s needs are, while the KPI measure the success of these issues. KRAs range from standard triangle (Time-Cost-Quality) performance criteria to performance expectations on environmental and social dimensions. Examples of KRAs might be ‘Cost Performance’ and ‘Safety’ as well as ‘Stakeholders Satisfaction’ and ‘Teamwork and Culture’. Once the team is formed, the team outcome will be measured against agreed KRA.

BIM-BASED COLLABORATIVE CONTRACTING FRAMEWORK

STAGE 1

Strategy

Client duty:

- Identify Key Stakeholders and End Users
- Involve asset manager /operator/FM
- Appoint BIM/DE advisor if needed

⬇

- Together define:
    - Initial project scope
    - KRA/initial performance expectation
    - BIM/DE goals aligned with project goals, clarify ***WHY*** and ***WHAT***.
    - Establish initial BIM Uses
    - Initial client's exchange information requirement (CEIR) contains the asset information strategy.

STAGE 2

Team selection

Qualitative-based selection:

- Interview
- Workshop

Assessment

- Financial
- Behaviour and collaborative working.
- Digital
    - Past experience
    - Pre-Contract BIM Management Plan (BMP) to assess the team's understanding and capabilities to respond to the client/key stakeholders/end users/ asset managers expectations. Ask ***HOW***

STAGE 3

Contract Negotiation

- Multi-party Contract (at minimum client, lead consultants, main contractor, key supplier(s)
- Risk/Reward Pool (Core-Design Consultants, Contractor(s), Core-Service Contractor(s)
- No fault-No blame
- Joint decision making
- Integrated Insurance

Team Establishment

- PLT: Project Leadership Team
- PMT: Project Management Team
    - Project Manager
    - Information Manager (client)
    - Asset manager
- PIT: Project Implementation Team
    - BIM manager(s)
    - Cost
    - Core-Design Consultants
    - Contractor(s)
    - Core-Service Contractor(s)

Co-location

Foundation workshop → Coach/Facilitator knowledge in team and process improvement
Develop the Culture: Mutual trust, Respect, Open Communication

5.3.3 Stage 2: Selection Process

The selection process should guarantee that the proposed team members are aligned, competent and committed with the principles and culture that support the team goals. Thus, the request for proposal (RFP) should clearly express the type of environment clients are attempting to create. The section of the team is based on qualification, which means that proponents are ranked by their qualifications and capability without consideration of the price. The elements of self-awareness, awareness of others, team development, communication, and principles of high performance are essential for the success of collaborative contracting (Morwood, Scott et al., 2008). Collaborative contracting, therefore, calls for new behaviours from all team participants including clients. Clients should show leadership and vision in describing the kind of behaviours they want and throughout the process keep the attention on characteristics that are consistent with their values. Proponents should be assessed according to three criteria:

- Financial: e.g., how overhead and profit will be calculated
- Collaborative working attitude: individual and as a team
- Digital skills: BIM skills, experience and capability to respond to the EIR

After the submission of the proposal, the client will make a short listing of two/three proponents to proceed to the interview stage. The interview stage aims to help the client to assess the proponent's capabilities and relevant skills, as well as the team and the individual ability to collaborate. It is also the moment to assess team capabilities in BIM/DE such as prior experience and skills. The team is expected to have prepared an initial BIM Management Plan (BMP) in response to the client EIR, demonstrating their knowledge, capabilities and strategy to satisfy the client's digital requirements. The proponent should also include the proposed names of the individuals within their own organisation who will take the role of information manager on behalf of the organisation, and a responsibility matrix

During the selection process, the client should evaluate the team's ability against each of the Model Uses expressed in the EIR. An example of assessment questions can be found in the work of Succar, Saleeb et al. (2016). In order to assess individual and team digital capabilities the, BIMcredits developed by BuildingSmart Australasia or the BIM Excellence developed by Bilal Succar could be adopted. While the BIMcredits has been developed to assess individual know-how, the BIM Excellence allows measurement of the capability at individual, organisational and project team levels within a single organisation as well as among two or more organisations that are entered in a collaborative environment. Whatever the approach is that the client will use, it is recommended to include in the selection panel (procurement team) the BIM manager in order to assess directly the digital team competences.

It is very important that the proponent brings in the best qualified and suitable people who will actually work on the projects. Personality assessment should also be considered when choosing the team members. The Meyers-Briggs Type Indicator (MBTI) is one of the most widely used psychological assessments helping to understand personality profiles.

Following the interview stage the client will present a short list of two proponents with the highest score for the one/two days workshop. The aim of the workshop is to reinforce the relationships among the team and the client by collaboratively establishing the vision, project objective, culture and behaviour, and that the organisational structure includes role and responsibilities, the approach to problem solving and continuous improvement (Morwood, Scott et al., 2008). Following the workshop, the panel will select the preferred proponent team that will deliver the project.

Who should be part of the core-team?

The size of the team depends on the needs of the project. The main factor of collaborative contracting, which distinguishes it from any other type of contract, is the early involvement of the key actors. The strategic decision of what companies are inside the risk pool and what companies are outside the risk pool becomes highly important. People outside the risk pool are expected to have completely different behaviours and attitudes in comparison with the parties inside the risk regime. They will be appointed under a fixed price contract, which is well known for driving silo mentality and finger pointing behaviour.

The core team, therefore, should not be limited to the client, architect and main contractor, rather it should incorporate all the parties in the supply chain whose contributions effect the success of the project. The right people include all the parties who will have the most significant influence on costs, scope of work and greatest impact on value.

Depending on the complexity of the project and experience of the client in collaborative contracting, two options can be used to establish the team. The first option is to issue an RFP for a complete core-team, leaving to the proponents the task of forming the cohesive team. In this case, the agreement will be signed by all parties that form the proponent’s team and therefore all parties will be part of the risk/reward compensation regime. Moreover, all the teams will start the discussion regarding team values and culture right before the selection process.

Alternatively, the client can issue an RFP for the team composed by the lead consultant and contractor. Subsequently the team, including the client, will select the core-team consultants and core-service contractor(s) at the time their contribution affects the project. In this scenario, the agreement will be signed only by client, consultant and contractor, however, new parties will be able to participate in the risk/reward poll even though they don't sign the agreement. However, this approach may not allow the building of a cohesive team right from the beginning, since parties will be appointed after the core-team culture is established.

BIM-BASED COLLABORATIVE CONTRACTING FRAMEWORK

STAGE 1

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STAGE 3

Contract Negotiation

- Multi-party Contract (at minimum client, lead consultants, main contractor, key supplier(s)
- Risk/Reward Pool (Core-Design Consultants, Contractor(s), Core-Service Contractor(s)
- No fault-No blame
- Joint decision making
- Integrated Insurance

Team Establishment

- PLT: Project Leadership Team
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Co-location

Foundation workshop → Coach/Facilitator knowledge in team and process improvement
Develop the Culture: Mutual trust, Respect, Open Communication

5.3.4 Stage 3: Contract Negotiation

The selected proponent - which includes core-design consultants, contractor(s) and core-service contractors - and the client work together to achieve commercial and cultural alignment (Integrate Project Initiatives Ltd, 2014). The discussion should aim to obtain agreement around the commercial alignment process and risk and reward arrangement, including the percentage that the parties will put 'at risk' (Morwood, Scott et al., 2008). The commercial framework must be the basis for establishing and driving what is 'best for project' behaviours to achieve an outstanding outcome. The collaborative contracting agreement should be based upon five main features:

1) *Multi-party contract:* a single contract is signed between the client and the proponent team.
2) *Risk/Reward regime:* a fundamental principle of collaborative contracting is that results are achieved according to project outcomes rather than individual firm contributions, if one participant wins, all win, as well as if one loses, all lose (AIACC, 2014, Hutchinson and Gallagher, 2003, Morwood, Scott et al., 2008). The compensation structure should include three components: i) actual cost, ii) corporate overhead and profit, iii) risk/reward sharing.
3) *No fault, no blame, no dispute:* the collaborative contracting agreement does not provide for any dispute resolution mechanism with all disputes being unanimously aligned upon by the project leadership team (Hutchinson and Gallagher, 2003).
4) *Unanimous decision-making:* every decision made by the project leadership team (PLT) is unanimous. In case one participant does not support a decision or solution, the project leadership team will not accept that solution and another solution must be found (Hutchinson and Gallagher, 2003).
5) *Integrated Insurance:* get the insurance right to sustain the no-blame culture. The basic principle is to have an integrated insurance regime which results in a collective responsibility, rather than to allocate responsibilities only to the design professional.

Organisation and Role

The structure of collaborative contracting can be compared to a virtual organisation created to deliver a project (Morwood, Scott et al., 2008). The core team comprises the firms that are part of the risk and reward structure, other companies are referred to as non-core. The organisational structure of collaborative contracting, which identifies the key leaders and decision makers, is typically divided into three levels:

(1) Project Leadership Team (PLT)

(2) Project Management Team (PMT), including Project Manager

(3) Project Implementation Team (PIT)

The structure of collaborative contracting can be compared to a virtual organisation created to deliver a project (Morwood, Scott et al., 2008). Following the analogy, the equivalent in a company is the board (PLT), the management team (PMT) and the chief executive officer (PIT).

The PLT is typically formed by 1 or 2 representatives from each of the participating firms: client, core-consultants, contractor(s), core-services contractors. The PLT is responsible for providing governance and high levels of leadership; set the vision, objectives and behaviour principles; resolve issues and make unanimous decisions as well as mentor, coach and empower individuals on the core team as required (Morwood, Scott et al., 2008).

The Project Management Team (PMT), is led by the Project Manager. The project manager can be someone who is already part of the team or appointed from an external organisation. The PMT's main responsibilities are: appoint and empower the PIT, report performance to the PLT and implement the PLT's decision, deliver the work and meet or exceed the project goals (Morwood, et al., 2008). Within the PMT sit the Information Manager whose roles is to ensure that all the information exchanges and data deliverables satisfy the client requirements. The Facility Manager is also part of the PMT to ensure that the information needed for the asset management operation and maintenance are defined, created and embedded into the model. It is expected that the Facility Manager will be involved initially in the PIT as well as during the PMT meetings and subsequently only in the PMT meetings to make sure their requirements are still met.

The Project Implementation Team (PIT) includes the PMT members and all the participants at the operational level including non-core team members. Each discipline has a BIM manager whose role is to make sure that all the deadlines are achieved and all disciplines are providing their component. The BIM managers need to be work very close with the client information manager to ensure the requirement are achieved along the project.

The PMT and PIT are co-located and work together every day, while the PLT meets occasionally when key decisions need to be taken.

Project culture

Collaborative contracting requires building the kind of work environment that assists and empowers teams and individuals to do the best they can. Clients should clearly state from the selection process, the behaviour and culture that are expected of the project team. To create a high-performance team, the members need to explore and agree on the type of culture, core values and behaviours that will characterise the collaborative team.

The foundation workshop is a team kick-off meeting that helps to begin developing the culture, aligning the team regarding project’s goal and values. A facilitator/ coach is a key figure to successfully build the desired environment. They provide an essential role in training and guiding the team through the process and make them feel like they are part of a unique organisation. Coaching sessions should be repeated with regularity throughout the project to reinforce collaborative behaviour and help new participants to quickly align with the team values.

BIM-BASED COLLABORATIVE CONTRACTING FRAMEWORK

STAGE 1

Strategy

Client duty:

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- Together define:
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Qualitative-based selection:

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Co-location

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5.3.5 Stage 4: Lean Digital Design & Construction

The integration between Lean and BIM during the design and construct of the project will be used to achieve, in the most efficient manner, the client' objectives for the project. Lean Design and Construction applies specific management tools to achieve the objectives of a Lean production system: delivering what the client wants while maximizing value and minimizing waste. According to Tzortzopoulos (1999) and Koskela (2000), the application of Lean construction principles in the design process must take into consideration three different views of the project: (1) design as conversion; (2) design as flow of information and (3) design as a source for generating value (from the customer's point of view). The design and construction processes can be seen as an interactive loop process, like the Plan-Do-Check-Act (PDCA) cycle of continuous improvement. The entire process is built around the idea of continuous improvements of all facets of the construction project. The team need to understand that all the decisions made in one phase will affect subsequent phases. Therefore, all aspects of the total delivery process, from strategic plan to design, construction, handover and occupancy, must be integrated. Below, each step of the PDCA design and construction cycle are explained in more detail.

PLAN

The planning phase is extremely important to successfully implement BIM since it allows setting out of the initial planning of the digital strategy for the whole project. It is the phase in which typically the core team needs to invest major time and effort. Indeed, the project delivery team often makes the mistake to jump too soon into the design phase. Whereas the team should first ensure that everyone is aligned with the expectations about scope, cost, schedule, and that the final outcomes are realistic before the design phase begins.

Everyone is on board from day one, so everything is planned collaboratively with the end in mind. A well-documented BIM Management Plan (BMP) is the output of the planning strategy and it needs to be agreed among all the core team to ensure that everyone is aligned with the goals and each party's responsibilities. The plan should define the scope of BIM implementation on the project, identify the process flow for BIM tasks, define the information exchanges between parties, and describe the required project and company infrastructure needed to support the implementation (Computer Integrated Construction Research Group, 2011). The development of a BIM planning strategy requires deep discussions among team members. The plan will be updated and reviewed on a regular basis throughout the entire project lifecycle.

The development of the BMP can be described through the five Lean principles:

1) **Value:** The initial value and the project goals are defined by the client through the EIR as part of the RFP. As mentioned above, the client EIR also includes the Model Uses required for the project. During the planning phase, all of the core team, including the client, work together to revise and eventually add new Model Uses to achieve the project and team goals. A Model Use defines a modelling activity that adds value to the project, according to what the customer wants and is willing to pay (Massport, 2015). Therefore, it is paramount to establish 'why' a Model Use should be developed and WHAT is the purpose it is expected to achieve. Over-modelling is wasteful since the client is going to pay additional money for the information that it never needed. Under-modelling, on the other hand, affects the decision-making process and the client won't get the data that they may have wanted.

2) **Stream mapping:** the value stream mapping is best used for mapping the flow, identifying and eliminating any steps that do not deliver value to achieving a specific Model Use. Value stream mapping is defined as a tool that helps individuals visually see and understand a given process rather than simply looking at results (Seed, 2015). The Model Uses flow needs to be mapped, decision points established in accordance with the delivery schedule, and responsible parties identified.

3) **Flow:** Once the process has been mapped, the team evaluates which steps are value-added and which are non-value added. In this way, each team member can clearly understand the interaction between their work with other team member's work and constrains can be eliminated (Computer Integrated Construction Research Group, 2011). Each participant, in particular the transmitting and receiving parties for each information exchange transaction, should have a clearly understand the information content. To define these exchanges, the team needs to determine the

minimum amount of information, both geometrical and non-geometrical data, needed to answer each BIM Use. Anything beyond this minimum is considered as waste (ISO, 2017). As specified in ISO 19650-1 (2017) the level of information needs to define the extent and granularity of information and its purpose is to prevent the delivery of too much information. The key of this phase is to answer WHAT, WHEN and BY WHOM each information exchange needs to be developed to inform client/users/other participants.

4) **Pull:** select a single milestone of the design stage to be pulled. The pull planning requires working from a target backwards, to maximise the flow and determine what each task in the process requires from the one before it. This approach is required to change the prospective regarding who the customer is and how the value is delivered to them. The customer is not only the client or end user, they are whoever the work is handed off to. For instance, when an architect needs to hand their design to the structural engineer, the structural engineer becomes their customer and the architect needs to provide value, not only to the client but also to the structural engineer. Therefore, architect and structural engineering together should address the question: what is the information or what is the deliverable that needs to be handed off? A later task is to determine HOW and WHEN the earlier task should be accomplished to enable them to start working. Nothing should be done that is not required by a later step in the process (Massport, 2015). The pull phase also allows the identification of information required from a non-core member for each key milestone. The demand of information needs to cascade downwards, and supply of information to pull upwards. To do so, the core-team needs to develop an EIR for each of the non-core members, when they will appoint them to provide their contribution.

5) **Perfection:** perfection can be persuaded through continuous improvement. The team must first establish which approach they will adopt for problem solving, continuous improvement and learning stages. This corresponds to the ACT phase of the PDCA cycle of continuous

improvement, where bottlenecks are identified, and solutions adopted to improve the process.

The development of a well-documented BMP with the appropriate information needed to reach a Model Uses is extremely important to ensure the re-use of data. By agreeing which level of information will be transmitted to the receiving party at which stage of the project allows the parties to rely on the model and data they are receiving.

The level of information depends on the decision that needs to be made at each specific decision point, therefore the project information is expected to mature following the projects' stages. For instance, if the team decides to use the model for cost estimating during the schematic design, the estimator will first determinate what information they will need from their predecessors in order to perform the analysis. Subsequently, they will verify and validate the model before starting the estimation analysis. Once the design project reaches the development stage, the estimator will expect to receive the model that matches with the context of the production stage and therefore is embedded with the information needed to perform a more accurate analysis. Again, to be sure that the model is developed for this purpose, the estimator needs to collaborate with the predecessors to ensure they will develop the model with the data (geometrical and non-geometrical) required to estimate the cost and make important decisions.

This can be successfully accomplished as the parties are under the same umbrella, collocated in the same space and with a contract arrangement that enforces their collaboration. The whole team is able to define and agree on the sequence of information that needs to be delivered when and by whom. The BMP is not just a document, it is an extremely valuable tool to succeed in any BIM project, as, if done effectively, will allow the whole team to stay on track having focus on the key decision point. The BMP is a living document and hence, it needs to continuously be updated, monitored, and revised by the whole PIT as additional participants are added and follow the project's progress. To facilitate and make the BMP more agile, avoiding the disconnected workflow of a paper-based approach, platforms such as LODPlanner can be used to develop the BMP and the flow of information. The advantage is to have the management plan online, shared among all members and updated in real-time.

The sharing and coordination of information among the teams, including core and non-core teams, is ensured by the use of a Common Data Environment (CDE).

The CDE is both a technology and a process. The CDE is typically served by a document management system or a cloud-based service that allows the sharing of data among the project's team members through four stages, as defined in BS1192:2007

1) Work in Progress: when information is being developed by its original creator (e.g. architect, engineer). This data sits in a folder that is accessible and visible only by its original creator.
2) Shared: the data is now visible and accessible by other team parties but not editable. In this state for instance, coordination between architect and engineer on the model could be performed. This state also includes sharing with the client for review, feedback loops, or approval.
3) Published: The published state is used for information that has been authorized for use, for example in the construction of a new project or in the operation of an asset. This information is both 'coordinated' and 'validated' for use by the total project team, which is distinguished from the 'shared' state where multi-participants are in the process of coordination and validation.
4) Archive: is the record state, it holds all information that has been shared and published during the information management process as well as an audit trail of their development.

The PIT and the Information Manager must set up the CDM at the beginning of the design stage and define how this environment will be secured, and made stable and accessible to all teams including the non-core team members, as they will add to the project. The collaborative contracting structure eliminates the traditional and problematic 'transition between the design phase and the construction phase' as the key players are on board early and will continuously collaborate throughout the project.

DO

This is the stage in which the plan is implemented and executed, which means that the design starts, and a range of information is produced following the design's progress. This information will include models, structured data (such as project schedules or COBie files) and a range of reports or analyses (either in native formats or as pdfs).

During this first stage of the design, including the schematic design and part of the design development, the team needs to arrive at developing the target outturn cost (TOC).

The PIT starts to explore the possible solutions against the client's business goals. The use of the target value design (TVD) approach, which provides the team with continuous feedback to better inform decisions, can be useful in this stage, The TVD is a Lean philosophy of design to a budget, rather than budgeting a design (Allison, et al., 2018). It is composed of a set of other Lean tools including the set-based design to explore multiple options and Choose by Advantage to choose the best solution

CHECK

The check stage corresponds to the monitoring of progress by tracking and checking the plan's execution. It is performed by doing regular evaluations between the original plan and the actual condition. During the design stages, the checks are the gateway through which the information delivered needs to be checked against the requirements and decisions are needed to be taken. Gateways provide the opportunity for the project team to represent any decisions, iterations or quality control checks required before the completion of a BIM task (Computer Integrated Construction Research Group, 2011). A gateway can be used to ensure that the deliverables or results of a process are met. The gateway has been classified in three levels:

- PLT decision points: strategic decision making at defined project milestones to check against the KRA and KPI. Depending on the complexity of the projects, during the schematic design there would probably be weekly or fortnightly meetings, which then would become fortnightly during the design development, and monthly during construction documentation. This outlines the fact that more energy needs to be spent at the beginning of the project to address important decisions while during construction, they simply need to respond to issues that come up during construction. During the meeting, the PLT will have a meeting agenda with different sections that different people coming into the meeting will address. While the project manager will be there the whole time, the information manager will deal with the sections on the agenda.

- PMT decision point: corresponding to the design review; the meeting should occur every week at the beginning and then move to every two weeks during the design development and construction documentation stage. At defined project milestones, the team will also need to verify if the information required to meet a specific criteria or model use has been delivered. This provides an opportunity for the team to check and validate the project's compliance with the initial EIR.
- PIT decision point: corresponding to the design coordination meeting. During the design development, collaboration is the key. The coordination meeting should occur at a minimum, every two days to ensure everyone is on the same page. The PIT, the Information Manager and Facility Manager need to attend the meeting. In the latest stage of the design, the meeting should be at least once a week. In the construction phase, software such as Navisworks or 360 Field can be used for coordination and clash detection as well as monitoring reported problems and tracking their resolution.

Figure 5.2 describes the design process and decision-making points. The blue circles show the parties involved in the design contribution. As the design progresses, the number of parties involved in the design will increase. For instance, during the schematic design only the cost manager and core design consultants contribute to the design model, whereas during the design development phase the non-core design consultants will also be involved in contributing to the design (dotted blue circle). The green, yellow stars and the red diamond indicate the PIT, PMT and PLT key decision points respectively. As can be seen from figure, the parties involved in the decision-making points, therefore, will not be the only ones who are contributing to the design.

This is the key aspect of collaborative contracting, to get the right people on-board at the time that their decisions can influence the success. For instance, during the schematic design, the core-consultant team will be the only one contributing to the model with the cost manager. However, both the contractors and the core-service consultants must be part of the decision-making process to provide the constructability input. The Information Manager and Facility Manager also need to be there to ensure that the client and asset owner requirements are identified and addressed. During the design development, the non-core parties will start to provide their contribution to the model and therefore they need to be involved in the decision making. In the construction documentation phase, the core-members need to coordinate the model with the non-core team members who will also be part of the decision meeting point.

Finally, the circular arrows on the bottom of each decision's point represent the CHECK and ACT stage. The arrow to the left represents the checking of the model use and information against the requirements. The arrow to the right represents the checking if the information needed to start the next project stage is available.

Figure 5.3 describes the process of information deliverables to support the key decision point. The core-team will establish the information requirements (EIR) that will flow down as it cascades to the non-core party who will then pull it up as information and model deliverables to the project information model. The digital deliverables created by the core-team as well as the non-core team will pass through all three decision points and are checked against the client's EIR before adding it into the project information model (PIM).

ACT

The ACT stage is the last step of the cycle where the learning generated by the entire process can be integrated in order to complete the information exchange, adjust the goal, review the plan or add value to the solution. During the Check and Act stages, some important Lean tools such as A3 problem solving, 5Why technique and Plus/Delta for continuous improvement are highly recommended to be adopted. The A3 problem solving consists of describing; by using A3 sheet of paper, a problem, the possible options, a proposed solution and action plan. The 5Why technique helps to find the root causes of why the team do not achieve the expected outcome by asking 5 times 'Why", each time investigating into why the previous one occurs. Finally, the Plus/Delta assesses what is working and what is not working in the process. The 'plus' indicates everything that is going well and should be repeated, the 'delta', conversely, indicates what did not go well and should be improved. The Plus/delta should be performed at the end of each meeting (Allison, et al., 2018).

The PLAN-DO-CHECK-ACT is an interactive loop that needs to be followed throughout all of the design and construction stages in conjunction with the five Lean principles respectively: value, stream mapping, flow, pull, and perfection. The aim is to continuously find new ways to improve the process and therefore increase the value. The Last Planner System can be used as a management tool to manage both the design and the construction processes as well as to measure the team performance to deliver what they have done against what they have promised. The LPS is developed in four levels of planning steps: master schedule, phase pull scheduling, lookahead planning, and weekly work plan or commitment planning. While the LPS has been widely adopted in the construction phase, its use at the design stage is relatively new. Considering that collaborative contracting requires a lot more effort in the initial phase with input coming from several stakeholders, a good approach of collaborative planning is essential. During the design, the LPS is carried in a slightly different way, where the tasks that need to be completed are actually the information that needs to be delivered in order for another party to rely on the model it is receiving and carry out the next task.

The key of this whole process is the co-location. Indeed, under collaborative contracting the core-team is collocated in the same space, allowing participants to solve issues in real time breaking down traditional discipline silos. The room is set up with a visual graph, imagines, whiteboards and any kind of collaborative materials that can help participants to make decisions and find creative solutions together about a specific issue.

STAGE 4

Schematic Design + Design development

Plan

The PIT developed team BIM Management Plan:

❖ Apply Lean Principles:

6) **VALUE:** Start with the End in Mind. Define BIM/DE Uses to achieve project goals. For each project's milestones. Ask: ***WHY*** and ***WHAT***.
7) **PLAN:** BIM/DE uses mapping at each project's milestone and integrated with the delivery schedule. Define the Responsible Party for each BIM uses. Ask: ***WHEN*** and ***BY WHO***. Identify INPUT and OUTPUT.
8) **FLOW:** Define Information Exchange for each project's milestone stages. Ask: ***WHAT***, ***WHEN*** and ***BY WHO***, (Level of Information need ISO 19650).
9) **PULL:** Select the milestone to pull. Work from a target backwards to maximise the flow and determine what each task in the process requires from the one before it. The customer is whoever the work is handed off to, ask: what is the information needs to be handed off for the next task start? →Conversation among transmitting and receiving parties. Identify the information requirement from non-core team parties for each decision points that they need to pull upward.
10) **PERFECTION:** establish Quality Assurance (QA) and Quality Control(QC) of the model and information embedded for continuous improvement

Do

Model-discipline (s)
PDF & Open Docs
Cobie Data

- Set-based Design
- Target Value Design
- Choosing by Advantage

Check

- At each decision point check the information delivered against the requirements.
- Ensure information against what is needed to start the next stage is available
- QA/QC

The decision point can be:
- Internal among (PIT)
- External (Team to supplier)
- Client decision points

Big Room

Act

- Review the plan
- Revised client requirements
- Add value to the solution

- A3 Problem Solving
- Big Room
- Plus/Delta Continuous Improvement

Common Data Environment ISO 19650

Big Room

Collaborative planning/Last Planner System Design

Develop the Target Outturn Cost

Coaching sessions repeated with regularity to reinforce collaborative behaviour and help new participants to quickly align with the team value.

STAGE 4

STAGE 5

Complete design development

Construction Documentation

Construction

O&M

- Focus to continuously adding value to the project through the 5 Lean principles: Value, Value Stream Mapping, Flow, Pull, Perfection
- Interactive loop process: Plan-Do-Check-Act
- QA/QC
- Involvement of the right people at the right time
- Develop the EIR and agree to the BIM Protocol with the NON-core design consultants and non-core contractors when is needed

Model-discipline (s)
PDF & Open Docs
Cobie Data

Validation as built content in the model

Integrated FM system with BIM

Keep the maintenance of the model update

PLAN-DO-CHECK-ACT LOOP

Collaborative planning/Last Planner System Design & Construction integration 4D BIM

Big Room

Coaching sessions repeat with regularity to reinforce collaborative behaviour and help new participants to quickly align with the team value.

5.3.6 Stage 5: Operate and Maintains

The established gateways within the process will guarantee that the Project Information Model is properly validated along the process with all the embedded information required to handover the Asset Information Model (AIM) for the asset management's purpose (ISO, 2018b). If the information cycle has been done properly throughout the project, the BIM model and information should be passed to the operator/facility manager as soon the construction is completed, allowing the operation and maintenance stage to begin. Indeed, the model will need to be continuously maintained and updated during the operational period until the asset has reached its end of life for demolition.

STAGE 4

STAGE 5

Complete design development

Construction Documentation

Construction

O&M

- Focus to continuously adding value to the project through the 5 Lean principles: Value, Value Stream Mapping, Flow, Pull, Perfection
- Interactive loop process: Plan-Do-Check-Act
- QA/QC
- Involvement of the right people at the right time
- Develop the EIR and agree to the BIM Protocol with the NON-core design consultants and non-core contractors when is needed

Model-discipline (s)
PDF & Open Docs
Cobie Data

Validation as built content in the model

Integrated FM system with BIM

Keep the maintenance of the model update

PLAN-DO-CHECK-ACT LOOP

Collaborative planning/Last Planner System Design & Construction integration 4D BIM

Big Room

Coaching sessions repeat with regularity to reinforce collaborative behaviour and help new participants to quickly align with the team value.

5.3.7 Summary

This chapter illustrates the BIM-based collaborative contracting framework developed based on research finding. The chapter describes the 5 stages of the framework from the identification of client needs and requirements (stage 1), to the selection process (stage 2), analysing the key features of the contract negotiation, including organisation structure and the project culture (stage 3) throughout the integration of Lean design and construction (stage 4) to the final stage of the whole life-cycle, the operation and maintenance stage (stage 5)

Chapter 6: Conclusions

6.1 BACKGROUND SUMMARY

The need for the construction industry to became more collaborative and embrace integrated practice is not new. More than two decades have passed since the publication of Latham (1994) and Egan (1998) reports, which promoted more integrated processes by adopting partnering and collaborative working. Twenty years later, the Farmer's (2016) report 'Modernise or Die' reinforces that these decade-old problems that the construction industry is facing must be addressed. More so the review highlights that the lack of collaboration and innovation in the construction sector is due to non-aligned interests among clients and other stakeholders. These problems are fortified by traditional procurement models and a strong culture reluctant to change.

The last couple of decades have seen the emergence of a spectrum of collaborative procurements in response to the continuous dissatisfaction of many client organisations. Collaborative contracting, a client-centric model, is the highest extension of collaboration, which often uses Lean principles and tools as a means to effective collaboration. Likewise, great improvements have been made in the digital space where digital processes and advanced technology can now help clients and stakeholders to work collaboratively to accelerate project schedules and reduce project costs by making more informed decisions and limiting uncertainty and risk.

Several studies have repeatedly expressed the potential benefits achievable by using BIM within the framework of collaborative contracting. Indeed, BIM to fully realize its potential needs collaborative working environments that break down the siloed walls among the supply chain and aligns party's interests to commit for the best of the project, allowing a Lean workflow of information in a data-centric project.

However, to date, the collaborative contracting framework has not integrated the digital strategy within the procurement model. This research intends to provide such integration, thus improving and filling the gap of the already available collaborative contracting framework in the Australian construction industry. As such, the aim of this research is to develop a theoretical framework for collaborative contracting, which exploits the benefits of BIM processes and information management integrated within the Lean environment for the Australian construction industry

Three research questions were developed against three research objectives:

- **Research Question 1:** What are the contractual barriers to collaboration under conventional procurement models and how can these be overcome using collaborative contracting?

  Research Objective 1: Identify contractual barriers to collaboration under conventional procurement models. Analyse collaborative contracting methods and identify how the barriers can be resolved.
- **Research Question 2:** What are the challenges in adopting BIM in construction procurement in Australia?

  Research Objective 2: Identify the challenges in adopting BIM for construction procurement in Australia.
- **Research Question 3:** How can collaborative contracting enhance the effectiveness of BIM and Lean?

  Research Objective 3: Identify how collaborative contracting can improve the effectiveness of BIM and Lean throughout the procurement process.

The research has adopted an exploratory approach through semi-structured interviews and direct observation. Interviews were conducted with professionals from Australia, UK and US, who are leaders in innovative procurements and digital tools and processes. Findings from the literature, exploratory studies and interviews shaped the development of the final framework. The framework aims to deploy a digital strategy, comprised of five stages, in the design and construction of a project under a collaborative contracting framework, showing how Lean principles and tools support BIM processes and the information management flow. The framework was checked, refined and confirmed by four experts and the BIM-based collaborative contracting framework was presented.

6.2 MAIN FINDINGS

The aim of this research was to develop a framework for collaborative contracting, which exploits the benefits of BIM processes and information management integrated within the Lean environment for the Australian construction industry. The framework has been successfully developed and extensively described in Chapter5.

To accomplish the aim, three research objectives were set for this research as outlined in section 6.1. The first objective was to analyse how contractual barriers to collaborate under conventional procurement models could be overcome by using collaborative contracting. Within the semi-structured interviews, participants were asked to discuss the challenges they encountered to collaborate within the traditional procurement models and the key features of collaborative contracting that enable overcoming such challenges. The second objective was to explore the challenges in adopting BIM in construction procurement in Australia. Within the semi-structured interviews, questions were addressed to understand the current level of BIM adoption in construction procurement and relatively legal challenges. Finally, the last objective was to exploit how collaborative contracting can enable the effectiveness of BIM and Lean. Within the semi-structured interviews questions were addressed to exploits how the collaborative contracting models enhanced BIM and Lean practices.

The following sections discuss in detail how the research questions were answered to accomplish the research objectives and achieve the primary research aim.

1. **Identify contractual barriers to collaboration under conventional procurement models. Analyse collaborative contracting methods and identify how the barriers can be resolved.**

High levels of collaboration and integration across parties are considered a catalyst to a project's success. The research funds four main barriers that limit collaboration and integration among a project's team members: fixed price contract and risk transfer mechanism, the lowest price selection and parties' relationships.

The fixed price contract and risk allocation set the limit of collaboration. Under the fixed price contract, parties are interest to perform only what is required to tick their box. They are only focussed to deliver value for themselves and not for the whole project. When things start to go wrong, rather than working collaboratively to overcome the problem, the adversarial attitude of traditional contracts is to blame the other party for the problem, which party will successively try to blame other parties and so on. Indeed, the clear allocation of risks and responsibilities encourages parties to behave more risk-aversely to protect their commercial interests.

The lowest price bid has been criticized since it does not establish which team is the best placed to deliver both the client's project and digital requirements, but rather it focuses most just on the party who submitted the lowest price. Therefore, it does not incentivize the team to come out with innovative ideas; neither does it assess the team capabilities to deliver the digital requirement. Indeed, the tender stage is still based on paper drawing, missing the opportunity to potentially obtain a more reliable price by managing much more accurately the actual risk of overbidding or adding contingencies to cover that risk.

Finally, although parties agreed that projects could benefit from more integration and early engagement of both contractor and subcontractors to resolve in advance several constructability issues that are more expensive to be fixed in the construction stage, the procurement models that promote early collaboration do not necessarily drive the expected collaborative behaviour and integration. For instance, although D&C procurement promotes early involvement of the contractor, the parties still work within the boundaries of traditional contracts. The contractor is the party most likely to assume the lead position once the contract is signed and set up a quite adversarial environment. They may try to rebuild their authority with the design team but are still a sub-consultant with no equal level of voice in the process.

Conversely, collaborative contracting represents a unique procurement strategy that enables the creation of a cohesive and integrated team early in the project's inception to optimize the efficiency of the single phases with the vision of the whole project. The research found that the effectiveness of collaborative contracting to fostering collaboration is enabled by a combination of both legal and procedural features.

The legal features comprise:

1) Multi-party agreement
2) Mutual responsibilities
3) Risks and reward sharing mechanism that includes all the key parties.

4) Open book
5) No fault-no blame
6) Joint project control & decision making
7) Project Insurance

The procedural features include:

1) Client focus
2) Team selection based on qualification
3) Goal definition/ team alignment
4) Best for the project's culture and behaviour
5) Integration/ Early involvement of key parties
6) Intensified design and planning
7) Co-location
8) Performance measure

The legal features align the team financially and enhance collaboration by a risk and reward sharing mechanism, financial transparency and a good insurance regime that supports the no-blame culture. The contract is a multi-party contract signed between client and the key parties. These may include only design and constructor or be extended to the main sub-consultants and sub-contractor. It is highly recommended to involve early all the parties in the supply chain whose contribution affects the success of the project by significantly influencing the scope of work and cost. These parties can be incorporated in the main contract or sign a sub-contract but be included in the risk sharing mechanism. Under collaborative contracting, parties cannot seek redress and cannot sue, as the contract does not allow a win/lose approach. If an issue emerges, all teams work cooperatively to find the best solution to resolve the issue. This approach needs the right insurance in place. The insurance regime needs to protect the interest of everyone equally rather than allocate the responsibilities to the single parties.

On the other side, the procedural features represent the essential elements necessary for project optimisation. Indeed, to obtain the maximum advantages from collaborative contracting, it is vital that the whole team understands the client needs and is aligned with the client goals and expectations. From the selection process, based on qualitative criteria, the integrated team works close with the client to develop the best project solution that provides value for money. Right from the beginning, great emphasis is used to align the team culture and build an environment of mutual trust, respect and open communication to favour the 'best for the project' behaviour. A coach/facilitator is extremely recommended in order to train and guide the team, particularly inexperienced teams, through the process. To reinforce the culture the team, including the client, is also physically co-located. Co-location has proved to be very effective in reducing the time for informed decision-making and enhancing productivity.

In Australia, there seems to be an assumption that this type of contract should be reserved for large, complex and high risk projects, because it requires initial additional investment in cost and time and high levels of client engagement. However, most recent forms of collaborative contracting emerging in the United States and the United Kingdom, developed taking into consideration the advantage provide by new technologies and processes, have been successfully used to deliver relatively small building projects. This presents very complicated functions and systems that need to be integrated, such as health care and education facilities. Therefore, it seems that there is not a real reason for limiting the use of collaborative contracting, apart from the client's unwillingness to be so exposed.

The research also found that clients often use hybrid forms of collaborative contracting, which partially incorporate the above characteristic, to avoid being exposed to the risk sharing mechanism. As a result, collaborative contracting is turned into a risk-transfer contract without embracing the no-blame culture. However, it has been pointed out this hybrid form is not necessarily going to deliver as good a value as the pure forms, since parties are not encouraged to innovate without fear of being sued as soon as problems start arising. The challenge in this regard is to educate clients to understand and embrace a risk-sharing regime allowing the team to work within an environment that focuses on solving a problem rather than suing when the problem occurs, which finally results in dispute and conflicts avoided.

2. **Identify the challenges in adopting BIM for construction procurement in Australia.**

In Australia, BIM is predominantly a self-driven approach used by individual organisations to de-risk and optimise their own work without the client necessarily requiring them to do so. Several consultants as well as contractors have developed their own internal BIM procedure and framework and they are educating their sub-consultants and sub-contractors to become more capable. However, while this approach can be beneficial for the single organisation, it limits the value that can be obtained from a more holistic approach.

It is generally agreed that to obtain the benefit of the digital practices clients need to start mandating the use of BIM in a consistent and effective way. Indeed, the discussion within client organisations should shift from the use of BIM as a set of technology to the use of BIM as a strategic process catalyst for driving change. A well-defined digital strategy allows to consistently and effectively create, develop, share and maintain a wide range of data and information to enable a range of stakeholders to make effective and more efficient decisions, and therefore de-risks many areas along the project life-cycle.

It requires upfront planning to enable clients to specify from the outset their digital requirements, so that the team can create the strategy to create, manage and deliver the model and information embedded in a way that provides value to the client. It should provide immediate benefits in term of cost, time and safety by enhancing decision making through visualisation, simulation, and cost and time integration. In the long term, a proper digital strategy should deliver at handover a set of data useful for management and operation purposes.

To deliver the digital strategy, first of all clients need to have a strong vision and be able to articulate that clearly. Therefore, the role of consultants, contractors or external advisor is to educate clients on the benefits of digital means and assist them to clearly articulate project digital goals and expectations. Indeed, it can be incredibly onerous for clients in terms of collecting data for the sake of data without having a mindful consideration of what they actually need and want and therefore are willing to pay for.

Secondly, a high level of collaboration and cooperation between project parties and client is needed to ensure that what has been required is properly delivered along the project. In this regard, the research found that the level of cross discipline collaboration needed to ensure efficiency in the information flow is limited by the type of procurement models and contractual boundaries among parties.

From the information management perspective, traditional procurements present a few bottlenecks in the transmission of the model and information due to the different stages in which parties are appointed. Information is created at single phases and it is not really built up to the next phase.

From the interviews emerged that one of the major pieces of evidence of inefficiency of this approach is showed during the tender stage. Clients do not want to bear the risk of inaccurate or missed information, therefore the BIM model is issued as information-only while the contract documents legally governing the work of contractors continue to be two-dimensional plans and specifications. This approach creates inconsistency and conflict between the information provided in the model and the information in the 2D drawing, and no value is added since contractors need to spend a lot of time and cost to rebuild the model to ensure they and their subcontractors can rely on it. Similarly, consultants in transmitting the model use a number of disclaimers to be absolved by any liability due to error and omissions in their digital data once the model is no longer in their control.

As a result, a lot of potential value is missed. Considering the short time of the bidding process, the efficient use of a reliable model could allow the contractor a better and faster understanding of the complexity of the project. Meanwhile the estimator obtains a more accurate quantity take-off by automatically extracting quantity to better calculate the price during the tender, which will also drastically reduce the time on estimates. Therefore, clients could potentially obtain a more reliable and accurate price during the tender process, which should reduce variation during the construction.

A few legal challenges also have been mentioned when BIM is used under conventional procurement models. The first issue regards the liability. It is often stated that working with BIM does not change the liability position since the liability of each party is limited within the scope of its contract with the client. While this seems to be confirmed, the research however outlines the obstacle of transmitting and sharing information due to a liability issue. Therefore, while it may not be considered a legal problem, it presents challenges regarding the efficient and effective use of information among different stakeholders along the project.

Another challenge highlighted is encountered when the interests of parties are not aligned and the commercial framework clearly allocates risk and responsibilities to each member. When parties work together with traditional contract boundaries, they still have different legal contracts between each other. Problem can arise because each firm may have an internal BIM procedure and standard they want to use, or friction may occur between parties regarding a specific role, creating a competitive environment.

This scenario facilitates the arising of legal concerns. Parties may work using different servers and therefore not share real-time models and information, to avoid dispute due to liability and protect their intellectual property. A branch of intellectual property rights is created, and great effort is needed to ensure that this sort of back-to-back intellectual property licence and indemnity flows down to the whole supply chain. The commercial framework, therefore, determines how difficult the relationship becomes and the impact that it has on the project where each party is trying to protect their financial interest as opposed to acting for the best of the project interest.

At present in Australia, there are no published standard forms of contracts, neither protocol nor addendum, written to incorporate BIM and to address potential legal issues. While the development of a BIM protocol could be a good first step, it is recommended that the current standard forms of contracts are revised to accommodate the new data-centric processes.

3. **Identify how collaborative contracting can improve the effectiveness of BIM and Lean throughout the procurement process.**

The major driver for collaborative contracting is to deliver value for money to the client and therefore searching the best way to maximise the value. From the interviews conduct with expert in the US, it appeared that the US construction market has defined collaborative contracting as a Lean project delivery system to show the strong relationship between the contracting method and the implementation of Lean principles in the management of the project. The interviews highlighted the relationship from Lean and collaborative contracting: Lean philosophy focuses on satisfying customers' needs by working together to eliminate all the waste in the process and improve flow efficiency. Similar collaborative contracting provides an environment where parties are integrated as a unique enterprise and work collaboratively to deliver the best value for the project.

The Lean culture empowers people to solve problems and find innovative ideas to continuously try to improve the process. Likewise, under collaborative contracting, parties are no longer involved just to provide the means to accomplish what the client is thought to need, but rather to come in with their own ideas and bring the best of themselves to the project. It is about collaborative effort that involves trust and the need to feel psychological safety to seek for guidance.

Experts in IPD, stated that the use of Lean is fundamental to achieve the benefits of collaborative contracting since just setting up an alignment contract does not guarantee that people will change their traditional mindset. Therefore, while the contract aligns the team financially and acts as an accelerator to the ability to collaborate, the Lean principles and tools provide the means to effective collaboration. Lean principles and tools can be used in any type of procurement models, however their effectiveness is limited under conventional procurement methods, where each party tries to provide value for their job instead of for the whole project.

Lean demands a start of thinking with the end in mind, which is a goal-setting approach that requires a clear vision of the end goals to develop a strategy to persuade those goals. By setting the customer expectations at specific gates for quality check, all the steps required to reach the goal need to be mapped and successively pulled in order to eliminate waste in the process. Client engagement is catalyst to continuously ensure that the team is delivering what is considered value for the client.

Within the framework of collaborative contracting, the client together with the key parties place a lot of effort during the front-end planning in order to define the value for the client and set the team toward that outcome.

This environment is considered the most effective to enable BIM. Information can flow without bottlenecks, creating value-adding from one model use to the next, reducing the amount of waste that is usually created through the different stages of conventional delivery methods. The integrated team establishes right from the beginning how the models will be developed and constructed as well as establishing which information will be needed at each key decision point. This approach allows optimisation of all the processes by mapping the value of BIM through the value stream and defining why, what, when and by whom information needs to be developed to achieve specific BIM uses, meanwhile eliminating any step that does not deliver value. This guarantees that only the information needed is actually created and delivered to the right persons at the time they are expected to avoid any over-production or under-production of information.

The IPD approach uses several Lean tools during both the design and the construction stage to drive the team toward the best for the project solution. The Lean tools include: the target value design, set based-design, last planner system and choosing by advantages The BIM model supports this process by providing high-quality design, faster analysis and simulation to fulfil the client requirements. As well as it supporting the team to better understand the project' objectives and make more informed decisions among the projects.

Regarding the legal considerations arising when BIM is used, it has been argued that the legal features of collaborative contracting, such as the collective responsibilities between parties and the disputes avoidance regime, enable participants to be more willing to accept the model as a contract document and to agree that all of the key participants have the right to rely on the accuracy of the model. Indeed, the potential liability barriers that may arise under traditional contracts are overcome by a collaborative framework that allocates all parties under the same umbrella. Everyone works as a virtual company in a single server and nobody holds liability. The dispute resolution process with the 'no blame' regime together with the integrated insurance should ensure that parties will hardly recourse to adversarial procedures from any problem coming out from the use of the model. If a mistake in the model is detected or a participant enters inaccurate data in the model, it is in the interest of all parties, including the client, to solve the problem in the most efficient and effective way possible that maximises the financial outcome for everyone.

The collaborative contracting environment allows project teams to work all in one central model hosted in the cloud to leverage real-time sharing data. If there is a change in the model, this is immediately available to other users of that model. Conversely, under the conventional delivery method this level of integration is obstructed by the commercial framework. Parties may work in a common data environment, however the process is still divided into four phases: Work in Progress, Shared, Published and Archive. Indeed, when in working progress, the work can only be accessible by its original creator. In the shared stage, information is shared to others but not editable. Finally, the published folder contains information that has been authorized for use.

Every participant needs to have the right to access to the BIM model in order to perform their obligations. However, a recent case that reached the UK court outlined the importance of negotiating early between those involved in a BIM-enabled project regarding which party should host, coordinate, control and allow the access to the CDE. Without clearly specifying the responsibilities, parties may not be adequately protected and the data contained in the CDE could be used as a tool in a bi-party dispute. Conversely, under a collaborative contracting model it would not be in the interests of any core participants to turn off the access to one party and create issues with that party, because those problems will then turn into problems for the project, and everyone will share in the pain of the problem.

From an overall perspective, collaborative contracting is about being Lean and agile, mitigating risk and reducing waste. BIM is all about these from an information of point-of-view. That is way the three strategies work really well together.

6.3 RESEARCH CONTRIBUTION

To academia, apart from gaining more information on the research design process and methodology, this research adds more insights to the collective knowledge of BIM and contracts, specifically to better understand legal implications when BIM is used as well as evaluating how procurement models and contracts accommodate BIM processes. These include benefits in terms of recognising the current contractual challenges of BIM adoption in several project delivery methods as well as the benefits of using collaborative contracting to exploit the full benefits of BIM.

Moreover, this work contributes to empirical research on the adoption of BIM and Lean management practices to support collaborative contracting outlining the synergy and the mutual benefits when the three approaches are used in an integrated and consistent manner. This work contributes in the area of research in BIM and Lean by focusing on their integration in the context of collaborative contracting, adding therefore a third element. From the literature emerged that a great worked have been performed to identify their synergy and their operational application, for instance using BIM and Last Planner System. However, there are not examples of their integration within a project delivery framework. While there is some work in describing the possible application of BIM under traditional contracting, there are not studying that try to address the BIM adoption in the context of collaborative contracting. The collaborative contracting framework is a game changer for the industry, especially now that the new advance technologies can support to build the level of trust that has been lacking for many years in the industry. Therefore, it is paramount that the procurement model reflects the currents trend in digital process and business improvement.

In do so, the framework describes an approach to facilitate a Lean adoption of BIM within the contest of collaborative contracting, addressing legal, procedural as well as organisational considerations to enable project participants to find the guide to navigate along the process. The framework is a Target State on how projects should be delivered. In its strategic level, it provides an overview of the process, including the lean tools that need to be adopted. Further work will need to be done on describing at the operational level all the activities for each projects stage, including a detailed indication of each role and responsibilities.

To industry, this research provides evidence for why traditional approaches are no longer effective and their need to shift and embrace new trends to stay competitive in the global market. It also aims to encourage Australian public client organisations to move beyond the risk-averse contract models and step into a new era of collaborative contracting supported by risk and reward sharing, a no-blame culture and integrated insurance. These are the key features that really allow teams to truly collaborate. Other form of contracts, although promoting early integration, do not tie together parties through a risk and reward and no-dispute previsions. Therefore, there is an incentive to abandon collaboration when things start going wrong.

These characteristics are considered also pivotal to effectively implement BIM and data management, from the project outline to the end of the life-cycle, enabling depth collaboration and reliable sharing of information to continuously improve the value to the project.

The proposed Lean BIM-based collaborative contracting framework can be used as an initial footing for developing a new national standard contract to progressively incentivize the adoption of collaborative approaches. It has been developed considering both the vertical and horizontal construction industry.

Moreover, although the framework has been created considering the Australian construction market, it has been developed in accordance with the ISO 19650 and therefore there is no real reason that prevents it from being implemented in other collaborative contracting environments worldwide, by adjusting it to fit within the context.

6.4 RESEARCH LIMITATIONS

One of the main limitations of this research is that to date in Australia there are no building or infrastructure projects that have been delivered mandating the use of BIM for managing information under a collaborative contracting framework. Therefore, there were significant challenges in recruiting participants with a cross-knowledge and understanding on digital. procurement strategies and lean.

Some of these limits have been overcome by interviewing experts across Canada, the United States and the United Kingdom. In particular, in the first two countries a number of projects have already been delivered by using collaborative contracting, BIM and Lean. However, different countries have different regulations and legislation, therefore it would have been more effective to hear the experience of Australian practitioners directly involved in these types of projects.

Furthermore, some limitation can be attributed to the exploratory nature of the research. Qualitative method of data collection was the predominant method. Although the number of samples was relatively high, it did not adequately represent the target industry. However, the inductive approach allowed to form the basis for future deductive research to build upon. Specifically, there is the need for more quantitative methods to be applied to real project data in order to properly measure and evaluate the effect of using BIM and data management to benefit project outcomes in the context of collaborative contracting. Also, it would be beneficial to analyse several projects that utilise BIM as a data strategy within different contractual frameworks, to benchmark the outcomes and provide more realistic information.

6.5 DIRECTION OF FUTURE RESEARCH

The research succeeded in reaching the objective of developing a framework for collaborative contracting, which integrated the use of BIM and Lean management techniques for the Australian construction industry. However, due to limitations in scope of the research, future works in the areas under investigation are recommended as follows:

- The framework has been confirmed but it has not been validated. Therefore, it needs to be assessed under real project conditions. Considering the length of a construction project, it is suggested to divide the framework validation into three blocks: (1) BIM strategy and tendering process, (2) Lean integration of design and construction, (3) operation and maintenance.
- Block 1 may focus on the development of the initial BIM strategy, the definition of BIM requirements and criteria for the selection of the most capable proponent. Indeed, the finding from this work has outlined the pivotal role of client and stakeholders in addressing the project goals and clearly defining the scope of work. To achieve the desirable outcome in terms of BIM and data management, it is essential that they are well expressed at the beginning of the project.
- Block 2 may study how Lean principles and tools can shape the use of BIM and information management within an integrated project team. The framework has been developed at the macro level, therefore, it would be beneficial to be studied at the micro level, providing guidelines and protocols and clearly defining the different roles. In the construction phase, it would be interesting to analyse the development of the model by non-core teams with the information required by the core-team.
- Block 3 would focus on the asset management strategy. In particular, how information developed during the design and construction phases is passed into the facility management system to facilitate the operation and maintenance stage.
- The framework has been developed for both infrastructure and civil projects within difference ranges of size, from small/medium to large projects. It would be interesting, for example, to analyse if the framework is adaptable for both building and civil projects, allowing for cross-project comparison studies.
- The current Australian contracts do not incorporate digital practices and therefore legal challenges may arise when BIM is used. It is recommended to develop a new multi-party contract that clearly defines roles, duties and responsibilities of both client and project parties in the BIM environment.

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