Developing the Construction Procurement Methods in the UAE to Implement Building Information Modelling (BIM)

تطوير عقود الانشاء في دولة الامارات العربية المتحدة لتطبيق نظام نمذجة البناء

By

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APPENDIX A

STUDENT DISSERTATION RECEIPT

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Abstract

Building Information Modelling (BIM) is a revolutionary technology that presents strong potential to evolve the productivity and performance of the construction industry through improving the integration among stakeholders. Nevertheless, the performance of a new technology can be impaired if it is implemented in an inappropriate process. Therefore, implementing BIM effectively requires significant changes in the construction business practices in order to create more efficient methods for improving communication, collaboration and sharing information among team members in design, construction and operating phases.

To keep pace with the global trend of adopting BIM to improve the performance of the construction industry, the United Arab Emirates (UAE) has mandated BIM in the Architecture, Engineering and Construction (AEC) industry. Therefore, the currently used processes and framework of the procurement methods in the UAE construction industry need reconsideration so as to ensure the success of BIM implementation.

The purpose of this study is to investigate the required reformation in the framework of current procurement methods in the UAE to implement BIM appropriately, and to propose overtures to assist the UAE AEC industry to adopt BIM and facilitate the organisations to utilise maximum benefits of BIM. Accordingly, the research has conducted extensive literature studies in order to identify the required changes needed for the framework of procurement methods to be compatible with adoption of BIM.

The literature studies led to the theoretical framework which illustrated that the demanded changes in the procurement methods to ensure proper adoption of BIM are: change in the relationship among participants, change in the contractual agreements, sharing the risks and rewards among stakeholders, early involvement of stakeholders, and involvement of new participants.

To examine the information obtained from the literature review, this study adopted qualitative approach to collect the data from practical perspective thereby creating four case studies by conducting face-to-face interviews with hand-picked professionals in the AEC industry, who had vast experience in projects that adopted BIM. The open-ended discussion has participated in identifying the required changes in the procurement methods framework and has assisted in proposing a set of practical approaches to reform the project delivery methods for ensuring successful adoption of BIM.

The research findings have articulated that in order to implement BIM process correctly, it is mandatory to change the relationship among participants to be more collaborative, and create a system to share the risks and rewards among the participants to promote cooperation among them. In addition, the most important requisite change is involving the key players from design stage to create proper BIM model that will save time and cost. Furthermore, there are required changes in contracts to oblige the participants to adopt BIM, identify the level of development (LOD) in each stage and determine the responsibilities and intellectual property rights of each stakeholder.

Moreover, it is recommended that new stakeholders be involved, like BIM management firm, to manage the BIM process in every stage, determine the required inputs of each stakeholder and the time of each input and control the flow of information among participants.

Keywords*: BIM, Procurement methods, Driving forces, Changes, Benefit.*

ملخص البحث

يعتبرنظام نمذجة البناء ثروة تكنولوجيا ذات امكانيات قوية تقدم حلول فعالة لتحسين اداء و انتاجية صناعة الانشاءات, حيث انها تعمل على تكامل الاداء بين أعضاء فريق عمل المشروع. ولكن أداء هذه التكنولجيا قد يكون ضعيفا إذا تم تطبيقها بشكل غير صحيح. لذلك يجب ان يحدث تغير واضح في إدارة أعمال صناعة البناء لتضمن تطبيق فعال لنظام نمذجة البناء. هذا التغير يهدف الى تحسين عملية التواصل بين أعضاء المشروع و زيادة التعاون بينهم و تسهيل عملية تبادل المعلومات الخاصة بالمشروع فيما بينهم في جميع مراحل المشروع بدءاً من مرحلة التصميم ثم البناء ثم ادارة و صيانة المبنى فيما بعد .

مواكبة للاتجاه العالمي في تطبيق نظام نمذجة البناء , اتخذت دولة الامارات العربية المتحدة خطوات جادة لالزام الشركات اللتي تعمل في قطاع الانشاءات إلى تفعيل تطبيق نظام نمذجة البناء . و هذا يستوجب تغير جوهري في الأساليب و الطرق المستخدمة حالياً في قطاع الإنشاءات في دولة الإمارات العربية المتحدة لضمان نجاح عملية تطبيق نظام نمذجة البناء .

لذلك تهدف هذه الدراسة إلى تحديد التغيرات المطلوبة في أساليب العقود المستخدمة حالياً في دولة الإمارات العربية المتحدة لإنجاح عملية تطبيق نظام نمذجة البناء , و العمل على تقديم مقترحات لكيفية عمل هذه التغيرات لتساعد قطاع الإنشاءات في إعتماد نظام نمذجة البناء و تساعد الشركات التي تعمل في قطاع الإنشاءات من تحقيق أقصى إستفادة من تطبيق نظام نمذجة البناء . ووفقاً لذلك تم مراجعة الدراسات السابقة لنفس الموضوع ودراستها دراسة شاملة للوقوف على العناصر المطلوب تعديلها في العقود الإنشائية لضمان تطبيق نظام نمذجة البناء بشكل صحيح .
مراجعة الدراسات السابقة أوصلت إلى انشاء إطار نظري تم من خلاله التعرف على التغيرات المطلوبة في عقود الإنشاء و كانت على النحو التالي :

- تغير العلاقات بين أعضاء المشروع .
- تعديل الإتفاقيات التعاقدية .
- تقاسم مخاطر ومكافآت المشروع بين الشركات المساهمة في المشروع .
- تعين المشاركين في تنفيذ المشروع من مرحلة التصميم .
- إشراك أعضاءجدد في المشاريع الإنشائية .

من أجل التحقق من المعلومات المستخلصة من مراجعة الدراسات السابقة و إستخدمت هذه الدراسة احد مناهج البحث العلمي و هو المنهج الإستقصائي في جمع المعلومات من وجهة النظر العملية من خلال إنشاء اربع حالات للدراسة تم تكوينها من مقابلات شخصية مع متخصصين في مجال الإنشاء تم اختيارهم بعناية تامة بحيث يكون لهم خبرة طويلة في المشاريع الإنشائية اللتي تم فيها تطبيق نظام نمذجة البناء . و قد ساهمت هذه المقابلات في التعرف من المنظور العملي على التغيرات المطلوبة في عقود الإنشاء و تقديم مقترحات لعمل هذه التغيرات لضمان نجاح تطبيق نظام نمذجة البناء.

و بعد تحليل نتائج البحث بالطرق العلمية , تم التوصل الى أن نجاح تطبيق نظام نمذجة البناء يتطلب تغير في العلاقات بين الشركات المساهمة في المشروع حيث أن هذه العلاقات يجب ان تكون مبنية على الثقة و التعاون فيما بينهم . كما أن وجود نظام يسمح بمشاركة المخاطر و المكافآت بين أعضاء المشروع يساهم بشكل كبير في تعزيز التعاون بينهم . توصلت الدراسة أيضا أن أهم تغير يجب أن يحدث هو إختيار و تعين المشاركين في المشروع من مرحلة التصميم حتى يتم بناء نموذج صحيح من البداية يمكن أن يتطور في كل مرحلة من مراحل المشروع و هذا التغير يساهم بشكل كبير في تقليص تكلفة و زمن المشروع .

بالإضافة إلى ذلك فإن الدراسة خلصت إلى أنه يجب عمل تعديل جوهري في الإتفاقيات التعاقدية لإ إلزام الشركات العاملة في المشروع بتطبيق نظام نمذجة البناء و تحديد مستوى التفاصيل المطلوبه من كل شركة في كل مرحلة , وأيضا تحديد مسئوليات كل شركة و ضمان حقوق الملكية الفكرية لكل شركة مساهمة في بناء النموذج .

كما أن الدراسة اشارت إلى أنه من المستحسن ضم مؤسسات جديدة إلى مشاريع البناء مثل مؤسسة لإدارة نظام نمذجة البناء لإدارة عملية نظام نمذجة البناء و تحديد المدخلات المطلوبة من كل شركة و توقيت هذه المدخلات و التحكم في عملية تبادل العلومات بيت المساهمين في المشروع .

الكلمات المفتاحية : *نظام نمذجة البناء , العقود الإنشائية , القوى الدافعة , التغييرات، المميزات* .

Dedication

- At a time when I finish this dissertation, I will be waiting for the birth of my first daughter. I wish her a wonderful new life as I wish for myself the new step in my career.

'To my daughter'

- The person who endured a lot for me and taught me that in order to make your dreams come true, it takes an awful lot of determination, dedication, self-discipline and effort, and your dreams end when you die.

'To my Mother'

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List of Abbreviations

2D Two Dimensions

3D Three Dimensions

AIA American Institute of Architects

ACIF the Australian Construction Industry Forum

AEC Architecture, Engineering and Construction

AECO Architecture, Engineering, Construction and Operation

BIM Building Information Modelling

BOQ Bill of Quantities

CAD Computer-Aided Design

CEO Chief Executive Officer

CM Construction Management

CMr Construction Manager

CPD Collaborative Project Delivery

D&B Design and Build

DBB Design–Bid–Build

DBIA the Design-Build Institute of America

ECMAG Electrical Contractor Magazine

GIS Geographic Information System

GMP Guaranteed Maximum Price

HOK Hellmuth, Obata+Kassabaum

ICT	Information and Communication Technology
IFC	Industry Foundation Classes
IFOA	Integrated Form of Agreement
IPD	Integrated Project Delivery
LOD	Level of Development
MCA	Model Component Authority
NBS	National Building Specifications
O&M	Operation and Maintenance
PA	Project Alliance
REDAS	Real Estate Developers' Association of Singapore
PDF	Portable Document File
RFI	Request for Information
RPDA	Relational Project Delivery Arrangement
SIA	Singapore Institute of Architects
TCE	Target Cost Estimate
TOC	Target Outturn Cost

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CHAPTER ONE: INTRODUCTION

1.1. Background

Construction is a very complicated industry due to the reciprocal interdependencies among stakeholders, and it has been criticised for its fragmented working patterns, in addition to its poor productivity as compared to other industries (Dulaimi et al. 2002; Ibrahim, Costello & Wilkinson 2011). Traditionally, the construction industry consists of many parties with various specialities and backgrounds, and heterogeneous cultures and interests. Therefore, the performance of a project is influenced by the integration between these parties, and lack of integration often diminishes the chance of improving performance (Ibrahim, Costello & Wilkinson 2011).

Such pressures have driven the industry to explore the information and communication technology (ICT) to promote the integration among stakeholders in various construction processes, that leading to the emergence of Building Information Modelling (BIM) that promotes the design, construction, operation and maintenance activities. BIM has been defined as “a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle” (Succar 2009, p. 357). BIM is a digital model containing the complete project information, accessible for all participants and broken down to object-level nuggets of information for ease of reference. Furthermore, the BIM model also includes the dates of site activities till the completion, manufacturing information, operation and maintenance (O&M) information, and even the demolition procedures, as the model can be used for the full life cycle of the facility.

BIM is not just software used to design a building in intelligent way, it is in fact considered as a giant leap in the way of thinking in the construction industry. According to the McGraw-Hill Construction Research and Analytics (2012), BIM has excellent track record of efficient contribution in the evolution of the efficiency and productivity of the construction industry, by improving the collaboration among the project participants and promoting the information-sharing strategies. Figure 01 shows the extent of influences of BIM on construction performance.

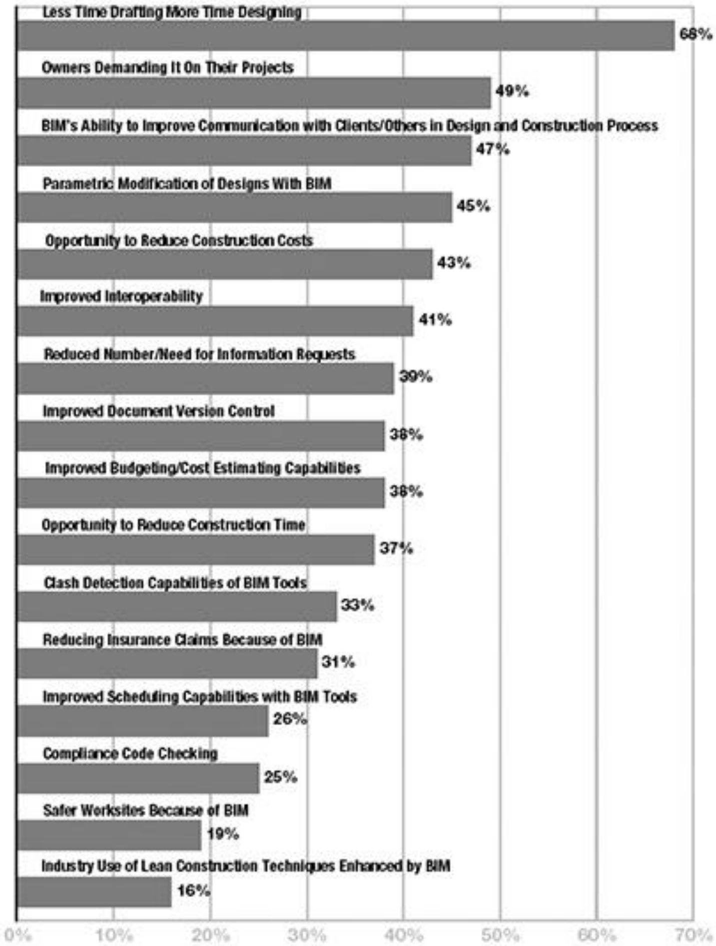

Figure 01: The extent of influences of BIM on construction performance (McGraw-Hill Construction Research and Analytics 2012).

Nevertheless, the old process and traditional procurement methods in construction industry might be a hindrance to the successful implementation of BIM due to low level of integration among stakeholders and lack of information sharing (AIA 2007). Therefore, there are required changes in the framework of the traditional procurement methods to allow stakeholders to maximise the benefits of BIM adoption.

For instance, when BIM is implemented in a construction project, an early engagement of clients, architects, contractors and significant sub-contractors is essential in the initial stages, this has become a priority as their inputs can add great value to the project and can identify the conflicts earlier. While, in traditional procurement methods, such as design–Bid–Build (DBB), design and build (D&B) and construction management (CM), each team involves in different stages of building life cycle, thus allowing varying degrees of BIM processes to be implemented in each procurement method.

The need to improve integration between project participants and effective BIM implementation to achieve efficient project delivery led to the emergence of a new concept of delivery method known as integrated project delivery (IPD); it aims to take the integration to a whole new level.

IPD allows for implementing a greater degree of BIM process to promote a successful project delivery and achieve project balance and rewards in terms of profits, professional relationships and reputation.

Improving the project delivery methods with BIM implementation definitely has impacts on the contractual agreement process and type. Furthermore, it influences the tender documents and methods of selecting the participants. In the traditional procurement methods, the owners have separate contract with each participant; however, this scenario would change with the implementation of BIM, as then the contract would be with various participants. This means that clearly defined tasks, responsibilities and rights at the onset of a project, and the protocols of sharing, owning and transferring information throughout the project would be outlined right in the beginning. Hence, it requires that the participants have an understanding of BIM process, model sharing and ownership privileges.

However, the BIM contract is still in its initial stages, as organisations such as American Institute of Architects (AIA), the Associate General Contractors of America (AGC) and the Design-Build Institute of America (DBIA) are still attempting to frame contracts and develop a language that can be used in BIM agreements. These organisations have developed an initial BIM contract language that deals specifically with roles and responsibilities of BIM (Hardin 2009).

This study aims to study to what extent BIM drives a change in the framework of the current procurement methods to be compatible with BIM adoption. The research herein will assess the degree to which the BIM process can be effectively implemented with the traditional procurement methods, and would compare that with adopting BIM in new project delivery methods, such as IPD and project alliance (PA), in terms of collaboration, communication and integration among project participants.

1.2. Motivation of the Study

The construction industry plays a vital role in developing the economy of a nation. However, it has been criticised because of its low productivity as compared to other industries. The decline in productivity is due to lack of collaboration and communication among stakeholders (Halttula, Aapaoja & Haapasalo 2015).

Adoption of new technology has been seen as a solution to improve the industry. Therefore, the emergence of BIM is anticipated to be the key to overcome the realised problems. BIM has been considered as a solution of fragmented network of stakeholders and a way to improve the flow of information and data and accelerate the process (Succar 2009).

As many countries have realised the benefits of implementing BIM in order to improve the output of the construction industry. Therefore, several countries intend to implement BIM as a compulsory factor in new construction contracts. The government of the United Kingdom has stated that from 2016 onwards all stakeholders will have to work collaboratively through the use of BIM (Bryde, Broquetas & Volm 2013). Finland has followed the suit and has now 93% of its firms adopting BIM in their projects. Following the example of the United Kingdom and Finland, several countries have mandated the adoption of BIM in their construction projects, for instance the United States, Denmark, Singapore, Hong Kong, Norway, Germany, France, South Korea, Australia and Canada (Lu et al. 2014).

Whereas, the mutation to BIM in the Middle East is still at an embarking stage as most of the firms are just using it as a drawing tool and not as an integrated process. To realise the significant benefits of BIM, it should be applied as a collaborative process. However, some organisations recognised the market trend and the benefits of integration process, so they have adopted the BIM process in order to become leaders in the Architecture, Engineering and Construction (AEC) industry industry (Building Smart Report 2011).

While, the remaining organisations, not only in the Middle East but also all over the world, will adopt BIM sooner or later, as predicted by Eastman et al. (2011) that in the immediate future BIM will be mandatory in the AEC industry all over the world. Therefore, the firms which are not willing to adopt BIM, their competitive advantage will be badly affected and sooner they will out of the market.

The UAE market is one of the greatest construction markets in the Middle East in terms of the scale of the projects and the amount of funds invested in the construction industry, and it has seen a dramatic rise in early 2000s.

The UAE government has realised the importance of BIM, therefore to improve the performance of the construction industry it has taken steps to implement BIM extensively. BIM is very efficient to ameliorate the construction performance, particularly for the countries where the construction industry is booming (Eastman et al. 2011).

In 2013, Dubai government decided to reshape the AEC industry by adopting BIM. On18th of November 2013, Dubai Municipality issued the Circular No. 196 that from 1st of January 2014 implementation of BIM is compulsory on specific projects for all stakeholders (DM 2013). Although the implementation of BIM is not yet compulsory for the remaining emirates, but there are initiatives to impose BIM in the particular projects.

The implementation of BIM process requires reshaping or changing the old practices, tools and project delivery methods. In addition, it demands changing the way of thinking, relationship among participants, the culture and the hierarchy of organisations and the contractual agreements among participants. Therefore, the implementation of BIM is not an easy process and takes relatively longer time.

Recognising the required change in the current project delivery methods so as to implement BIM was the motivation of this study. As mentioned earlier, all the main participants (such as developers, consultants and contractors) in the UAE AEC industry are enforced to adopt BIM in their projects. Thus, exploring the catalysts to implement BIM and investigating the required changes in the current procurement methods will assist the firms and will pave the road for swift adoption of BIM and reap the maximum rewards of BIM.

1.3. Research Problem and Questions

The construction industry is suffering from tremendous amount of problems such as low level of communication, design errors and clashes, weak flow of information among parties and unauthenticated data for facility management during the operation. Therefore, management professionals and researchers looked into bridging the recognised gaps of the AEC industry.

It is apparent that BIM is a revolutionary technology and process in the AEC industry which is able to integrate stakeholders to improve the performance of the industry. BIM allows the project stakeholders to identify potential interference in design, construction and operation by visualising the building in a simulated environment. Furthermore, it improves the collaboration and encourages the integration by reshaping the relationship between project team to achieve a successful project delivery. Therefore, BIM is considered as a driver for amending the complete construction cycle from design to operation stage.

The construction industry in the UAE is considered as young industry as compared to other countries. Despite that it is a main pillar in the UAE's economy and is considered one of the most important markets in the Middle East owing to the construction boom experienced recently. Consequently, it faces the same problems that the AEC industry is suffering in other countries.

Therefore, there is an utmost necessity to impose the implementation of BIM in order to eradicate the recognised problems. Undoubtedly, the implementation of any new process will face tremendous problems, either corporeal like the cost of changing the tools and process or moral like resistance to change. Similarly, the implementation of BIM will also face problems that might affect the efficiency of applying BIM process.

By forcing firms to implement BIM without eliminating its challenges will have negative effects on the industry. The purpose of this study is to recognise the factors that affect the adoption of BIM in terms of change in the relationships among participants and the implications of this change. The reshaping of the reciprocal interdependencies between stakeholders demands amendment in the methods of project delivery and the contractual agreements.

This paper will present an overview of BIM and the driving force in the UAE to adopt BIM. In addition, it will focus on the required changes in the framework of the procurement methods to be compatible with the adoption of BIM, and will assess to what extent the changes will promote the integration among project participants. It will also identify the impact of reshaping the relationship among stakeholders on the contractual stage. Eventually, the study will attempt to answer the following questions:

- What are the benefits of BIM?
- In what ways BIM can drive change in procurement methods?
- What are the required changes in procurement framework to ensure proper implantation of BIM?
- What is the impact of the needed changes on the contractual agreements?

1.4. Research Aim

This research aims to investigate the ways that procurement frameworks need to change in order to enable the adoption of BIM in the UAE AEC industry and present the solutions for the defects in the current and innovative procurement methods to ensure efficient BIM implementation and to assist the firms to utilise the maximum benefits of BIM.

It is essential to evaluate the competence of current procurement methods by adopting BIM on various project stages, in particular, in the initial agreements stage, moreover the information and workflow and the relationship among entrants.

1.5. Research Objectives

Undoubtedly, BIM is a revolutionary technology in the construction industry, and it is a driver for changing the strategies of delivering the projects, especially the procurement method. Therefore, it is a mandatory to explore the required changes the framework of the procurement method and the contractual agreements to be compatible for BIM adoption.

Hence, to meet the aim of this research, the following are the objectives:

- Investigate the driving forces to adopt BIM in the AEC industry in the UAE.
- Identify what are the main challenges and obstacles in currently used procurement methods that are probably hindering the BIM implementation.
- Investigate the required changes in the procurement methods to improve the efficiency of adopting BIM.
- Recommend solutions for the AEC firms in the UAE to reform procurement methods to maximise the utilisation of BIM implementation benefits.

1.6. Dissertation Structure

This dissertation consists of five chapters in order to pave the way towards achieving the main aim of the research. The chapters are as follows:

- **Chapter One**: This chapter introduces the dissertation topic by giving an overview about BIM and the status of BIM in the construction industry in several countries. Furthermore, it highlights the research problem, and states the motivation of the study, aim, objectives and the methodology of collecting data to achieve the objective.
- **Chapter Two:** This chapter is the literature review that presents what has been investigated by prominent authors about BIM, the history of BIM and the forces to impose BIM in the AEC industry. It then states their viewpoint in the required reformation for the procurement methods to suit BIM adoption. In addition, the literature review explores the most popular procurement methods and to what extent they are suitable for BIM implementation. The literature studies aim to build a profound understanding of a proper implementation of BIM process to ensure the integration among project participants.
- **Chapter Three:** This chapter elaborates the theoretical framework that has been extracted from literature review and has been simplified in diagram. The theoretical framework develops the study concept that the procurement strategies must renovate their processes to accommodate the implementation of BIM in order to accelerate the growth in the UAE AEC industry.

- **Chapter Four:** This chapter contains the methodology approach that has been adopted to collect and analyse the data, and the discussion about the collected data. The quantitative approach has been adopted in this study, where it is suitable to the research aim, objectives and questions. Face-to-face interviews have been conducted in order to investigate the research hypothesis that has been extracted from the literature review and build the case studies to improve the BIM implementation with current procurement methods that are used in the UAE AEC industry.
- **Chapter Five:** This chapter includes the conclusion and recommendation that has emerged from the data analysis to assist the firms in solving the problems arising from adopting BIM with current procurement methods. Furthermore, this chapter ends with research limitations and recommendations for further studies.

CHAPTER TWO: LITERATURE REVIEW

2.1. Background of BIM

2.1.1. What is BIM?

The design of buildings until the mid of nineteenth century depended on simple tools, such as pencil, paper and ruler. Subsequently, with contrivance the computer and the emergence of 2D CAD (Computer-Aided Design), the process of design developed and improved rapidly, as 2D drawings evolved into 3D modelling, which changed the relationship between the structural engineer and the architects , and transferred the design thinking from visualisation to simulation (Yan & Damian 2008).

The development of 3D modelling has led to a new approach called Building Information Modelling (BIM). It has been stated that BIM is a developed technological and procedural shift in the Architecture, Engineering, Construction and Operations (AECO) industry that aims to increase the productivity of the industry (Succar 2009; Saxon, 2013). From the technology perspective, BIM is a 3D model that emulates a facility and encompasses all the information related to the project from conceptual design to facility operation (Kymmell, 2008). Figure 02 describes BIM concept.

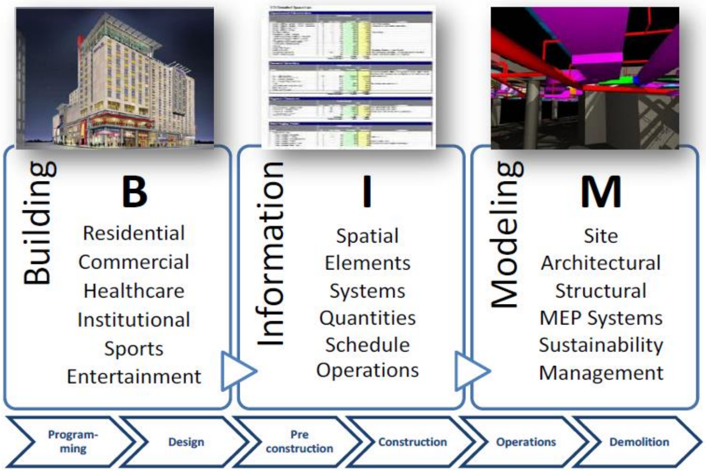

Figure 02: BIM concept (Kymmell 2008).

BIM can be defined as a digital simulation of physical and functional characteristics of a building and is a source of shared information about a building, forming a reliable basis for stakeholders to make decisions during the life cycle of a building from its design stage to its demolition (Olatunji 2014). The graphical entities in BIM are defined as building elements walls, slabs and beams (Azhar, Hein & Sketo 2008). Furthermore, BIM is an evolution of computer software that produces an intelligent digital building model simulating the construction and operation process; it contains data for various users that can be analysed and extracted and hence can be used in improving the delivery of the project (AGC 2005).

This data can be used by designers to analyse and develop the design concept, by contractors to manage and control the construction process and facility managers during the running and decommissioning of the building (Bryde, Broquetas & Volm 2013). Once created it can be used several times throughout the building life cycle and can also be shared and communicated among the participants, this forms are the core of BIM in the construction industry (Furneaux & Kivvits 2008).

Furthermore, Hardin (2009) describes BIM as a virtual construction of a building that consists of smart information in a single source file shared among team members, and improves the communication and collaboration among the participants. Since last 40 years, the productivity of construction industry has decreased significantly due to the shortage of integration among stakeholders. BIM is considered a solution for bridging the gap among project participants, where it is not just software; it is in fact a process that changes the workflow and project delivery processes significantly. Bolpagni (2013) argues that the aim of BIM is to improve the work flow through the integration of the team members. Figure 03 shows BIM process

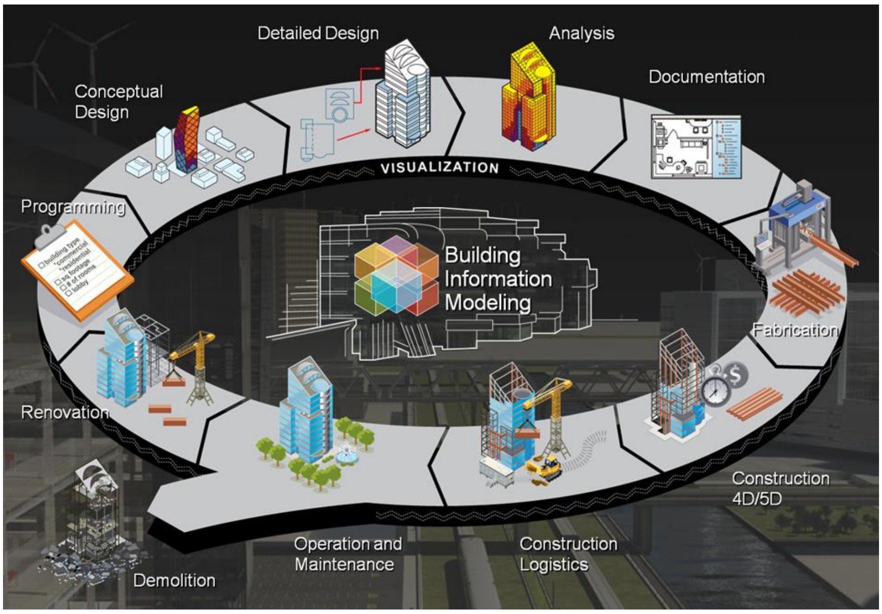

Figure 03: BIM process (Bolpagni 2013).

Azhar, Khalfan and Maqsood (2012) point out that BIM presents a new paradigm in the AEC industry that improves integration of the roles of participants on a project and promotes the efficiency and harmony among team members. Complementary to this, Carmona and Irwin (2007) state that BIM is a single virtual model that encompasses all aspects and disciplines of a facility and enhances the accuracy and efficiency of collaboration among project members (such as owners, architects, contractors, sub-contractors, suppliers and facility management).

Before being physically established, the model is created accurately as per the design requirements and project specifications based on the inputs of the participants. Likewise, Love et al (2013) argue that BIM is a tool and process for project management that delivers beneficial project outcomes by improving the collaboration among the stakeholders and reduces the time required for documentation. Moreover, BIM is transforming the workflow in the AEC industry from document paradigm to an integrated database paradigm.

Similarly, Succar (2009) illustrates that BIM is a set of interaction of three fields: technologies, process and polices. The technology field contains all the people who work in developing the software, hardware, devices and network system. The process field encompasses participants in design, construction, manufacture and operation. Finally, the policies field embraces the organisations who manage the preparatory phase and the regulatory and contractual issues.

2.1.2. History of BIM

Arguably, the thinking of BIM started with the innovation of computer and evolved with the passage of time. Indeed, in 1962, Douglas C. Englebart explained a revolutionary vision of the future of architecture by proposing object-based design, parametric manipulation and a relational database. Various design researchers have influenced the development of BIM, for example, Herbert Simon and Nicholas Negroponte, further to Ian McHarg who was developing a parallel track with Geographic Information Systems (GIS). However, the research of Christopher Alexander had the most prolific impact on the early concept of object-oriented programming in computer science (Quirk 2012).

In 1963, after the Second World War, Sketchpad software that had been developed by Ivan Sutherland was the nucleus of CAD (Yan & Damian 2008). With the emergence of CAD, the solid modelling programmes improved the computational representation of geometry (Bolpagni 2013).

BIM traces back its roots to the parametric modelling research that was conducted in the United States and Europe in late 1970s and early 1980s (Eastman et al. 2011). This led to the appearance of two methods of displaying and recording shape information: first being the constructive solid geometry that embraced series of primitive shapes, either solids or voids, and second being the boundary representation that represented the architectural elements (Bolpagni 2013).

The most important innovation of the time was the development of the object with database. The first successful software in creating an object with database was the Building Description System that was developed by Charles Eastman. It consisted of a library comprising architectural elements that could be added to the model. The database in this software allowed the user to restore information by attributes including material type and supplier. In 1977, Charles Eastman created software called Graphical Language for Interactive Design; it contained most of the BIM characteristics (Quirk 2012). In this context, Jerry Laiserin states, "rather than "Father of BIM" – as a few well-meaning but over-enthusiastic peers have labelled me – I prefer the unattributed epithet "godfather of BIM", in the sense that a godfather is an adult sponsor of a child not his own. If anyone deserves the title "father of BIM", surely it is Chuck Eastman" (Eastman et al, 2007, p xiii).

By 1980, various software systems had been developed and implemented in the construction industry in the United Kingdom, such as GDS, EDCAAD, Cedar, RUCAPS, Sonata and Reflex. Apparently, RUCAPS was the first software that contained the temporal phasing of the construction processes, and it was adopted in the construction process of Heathrow Airport's Terminal 3. Thereafter began the development of a 4D model with time attributes. In 1988, the first software with 4D model was founded by Paul Teicholz known as the Centre Integrated Facility Engineering (Bolpagni 2013).

On the other side of the world, there was a whole new story. Soviet Union made several attempts in this regard. In 1982, two genius programmers, Leonid Raiz and Gábor Bojár – who defined BIM as it is known today –were the respective co-founder and founder of Revit and ArchiCAD. In Budapest, Hungary, Gábor Bojár wrote the initial codes using similar technology as that of Building Description System and released Radar CH software in 1984, which later became ArchiCAD. It was the first BIM software that could be used in a personal computer. Leonid Raiz and Irwin Jungreis attempted to develop software that could be used in complex projects. They finally succeeded in 2000 by developing software called Revit – considered as a revolutionary in technology in construction (Quirk 2012).

During the last seven years, owing to the development of software that can be used in architectural design, structural and mechanical projects, many firms have started adopting the BIM process. This improvement enhances the collaboration and supports the integration. Such features were realised in 2004 in Revit that allowed a huge team of architects and engineers to work on one integrated model. However, the implementation of BIM is still in its infancy. More than one million projects worldwide have been executed by using BIM software and processes, particularly in Europe, where the firms of the AEC industry have realised the benefits of BIM (Bolpagni 2013).

Furthermore, in North America, the percentage of companies adopting BIM process has increased significantly in the last few years. While it was 28% in 2007, it jumped to 49% and 71% in 2009 and 2012, respectively (MCGraw-Hill 2012).

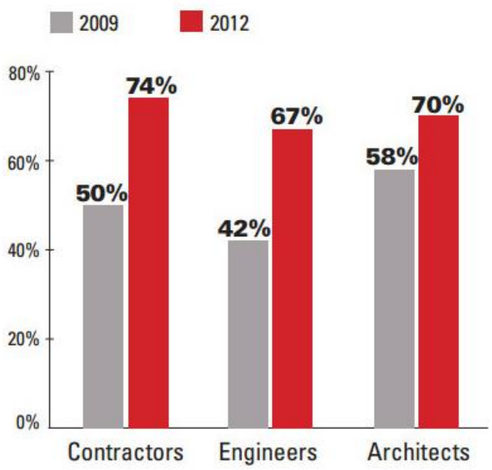

Figure 04: The percentage of BIM adoption in North America (MCGraw-Hill 2012).

2.2. BIM Benefits for Stakeholders

This section explores the benefits of BIM that forced the governments and clients to impose the adoption of BIM in construction projects, details of which will be highlighted in the next section.

BIM has significant benefits for project sponsors. These benefits include ensuring that the project requirements are achieved through early design assessment, decreasing the financial risk by obtaining estimation of reliable cost, 3D rendering and walkthrough animation to improve the project marketing (Azhar, Khalfan & Maqsood 2012; Eastman et al. 2011).

In addition, the Stanford university Center for Integrated Facility Engineering pointed out that owners yield numerous benefits from implementing BIM, such as accurate cost estimations, the elimination of up to 40% of unbudgeted change, the reduction of up to 10% of the contract value through clash disclosure and reduction of up to 7% of project time. That could increase the return on investment by around 16% (Chien, Wu & Huang 2014). Love et al (2013, p. 212) state that "a review of 32 projects in the US that had implemented BIM technology revealed:

- 7% reduction in schedule;
- 10% saving in contract value through clash detection;
- 40% elimination of unbudgeted change; and
- 80% reduction in the time taken to generate a cost estimate with
- Cost estimation accuracy within 3%."

Architects and engineers obtain worthy advantages from BIM such as improving the design through visual simulation (Azhar, Khalfan & Maqsood 2012), achieving less errors and conflicts in design stage (Bryde, Broquetas & Volm 2013) and improving the coordination in particular with the specialist consultants, where they can combine their specific portion of work with the visualised model to clarify the conflicts (Grilo & Jardim-Goncalves 2011). Furthermore, BIM enables to define defects points of structural elements early so as to prepare proper solution on time (Migilinskas et al 2013).

In addition, BIM has an efficient role in designing the green buildings through accurate energy analysis and estimating the carbon emission in order to achieve precise assessment of environmental performance of the facility (Lu et al 2014). Another point is that producing accurate shop-drawings and fabrication drawings participates in reducing the wastage in order to conserve the environment (Kymmell 2008).

From another perspective, adopting BIM promotes the competitive advantage, ensures the continuity of firms in the AEC market due to the adoption of BIM with its recognised benefits and presents enhanced capability for firms to compete in a wider spectrum of service areas and with various clients in the AEC markets (Liu, Issa & Olbina 2010; MCGraw-Hill 2012).

Implementing BIM by contractors and sub-contractors improves the project delivery performance, whereas BIM has the tools to ameliorate the accuracy of cost estimation and calculation of material quantity, realises the design errors early through clash detections, follows proper onsite activities, enhances the site safety planning and improves the communication and collaboration among the project stakeholders. Hence, contractors can achieve high profitability and product quality (Azhar et al. 2012; Hardin 2009).

In addition, BIM participates in reducing the cost through decreasing the number of requests for information (RFIs) by around 34%. It improves the productivity of the work due to the clarity of information as the activities will not be on hold till the team members receive the clear information (Chien, Wu & Huang 2014).

Moreover, BIM anticipates in avoiding change of orders by around 40%. It ensures that the design is more accurate and that the size of furniture, fixtures and equipment is convenient with the space before the onset of construction stage. While on the one hand, it assists in producing accurate bill of quantity that minimises overpayment to suppliers and sub-contractors; on the other hand, it improves the cooperation between contractor and sub-contractor that reduces the time of project delivery (Migilinskas et al 2013).

Adopting BIM provides significant benefits for facility management, where all the entire information related to facility exists in a single electronic file, the facility managers can obtain all the information about equipment and fixtures in just one click, for instance, the period of warranty, maintenance checks and the installation and repair procedures (Jordani 2010).

Moreover, the development of applications in smart phones and tablets allows the facility manager to obtain complete information of the building by just pointing the device towards it (Azhar et al. 2012). The aforementioned benefits can be summarized in Table 01.

Potential Benefits	Yield By				How
	Owner	Architect	Contractor	Facility Manager	
Less financial risk, increase return of investment and improve the profitability	●		●		Accurate estimation of reliable coast
Improve the project marketing	●			●	Improved quality of 3D rendering and walk through animation
Reduce of the contract value	●	●			Clash disclosure
Reduce time of project delivery	●	●	●	●	Improve the coordination and less errors
Improve the design	●	●			Visual Simulation
Less conflicts and errors	●	●	●		Coordination improvements with all team members
Early assessment of environmental performance	●	●		●	Energy analysis and estimate the carbon emission
produce accurate and quick shop drawing and fabrication drawing	●	●	●		Accurate visual simulation and software tools
Cost saving	●		●		Reduces RFI's and change orders
Proper following for site activities onsite		●	●		Proper progress schedule
Improve the project operation	●			●	All the information related to facility is exist in a single electronic file
Improve the project operation	●			●	All the information related to facility is exist in a single electronic file
market new business	●			●	competitive advantage for the organizations adopt BIM

Table 01: Summary of potential benefits of using BIM.

2.3. The Driving Forces for Imposing the Implementation of BIM

Technological advancements are regarded as the driving force for firms to improve their competitive position (Mitropoulos & Tatum 2000). Nevertheless, realising the benefits achieved from BIM adoption is not the main reason for organisations to put BIM adoption on their agenda. There are external pressures in the surrounding environment as well as internal readiness (Liu, Issa & Olbina 2010).

Firms in the AEC industry are driven by powerful external forces such as the local authority's obligations and the client's requirements that are leading firms to adopt BIM in order to improve their competitive advantages and be awarded more projects (Panuwatwanich & Peansupap 2013).

As mentioned above and based on the extensive literature review, it has been noted that the adoption of BIM is influenced by the following factors:

- **Pressures from Government and Clients:**

Last decade has noticed a significant growth of BIM implementation in the AEC industry due to government regulations and clients' pressure being the two main driving factors (Porwal & Hewage 2013; Chan 2014).

In response to the decline in the efficiency of the construction industry, many countries have adopted strategies to improve the productivity of the AEC industry and promote sustainability in the whole life cycle of the building in order to reduce energy consumption and carbon emissions. One of the main issues in these strategies is mandating the implementation of BIM. It has been seen as panacea of the recognised problems in the life cycle of a project ranging from its design to construction and operation and then finally to its demolition (Eadie et al. 2013; Lu et al 2014).

the United Kingdom government has taken steps towards improving the performance of its construction industry based on the recommendation stated on the reports of Sir Michael Latham dubbed "Construction and the team" published in 1994 and Sir John Egan's report "Rethinking construction" published in 1998, where they explored the weaknesses and challenges in the construction industry, and they recommended that to improve the performance of construction industry, it is mandatory to adopt innovative solutions in order to improve the communication and integration between players to act as a one team (Porwal & Hewage 2013).

The United Kingdom government has realised that one of the main step to emerge from the recession is to enforce the adoption of BIM. Thus, it mandated the adoption of BIM implementation in all publicly funded projects starting from 2016 onwards (Efficiency and Reform Group, 2011).

The Australian government followed the similar approach by imposing the implementation of BIM on public projects at the beginning of 2016 (Building SMART Australasia, 2012). Since 2007, some governmental organisations in the United States included BIM as a compulsory requirement for its projects (Wang, Chen & Lu 2015).

Finland was a pioneer in this area, it progressively adopted a strategy to transfer the AEC firms to BIM from 2001 onwards and imposed BIM as a mandatory requirement in 2010 (Wong, Wong & Nadeem 2009).

Dubai Municipality is considered to be the first organisation in the Middle East that imposed the implementation of BIM. Since 2014, BIM has become as a compulsory requirement in particular projects that require a high level of coordination such as hospitals, universities and buildings containing more than 40 storeys (DM 2013).

At the same time, clients realised that the implementation of BIM would lead to cost savings and the duration of the project could be reduced. This leads to impose implementation of BIM in the contracts, and therefore enforces other stakeholders to practise BIM (Porwal & Hewage 2013). In Hong Kong, during the last few years, many designers, contractors and consultants have been forced to implement BIM in response to the client’s requirement whether in the public sector or private sector, which has promoted them to invest in the implementation of BIM through recruiting BIM experts and provide necessary training to their staff (Chan 2014).

-Project Complexity:

The increase in the size of a construction project makes it more complicated due to growing number of participants and new players have been involved such as financing bodies, authorities, architects, engineers, lawyers, contractors, sub-contractors, suppliers and various other trades, thereby causing fragmentation among stakeholders because of lack of coordination and communication among various involved parties (Bryde, Broquetas & Volm 2013; Halttula, Aapaoja & Haapasalo 2015). In addition, there is number of separate enterprises working alongside that is required efficient control to the schedule of an activity and its redundant movements, as well as managing the time of the material to be supplied at the site (Fazli et al 2014).

One of the most efficient answers to those problems is BIM because it can save around 30% of the time spent in design and coordination between multi-disciplines and 80% of the time taken to generate a cost estimate. BIM can act as an information centre to improve communication and coordination among stakeholders and serve as a platform for multi-disciplinary collaboration (Chan 2014). Moreover, BIM is utilised to foster appropriate site logistics planning, safety analysis and strategy. BIM can also be used to coordinate between the site activities of several sub-contractors (Fazli et al 2014).

Therefore, the complexity of a project is considered as one of main driving forces for firms to implement BIM, especially for sophisticated firms that are looking to improve the outcomes and achieve the ultimate collaboration among project participants (Hardin 2009; Chan 2014).

On the other hand, the handover of final model to the maintenance and operation organisation provides an accurate and complementary 'real-time' dataset to make the maintenance accurate and faster. In addition, BIM helps the facility management to carry out space management activities, determine the number of maintenance staff and their location, and reduce corrective maintenance and emergency maintenance repairs (Eadie et al. 2013).

- Competitive Pressure:

The competition in the construction industry is very high and the current recession has exacerbated this. With increasing pressure to implement BIM from clients and governments, the early adopters of BIM will survive. Sooner or later the clients will require firms to demonstrate the ability to manage BIM projects though their track records of successfully delivered BIM projects (Eadie et al. 2013).

In addition, the earlier adoption of new technology than their competitors, gives an organisation a competitive edge to be awarded more projects (Ruikar et al. 2005). Therefore, the competitive pressure is a key factor in enforcing the organisations to implement BIM at a higher level before stipulated government deadline in order to be 'BIM experts' and to remain competitive (Liu, Issa & Olbina 2010).

The adopters of new technology have been divided into five groups: innovators, early adopters, early majority, late majority and the laggards (Porwal & Hewage 2013). The innovators and early adopters implement new technology without any external pressure in order to gain competitive advantage. This means that they have realised the benefits of BIM, and the adoption is coming from internal readiness (Coates et al. 2010).

Whereas, the late majority and laggards have a conservative approach to technology and they wait for external forces to implement the new technology. Such firms are lag behind the competition. From this it can be deduced that the adoption of BIM can be influenced by an organisation's intention to gain competitive advantage over their competitors (Ruikar, Anumba & Carrillo 2005).

BIM can also enhance coordination and collaboration among the several disciplines of the organisation, which improves its performance and productivity, and allows it to deliver its project at an economical price than its competitors, which improves their competitive advantage (Lu, Zhang & Rowlinson 2013).

At the same time, BIM has the potential to provide time and cost reduction by decreasing the efforts to generate architectural information and extract accurate bill of quantities and cost estimates. In addition, it can analyse the environmental factors at lowest cost in order to achieve sustainability, which gives the organisation an opportunity to offer the most competitive bid, and enhances its chances to win more projects (Coates et al. 2010).

- Keep Abreast of Technological Development:

There are many firms looking for innovativeness in order to improve their design and construction quality. These organisations are distinguished by their environment which promotes innovation and external communication channels that increase the awareness of innovation which enforces them to implement BIM (Mitropoulos & Tatum 2000).

The organisations that are classified as a "technology-oriented" are not waiting for external pressures to implement the new technology due to their aspiration is to be at the forefront of the AEC industry and they have the desire to improve their product quality. Such firms are keeping themselves abreast of technological development and it is their main motivation to implement BIM (Eadie et al. 2013).

Tatum (1989) identified the factors in an organisation that enhance the adoption of new technology:

- Organisational structure: the adoption of new technology often starts from a higher level to a lower level. Hence a reduction in the number of hierarchical levels enhances the communication among organisation members and accelerates the implementation of new technology.
- Organisational culture: the managers have to create the culture that enhances the adoption of new technology through increased awareness among the employees and providing the financial support.
- Key individuals: it is a very crucial factor to be able to select staff that is able to identify and implement new technology.

The readiness of top managers in any organisation plays a vital role in implementing BIM, especially when they are the decision maker. Hence, they should be aware of the benefits of BIM and take steps to enhance the adoption of BIM in order to achieve the business goal of the firms (Herranz, Colomo-Palacios & Amescua-Seco 2013).

Meanwhile, implementing BIM is a very complex process and requires meticulous planning, the absence of which may result in assigning ambiguous roles and responsibilities that can demotivate the employee to implement BIM (Mathiassen, Ngwenyama & Aaen 2005).

2.4. BIM and Procurement Methods

For many decades the construction industry has been facing several problems. These problems are related to missing link between design and construction, lack of integration and communication among stakeholders, an increase in project complexity, a change in the client's priorities, requirements and uncertainties (Naoum & Egbu 2015).

BIM is not merely a technology, it is a new process (Eastman et al 2011) that has reformed the method of involving stakeholders to work together in the construction industry; these include owners, architects, engineers, contractors, oversight groups, and other constituents (Pcholakis 2010). It also alters the work process in all disciplines. These new forms aim to improve the outcome in terms of quality, cost and time (Mcauley et al 2012).

The main objective of BIM adoption is to enhance all the construction process from the feasibility study till the facility management (Eastman et al 2011). That requires changes in the existing work practices to realise efficient results and improve the level of integration among the project participants (Porwal & Hewage 2013).

This section of literature review presents the aspect of BIM adoption that might reform the project delivery methods and to what extent that alteration will improve the project performance and productivity.

2.4.1. Construction Procurement Strategy

In the construction industry there is a common misconception about the clear definition of procurement: is it purchasing or a contract? Indeed, it includes both, providing services and merchandise (Grilo & Goncalves 2011). A procurement strategy in the construction industry is defined as an organisational structure that designates and specifies the liabilities and authorities to people and firms, and determines the relationships among various elements during the construction process (Love, Skitmore & Earl 1998). It is also a process in which the clients' requirements and objectives are elicited throughout the project life cycle (Dalgliesh, Bowen & Hill. 1997).

In addition, it has been defined as a collective process for the achievement of mutual benefit, where it adds value to the clients and profits for the participants through contractual structure (Koolwijk & Vrijhoef 2005). Furthermore, procurement strategy is not only organising the relationships but also forming the power structure (Dalgliesh, Bowen & Hill 1997).

The aim of a procurement strategy is the successful project delivery in terms of time, cost and quality to meet the client's expectations (Love, Skitmore & Earl 1998). It also improves the relationships and achieves the objectives of projects (Morledge, Smith & Kashiwagi 2006). The procurement method should be in compliance with the project's technical requirements along with stakeholders' interests (Alhazmi & McCaffer 2000).

Participants engage with the project through a procurement method which is driven by client, where client hires firms for various activities such as design, construction and maintenance and operation. The popular form of procurement method is the Design–Bid–Build (DBB) where the client hires the consultant for design purpose, and then hires a contractor for construction. Nevertheless, the increase in size and complexity of the project increases the number of participants. Where, many projects require special skills during the design and construction stage, the relationships among participants have been reformed (Rijn 2005). Figure 05 clarifies the relation between participants in the simple form.

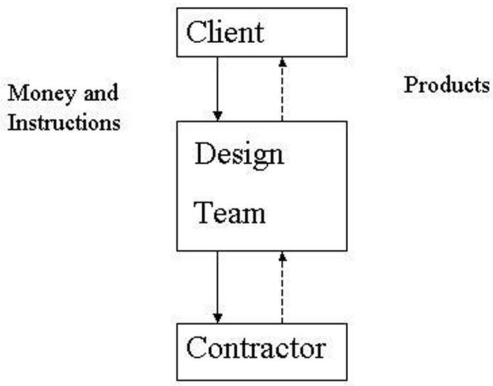

Figure 05: The relationship among participants in simple form (Rijn 2005).

The procurement methods in the construction industry are categorised in three forms. First, traditional methods that start by design stage, then tender and construction. Second, management methods that rely more on the coordination among participants and the new-fangled management principles of empowerment and power equalisation (Dalgliesh, Bowen & Hill 1997; Love, Skitmore & Earl 1998). Finally, a new approach has been introduced recently to improve the collaboration and enhance the integration, that is, relational project delivery arrangement (RPDA;Halttula, Aapaoja & Haapasalo 2015).

Morledge, Smith and Kashiwagi (2006) argue that although each procurement strategy has various processes and structures, there are common contents of procurement strategy to achieve the objectives. These are:

- Determine the needs
- Select the appropriate suppliers and contractors
- The responsibility matrix in terms of determining requirements, scope of work, quality standards and schedule
- Terms of payments
- Form and manage the contractual relationships
- Risk management
- Commercial and procedures

Selecting the appropriate procurement method is very critical, where the reconciliation of selection of the appropriate procurement methods participates in reducing the cost of the project by 5% (Alhazmi & McCaffer 2000), and the failure of procurement methods selection could cause project failure (Morledge, Smith & Kashiwagi 2006). Nevertheless, each project has an appropriate procurement method and there is no definite procurement method appropriate for any project (Alhazmi & McCaffer 2000). The factors that should be considered in selecting the appropriate procurement methods have been determined in various studies (Liu 1994; Love, Skitmore & Earl 1998; Alhazmi & McCaffer 2000; Morledge, Smith & Kashiwagi 2006), and have been defined as follows:

- **Project characteristics**: the size, complexity, location and distinction of the project influence the time, cost and risk.
- **External environment:** changes in the industry environment improve the procurement methods selection, where the improvements in technology and construction material, in addition to the availability of material, reform the criteria of procurement selection.

- **Client's characteristics:** the financial capability, experience and type of clients influence the adopted procurement method, where the procurement selection is influenced by the organisation's culture. In addition, the client's needs, including time, cost and quality, classify the selection of the procurement method.
- **Risk allocation or avoidance:** determine the liabilities, the degree of desired client's involvements, and to what extent the client wants to transfer the risk.
- **Ability to make changes:** change in the design and construction process is inevitable, so the selected procurement procedures should allow the client to make changes.

Morledge, Smith and Kashiwagi (2006) state that selecting the suitable procurement strategy has two components:

1) Analysis: addressing the priorities and objectives of the project and client's desire towards the risk avoidance.
2) Choice: determine the possible options, compare among them and choose the most appropriate.

While, Love (1996) presents other steps for analysis to select the proper project delivery method. The steps are as follows:

- Illustrate the project
- Address the project's objectives
- Set the delivery time and programme
- Determine the delivery structure to achieve project's objectives
- Draw the liabilities for the participants
- Create the method of hiring the project's players

However, selecting the method should be done logically and systematically. In this, the client's advisor plays a significant role in the selection of the procurement method that meets the client's needs, particularly in complex projects, where the project's objectives are ramified. Ordinarily, while selecting the procurement methods, the client tend to mitigate the amount of risk that they are willing to take (Love, Skitmore & Earl 1998; Morledge, Smith & Kashiwagi 2006; Naouma & Egbu 2015).

2.4.2. BIM Driver to Reform the Project Delivery Methods

The construction industry is often criticised that it has not been essentially developed for well over a century, because of methodologies and roles that form the culture and behaviour of participants (AIA 2007). The current procurement methods have been severely criticised, because they do not achieve the adequate level of integration and collaboration among participants, which leads to unexpected cost, delays and eventual disputes among parties (Eastman et al. 2011; Walker & Lloyd-Walker 2013).

The lack of integration stems from the conflicting interests of participants, inconsistent cultures of stakeholders, lack of information sharing (AIA 2007) and the separation of the design and construction process which impedes the coordination between the design and construction team (Porwal & Hewage 2013). Moreover, the risks and uncertainties are not quantifiable at the outset, and the risk is associated with cooperation performance (O'Connor 2009).

This criticism has been closely studied in the two reports published by Sir Michael Latham in 1994 and Sir John Egan's report in 1998. It has been argued that the deficiency of integration in the construction industry hinders the improvements of productivity, quality and effectiveness. In addition, the culture of organisations should move towards non-adversarial culture (Latham 1994; Egan 1998).

On the other hand, the construction projects are becoming more complicated because of multi-disciplines and the large amount of stakeholders are involved in a single project, which requires the inputs of new stakeholders who are specialists in specific disciplines. This, in turn, demands an increase in the level of coordination and cooperation through the project life cycle. In this context, the conventional process is becoming inconvenient with new workflow (Hooper 2012).

However, the construction industry is standing on the initial stage of positive transformation in response to numerous forces influencing it today, for instance the need to improve the productivity, technological development and owners' demand for sufficient return of investments. Moreover, the demand to promote the collaboration among project team to reduce the period of construction process (AIA 2007; Duke, Higgs & McMahon 2010). The emergence of 2D CAD played a significant role in improving the construction industry and the communication among parties. However, one of the common problems is that the required analyses, including cost estimate and value engineering, are done after the design stage, which is too late to make required changes and determine inconsistencies (Eastman et al. 2011).

BIM has presented a solid platform for effective and improved cooperation among parties, and it allows the sharing of risks and outcomes among stakeholders (AIA 2007). Hence, BIM offers a potential solution for the current fragmentation in the construction industry (Hardin 2009). It also reduces the cost of inadequate interoperability (Succar 2009).

It has been argued that BIM is changing the way of thinking and requires innovation in the procurement and delivery strategies. BIM demands a transformation from a traditional approach, where the participants work on isolated piece of information, to a completely integrated information platform, where participants can share and work on the same information (Smith 2014).

Notwithstanding, implementation of BIM requires the development of relationship and communication among parties, thereby changing the process of information sharing (Muthumanickam, Mahalingam & Varghese 2011). BIM is not just a new 3D technology; it is in fact a new process that reforms the way of involving people and organisations into the project and reshaping the method of working together (Pcholakis 2010). Implementing BIM efficiently demands significant changes in the operations of a construction business at every level; it requires innovation in the workflow, staff training, resetting the liabilities among stakeholders, and reformation of the organisational cultural and the behaviour towards the partners (Arayici et al. 2011). In addition, it requires change in the organisational structure and flow of the information (Succar 2009).

The effective adoption of BIM require the relationships to move towards a closer collaboration and more efficacious communication and reform the current delivery process, whereby BIM transforms the traditional methods into a virtual environment to increase the level of efficiency and improve the flow of data exchange (Bryde, Broquetas & Volm 2013). In 2011, the National Building Specifications (NBS) in the United Kingdom revealed on the basis of a survey that 90% of users adopting the BIM process demand an essential change in the current delivery process in the industry, which seeks to change organisational cultural, behavioural and operational changes (Porwal & Hewage 2013).

The main change required for successful adoption of BIM is cultural change, which can be attained by changing the mind-set of teams to embrace the new technology, transforming the working environment from adversarial to cooperative, promoting a 'no blame' culture, and increasing the awareness of the benefits of BIM. Furthermore, it requires developing a national strategy for the adoption of BIM to stimulate the public and private clients (O'Connor 2009; Mcauley et al 2012; Porwal & Hewage 2013; Smith 2014).

There are two pivotal pillars in the delivery process that should be reshaped to ensure successful implementation of BIM. First, the relationships among parties demand improvements in the communication, through regular meetings to develop the BIM team to ensure successful BIM adoption. Second, organisational structure in which adoption of BIM requires appointing new entrants, such as BIM manager who plays a significant role in designing and managing the BIM process at various levels, and BIM facilitator who coordinates between BIM team and construction team on site. In a nutshell, the roles of the participants have to be changed in order to improve the collaboration. (Muthumanickam, Mahalingam & Varghese 2011; Rizal 2011).

As a new entrant also is the BIM consultant who should be added to a project team, and his responsibilities are: specifying the level of details required in the model, coordinating among stakeholders' input to the BIM model, detecting errors and conflicts, matching the output of a BIM model with the contract drawings, preparing cost estimates from the BIM model and checking its accuracy and assisting in preparing the contract documents including drawing, BOQ and specifications (Porwal & Hewage 2013).

On the other hand, while adopting BIM, evaluating the bids based on the price is an incorrect method as BIM dramatically changes the client's behaviour to adopt new methodology for evaluating the bids, and it thus evaluates the bids based on the competence of parties in adopting technologies rather than the price. Furthermore, BIM approach assists the consultant to produce complete and consistent tender documentation, so the contractor has to submit accurate price without depending on the variations (Saxon 2013).

Ensuring an efficient BIM adoption requires an early involvement of partners to release the conflict of interest among parties and to add their inputs from the design stage, which indeed is not achieved in the traditional procurement methods (Azhar, Khalfan & Maqsood 2012).

Transforming the current procurement method to make them compatible with BIM adoption will face many challenges, where it demands organisational restructuring (Hardin 2009), and the firms are accustomed to the traditional process and structure; hence this resistance to change will hinder the ongoing process (Porwal & Hewage 2013). Furthermore, lack of awareness about BIM benefits creates uncertainties and concerns for stakeholders to reform the procurement methods (Bryde, Broquetas & Volm 2013).

At the same time, organisational restructuring will require ground-level changes in the structure such as hiring experts with special skills, redesigning the workflow and new distribution of the liabilities. This change is a hindrance for the top management to adopt BIM process. Lack of project managers who have full knowledge about the BIM process and the lack of time to train new people make the organisations adhere to the old tactics. In addition, unclear definition of responsibilities increases the anxieties (Eastman et al, 2008; Arayici et al. 2009).

Based on the aforementioned Table 02 summarizes the required changes to adopt BIM.

SR	**Changes**	**References**
01	Reform the culture of the organisation	Arayici et al 2011
02	Change the organisational structure	Succar 2009
03	Redefine responsibilities	Hardin 2009

04	Improving the relationship and communication among participants.	Muthumanickam, Mahalingam & Varghese 2011; Arayici et al 2011; O'Connor 2009; Smith 2014
05	New stakeholders	Muthumanickam, Mahalingam & Varghese 2011; Rizal 2011
06	Early involvement of participants	Azhar, Khalfan & Maqsood 2012
07	New roles and responsibilities	Porwal & Hewage 2013
08	Sharing risks and outcomes between stakeholders	(AIA 2007)

Table 02: List of changes required for adoption of BIM.

2.4.3. Implications of BIM on Contractual Agreements

The contractual agreement is defined as long-term obligations enforced by law between two or more firms in order to achieve particular business objectives by improving the effectiveness of each party's resources, and describes the responsibility of each participant. Usually, it seeks to achieve performance, time and cost objectives (Brown et al 2001; Elbeltagi 2009). The construction contracts should clearly describe all the construction processes including technical issues, financing conditions, risk management, insurance requirements and liabilities (Trinkūnienėa & Trinkūnas 2014).

There is a lack of support for BIM in the current contractual forms, where it relays only on paper drawings and the organisations are using the digital information under their responsibility. Although, BIM adoption depends primarily on digital information, it implies new workflow including contractual agreements in order to ensure sharing the data-rich model and increasing the confidence in the implementation of BIM (Hooper 2012).

The required changes mentioned in Table 02 to adopt BIM demand significant reform to the business and contractual agreements to realize the efficient adoption of BIM. As the implementation of BIM tools promotes collaboration, the industry should be catching up in terms of contacts, responsibilities and risk management. Thus, the appropriate and functioning BIM workflow requests reform for the current agreements. To ensure efficient implementation of BIM process, the new contract forms should achieve utmost clarity, increase the level of trust, improve the cooperation and share the risks (Hooper 2012; Migilinskas et al 2013).

In addition, the roles of participants require change and the contractual relationships need reorganisation to create collaborative processes (Rizal 2011).

The need to amend the construction contract to suit BIM adoption was the motive behind competent organisations to produce new contract forms which clearly define the liabilities, tasks and save rights. The main aim of new contract forms is to change the culture of blame game to improve the collaboration. AIA produced several forms of contract to suit most delivery methods such as ‘AIA A295-2008 General Condition of the Agreements for IPD’ and ‘A141 Standard Form of Agreement between Owner and Design Builder (Hardin 2009).

The aim of these agreements is sharing the risks and rewards among the participants. It will also enforce all participants to work together right from the early stage till the accomplishment of the project within the target objectives and cost (Hardin 2009; Thompson & Miner 2010).

While, the first contract form that focused on BIM was produced by AGC which is ConsensusDOCS 301 that aims to determine the liabilities of data sharing and collaboration. In addition, in Singapore there are protocols and forms published by the Singapore Institute of Architects (SIA form), by the Real Estate Developers Association of Singapore (REDAS D&B) and by the building and construction authority (PSSCOC). These forms are designed to define the liabilities of design, discrepancies and interoperability issues, as well as defining the structure of the relationships among parties and between the owner and the participants (Thompson & Miner 2010; Lip 2012; Smith 20140; Porwal & Hewage 2014; Anderson 2010).

However, the contractual issues of BIM adoption are still in their infancy and under development, so it creates considerable concerns for the participants (Smith 2014). It has been extracted from several studies that critical major contractual issues have to be added or reformed. These issues are illustrated as follows:

- **Design responsibility**:

BIM adoption requires involvement of all parties in the design stage. In case of any design errors, it would be hard to decide accountability for the failure. Evidently, none of the participant will be accepting the responsibility of other parties' input. Since the BIM process aims to improve the collaboration, the contractual agreements should be drafted to properly allocate the design responsibility and avoid the uncertainties by clarifying the required inputs from each contributor. In particular, design team should be engaged under contractual provisions for sharing and using digital information in order to ensure the collaboration and avoid the disputes. In addition, a robust system is required to track the design deliverables at critical stages and it should be able to track the inputs collected from respective parties (Thompson & Miner 2010; Rizal 2011; Lip 2012; Hooper 2012).

Therefore, AIA published AIA E202 BIM protocol to control the access to the model in each stage, and to determine the required level of detail and the "Model Component Authority" (MCA) for each region of responsibility (Anderson 2010).

Furthermore, the level of development (LOD) specification has been developed by AIA for the AIA G202-2013 Building Information Modelling Protocol Form and is organised by CSI Uniformat 2010. LOD is a reference to practitioners clearly specifying and articulating the level of details and reliability of the BIM model at each stage from design to delivery of the project in order to define the characteristics of the BIM model, determine the required inputs from each creator and to clarify the usability of the model (BIM Forum 2013).

- **Intellectual property rights:**

One of the main issues that should be addressed at the onset of a project is the owner of the model and the information arising from the model. The BIM model is created by various contributors, so the agreement should clearly address the legal ownership of the model. As the owner is paying for the design, he might feel that he has the copyrights of the model. Practically, the model ownership is solved uniquely in each project, depending on the project circumstances. In this regard, AIA realised 'Building Information Modelling Protocol Exhibit' to be attached to the agreements. In addition, 'ConsensusDocs 301 BIM addendum' has been published as an alternative family of construction industry contracts, which focusses on the BIM model to clarify the legal issues of digital communications, drawings and e-mails (Thompson and Miner 2010; Smith 2014; Porwal & Hewage 2014).

Apparently, it has been stated in clauses 1.9 and 1.10 of the Real Estate Developers Association of Singapore (REDAS D&B) that the copyright of drawings, specifications and model input goes to the party who creates them. However, the BIM model should remain with the operator of the facility to be used for maintenance and operation (M&O) and for future refurbishment (Lip 2012).

- **Defects liability and interoperability issues:**

As several parties contribute in the creation of the BIM model, diverse programmes might be used. Presently, not all BIM programmes are able to interact with each other, such as merge model or extract data that has been created by another programme. Therefore, the information extracted from the final model might be inaccurate or even unwittingly changed. Thus, the responsibility of the accuracy of information extracted from the model, which contributes in calculating cost and schedule of the project, legally lies with the firm or person involved and they should be aware of the interoperability among the diverse programmes and the coordination among the various inputs.

It has been stated in the standard forms published by the Singapore Institute of Architects (SIA form) clause (27).5 and in (REDAS D&B) clause 20.7 that the constructor has to accept the responsibilities for defects that are caused by the software system, the interoperability among various inputs and ensure the accuracy of extracted information from the BIM model (Hardin 2009; Lip 2012).

Clarification of the responsibilities of interoperability software issues aims to allay the concerns of defects appearance and determine who should be accountable for the accuracy of the data. Per the BIM standards in Australia, it is mandatory to determine the format of data that will be used in the project. Therefore, Industry Foundation Classes (IFCs) have been created to limit the problems streaming from the interoperability implications (Thompson & Miner 2010; Hardin 2009; Lip 2012; The Australian Construction Industry Forum (ACIF) 2014).

- **Risk allocation/assessment:**

Construction contract should be drafted carefully to preclude risk factors as much as possible. However, there will definitely be lot of concerns due to change in responsibilities happening in such documents (Porwal & Hewage 2014).

One of the main factors hindering the BIM adoption and the key concern of entrants is the uncertainty in the legal framework. Certainly, BIM adoption poses new risks that should be settled legally from the onset of a project. For instance, one of the risks unique to BIM adoption is that the participants elicit data based on the contribution of other participants; hence, it should be accurate (Lip 2012).

Therefore, the BIM addendum with contract form determines that each contributor is responsible for own input, and any damage resulting out of it. Another risk is of the software malfunction. Often one model includes entire data of the project, failure of which leads to project failure (Porwal & Hewage 2014).

Consequently, it has been stated in the new forms that owners are responsible for any software malfunction occurring and hence should take appropriate precautions to recover the data in case of any damage. Such risks catalyse AGC to issue 'ConsensusDOCS 301 BIM Addendum' that specifies the liabilities, rights and obligations in order to encourage stakeholders to adopt BIM in the construction industry (Lip 2012; Porwal & Hewage 2014).

The process of risk assessment in BIM comprises three steps: First, risk identification, the management has to distinctly identify and categorise the risk factor in the contractual stage an in the construction stage. Second, the risk assessment identifies the risk profile and adopted strategy for risk management. Third, risk response through implementation of a proper strategy to avoid or minimise the risk as much as possible by adopting collaborative project delivery methods. Implementation of BIM presents several risk factors. Table 03 summaries list of BIM risk factors (Chien , Wu & Huang2014; Cao et al 2015).

Category	Risk Factor
Technical risk	Inadequate project experience
	Lack of software compatibility
	Model management difficulties
	Inefficient data interoperability
Management risk	Management process change difficulties
	Inadequate top management commitment
	Workflow transition difficulties
Environmental Risk	Lack of available skilled personnel
	Increase in short-term workload
Financial Risk	Rise in short-term costs
Legal Risk	Additional expenditures
	Lack of BIM standards
	Unclear legal liability

Table 03: Summary of risk factors in BIM adoption (Chien, Wu & Huang 2014).

2.5. Implementation of BIM with Traditional Procurement Methods

To understand the implications of BIM in the procurements methods, it is mandatory to evaluate the impacts of the required changes which have mentioned earlier on the current process in terms of information sharing, relationship among stakeholders and early involvement of participants. Furthermore, the changes occurring in each delivery method should be duly addressed to ensure successful adoption of BIM in the current procurement methods (Hardin 2009). The most common construction procurement methods, as stated in several studies (Morledge, Smith & Kashiwagi 2006; Hardin 2009; Eastman et al 2011), are as follows:

- Design–Bid–Build (DBB)
- Design and Build (D&B)
- Construction Management (CM)

2.5.1. Design–Bid–Build

The Design–Bid–Build (DBB) is one of the most popular traditional delivery methods (Hardin, 2009; Eastman et al 2011). It has been adopted in the US construction industry since 1940s for the majority of projects undertaken in 20th century. It was majorly used for those clients who either had less experience in this industry or those who were not sure on design, cost and time of their project(Morledge, Smith & Kashiwagi 2006: Kent & Becerik-Gerber 2010).

Even though the construction market in the UAE is considered to be the most buoyant construction market in the Middle East, still the DBB is the most preferable procurement method used here, owing to the lack of firms that can handle both the process design and the construction (Asamoah 2012).

In DBB, the owners sign agreements with the architect to provide design services including developed design concept, mechanical, plumbing and electrical design, and then further produce full construction documents including design drawing and specification of the material. After this, the construction documents are distributed to a number of contractors for bidding (Hardin 2009; Morledge, Smith & Kashiwagi 2006). Usually, the wining contractor is the one whose bid was at the lowest price. Before the commencement of the work, the contractor has to submit shop-drawings to clarify the impact of construction process on the design which are used for actual fabrication. Therefore, it is necessary for the shop-drawings to be accurate, and in case of any error or inconsistency in the shop-drawings, it will take more time to reveal the errors, leading to additional cost (Eastman et al 2011).

Contractors calculate the cost based on the coordination between sub-contractors and defining their relevant work (Hardin, 2009) and the bill of quantities prepared by the contractor's team; thus they carrying out the financial risk and error of quantities. Whilst, the clients carry design risk and design team performance. Thence, if the work gets delayed on the contractor's end due to design failure, the client is obliged to pay extra cost to the contractor to complete the project (Morledge, Smith & Kashiwagi 2006). Figure 06 shows the relation between stakeholders in DBB.

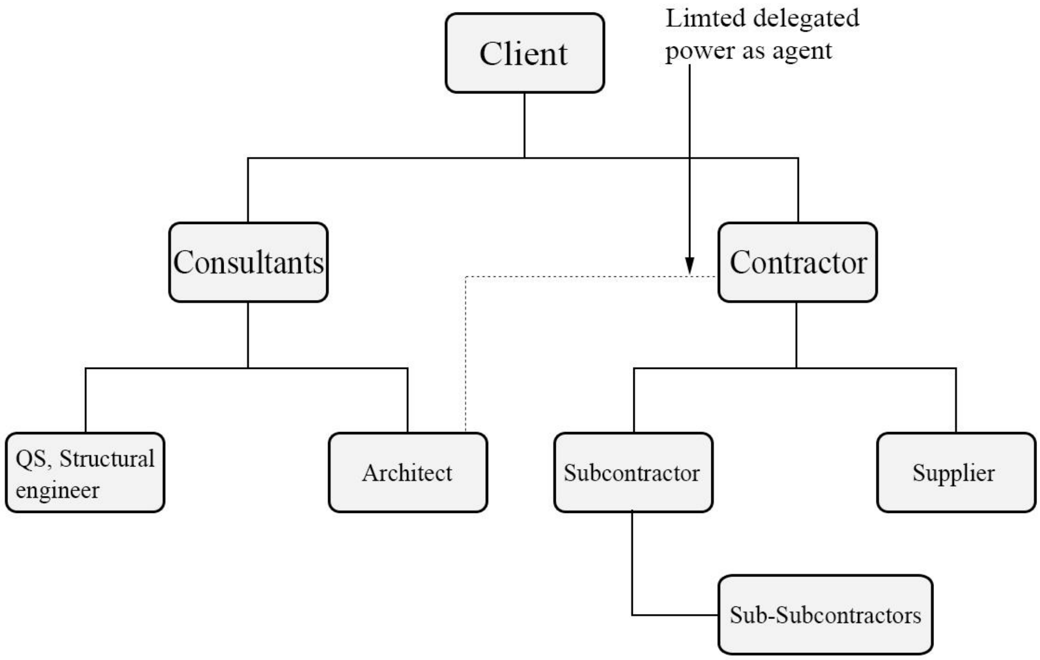

Figure 06: The DBB organisation (Morledge, Smith & Kashiwagi 2006).

Usually owner opens all the bids either privately or in public depending on type of the project and the selection of the contractor is generally based on the lowest price and pre-qualifications (Azhar, Kang & Ahmad 2014). The main steps for the DBB have been stated in Turner (1990) as follows and further clarify in Figure 07:

- Clients define the needs and technical requirements for the project.

- Design team develops the design and design drawing.
- Client approves the design work.
- Prepare tender documentation.
- Invite contractor to tenders.
- Contractors prepare their bid.
- Select the contractor and sign agreements.
- Construct the building.
- Test the building.

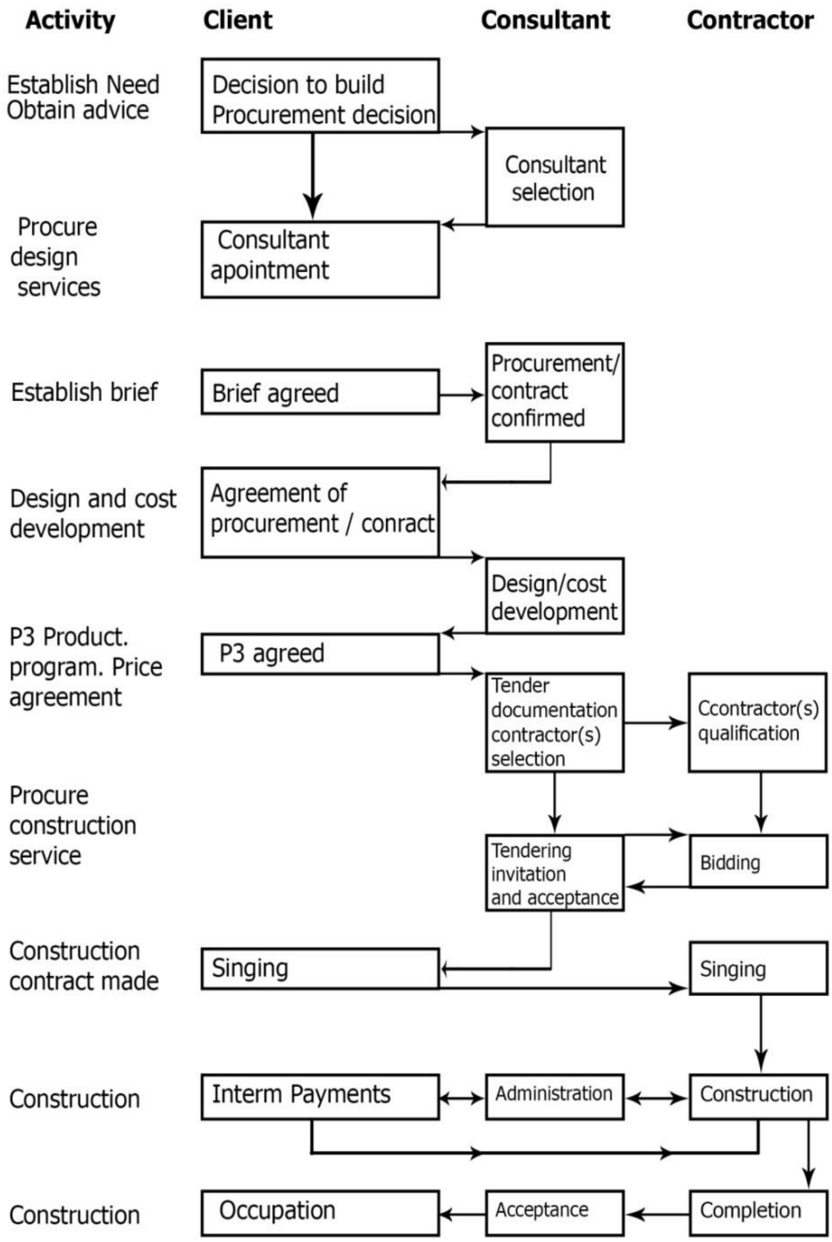

Figure 07: Main steps of DBB (Turner 1990).

Several studies determine the advantages and disadvantages of DBB (Turner 1990; Al Khalil 2002; Morledge, Smith & Kashiwagi 2006; Hardin 2009; Eastman et al 2011; Azhar Kang & Ahmad 2013; Lu et al 2014). The main advantages are as follows:

- The competition is transparent, as the contractors are bidding on the same criteria and client is getting the lowest price.
- The designer is ensuring high level of functionality and quality in the design and the client has direct influence on the design and is able to communicate directly with the designer.
- As clients have full control over design, they can verify to what extent the design solution is meeting their expectations.
- Client can alter designs without pressure of price and programme as a contractor is not yet involved.
- Achieve reasonable price based on the market price.
- The requirements and procedures are well known for all parties.
- The finical commitment is known to the client at tender stage before initiating the construction.

On the contrary, the disadvantages of DBB are as follows:

- The duration of the project is longer than other delivery methods, as the processes are sequential with no parallel work. Hence, the total cost is higher.
- There is no input from the contractors in early stages as they are involved after the design stage.
- The tender documentation should include sufficient details to make the bids more accurate, but usually the designers include few details that cause disputes and errors on fabrication.
- Contractors often bid very low price so as to win the tender thereby compensating the difference arising from the variation at later stages which cause multiple disputes between the contractor and the client.
- Facility manager has to hit hard to collect the accurate information after the construction phase.

The integration among participants in DBB is very limited because of the fact that different parties are responsible for design and construction as client signs separate agreements with architect, engineer and contractor. These parties do not working together efficiently and they usually have competing interest due to lack of information interoperability, which influences the integration, communication and collaboration (Lu et al 2014).

In DBB, the contractor engages after 100% completion of design phase; thus, implementation of BIM with DBB is ineffective and it limits the utilisation of BIM due to the lack of coordination between contractor and design team in early stage in terms of scheduling, clash disclosure and constructability. Furthermore, there is no adherence to share the model, if any, between the contractor and the design team. Nevertheless, BIM can be used to extract bill of quantities for estimation (Hardin, 2009). Despite this, in 2009, 32.7% of the BIM-based projects in the US construction industry were applying BIM with traditional delivery method DBB, and 88.7% of BIM-based projects in the Chinese construction industry were procuring BIM through DBB (Cao et al 2015).

Adoption of the BIM model in DBB faces a crucial problem in the tender phase as the model provided by the owner is not yet part of official tender documents, and thus the bidders cannot depend on any data extracted from the model (COBIM 2012). Therefore, the tender documents should be modified to contain the BIM model further to 2D drawings in order to support the adoption of BIM (Liu & Hsieh 2011). The owner thus must check the quality of design team who will create the BIM model, as in this case, the client is responsible for the BIM model and its content before being sent out to the tenderers (COBIM 2012). In addition, contents of the BIM model should be accurate to assist the bidders in providing an appropriate price (Roginski 2011).

The design team should update any relevant change in the tender documents to describe the BIM model content and should limit the restrictions to allow bidders to utilise the BIM model (COBIM 2012). In addition, the BIM model should be created and provided with most popular format and should implement standards and protocols with common languages. Nowadays, IFC (Industry Foundation Classes) is the most common format that supports most of the BIM software (Porwal & Hewage 2013). In places where BIM is not yet that advanced, the client should provide 2D drawings along with the BIM model; the contractor can obtain 2D drawing from model, add the necessary data and specification, and ensure the compliance between model and 2D drawings (COBIM 2012). Figure 08 shows the main aspects of the client's obligations in DBB in tender stage.

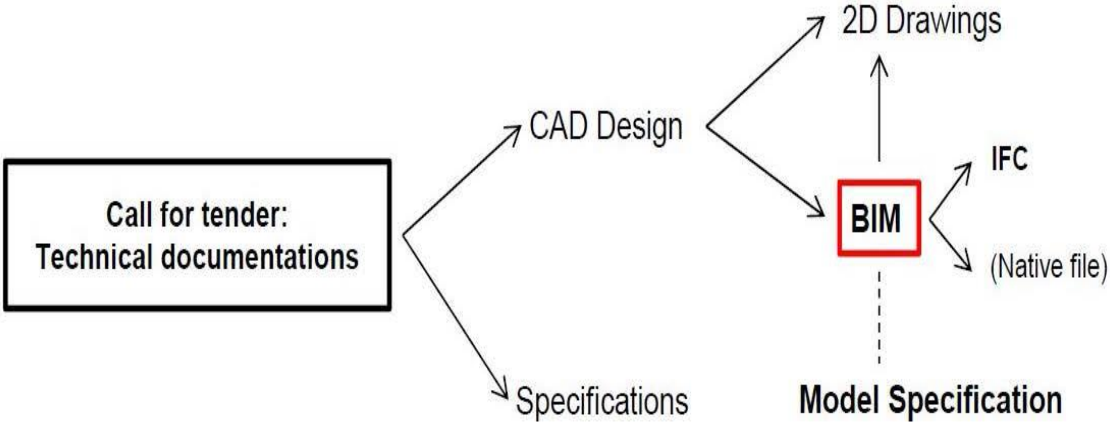

Figure 08: The main aspects of the client's obligations in DBB at tender stage (Bolpagni 2013).

However, the clients benefit from adoption of BIM with DBB, as they receives more accurate and reliable bids and the risk of later claims is also reduced because BIM process minimises the conflicts and inscrutability among tender documents (Saxon, 2013). In addition, BIM assures the conformity between the BIM model and 2D drawing due to the correlation among all documents, wherein a change in one part will automatically update the other part and thus be accordingly coordinated (Bolpagni 2013).

On the other hand, tenderers are also benefiting from BIM implementation by understanding the intricacy of the project swiftly – thanks to 3D model improvements (COBIM, 2012). Meanwhile, bidders can extract abundant information from the BIM model to provide fast and accurate price evaluation. Thus, BIM is not just a simple 3D model; it contains information that can be extracted. Furthermore, the quantities can be taken off to prepare accurate time schedule and cost and to assist supply chain management (Roginski 2011). Therefore, designer should provide the BIM model with as much data as possible.

There are many limitations of adopting BIM with the DBB delivery method. First, the involvement of a contractor after the design stage reduces utilisation of BIM process, in particular, the coordination and collaboration among participants, which otherwise is the main aim of BIM (Eastman et al 2011). Moreover, learning the process is mandatory for participants to maximise their potentials of BIM. At places where BIM is in its infant stage, the contractors, consultants and clients with BIM experience are rare, and the awareness of BIM benefits still limited. Subsequently, contents of the BIM model might not be able to carry enough data to provide reliable price (Roginski, 2011).

2.5.2. Design and Build

The design and build (D&B) method is developed to solve the problems found in DBB (Roginski 2011; Al Khalil 2002). D&B was established in 1990s to improve the cost, schedule, and quality over construction projects (Kent & Becerik-Gerber 2010). D&B is a project delivery method whereby a client hires single entity for design and construction under single contract based on the design requirements prepared by the client (Al Khalil 2002; Hardin 2009).

In these agreements the contractor warrants to provide the complete design documents, permits, construction schedule and estimation of total project cost. In addition, the contractor is responsible to construct and deliver the project according to construction schedule (Hardin 2009). The D&B approach is particularly effective in certain cases where the scope is obvious, design is standard and the schedule of the project is tight (Al Khalil 2002). Moreover, the client has the knowledge and experience about the performance of the major components. Client often hires design teams to prepare the requirements, project briefs and tender documents (Morledge, Smith & Kashiwagi 2006).

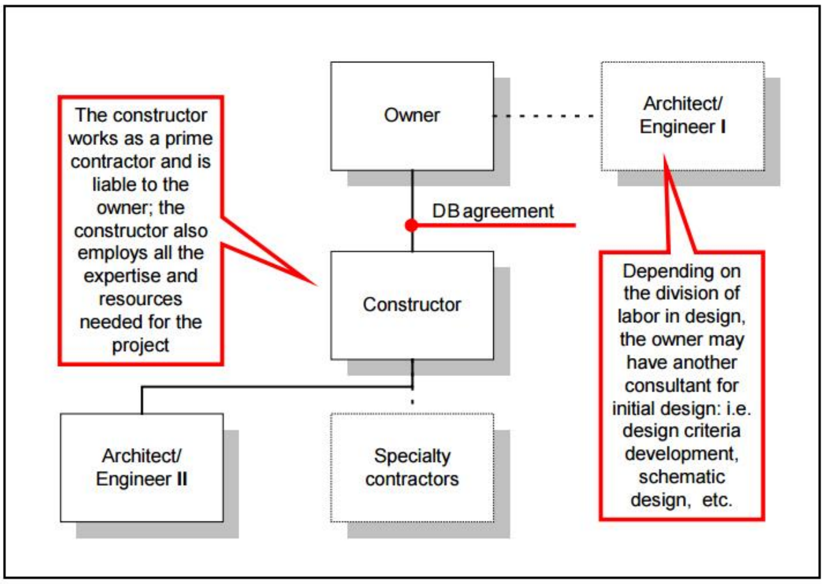

Figure 09: The D&B organisation (Lahdenperä 2001).

Selection of the contractor in the D&B method is usually done in the negotiation process with one or more contractors based on the combination of price, duration, proposer qualifications (Hardin 2009), quality of design solution (Turner 1990), and the prequalification and past performance in similar projects that plays a pivotal role in the selection process (Molenaar, Songer & Barash 1999).

In order to execute the successful project delivery in the D&B method, the contractor should be able to tackle the technical aspects of design and construction, be an expert in design and project management, be capable to achieve a level of coordination and be able to settle conflicts between project team (Takim, Esa & Abdul Hamid 2013).

Turner (1990) determines the main steps of the D&B as below; Figure 10 clarifies those main steps:

- Determining the client's requirements, scope of work.
- Selecting bidders for tenders.
- The contractor or contractors preparing their solutions, schedule and cost proposals.
- Agreement with the selected contractor. Criteria of selection are solely based on qualification and/or cost.
- Start the process of design and construction of the building.

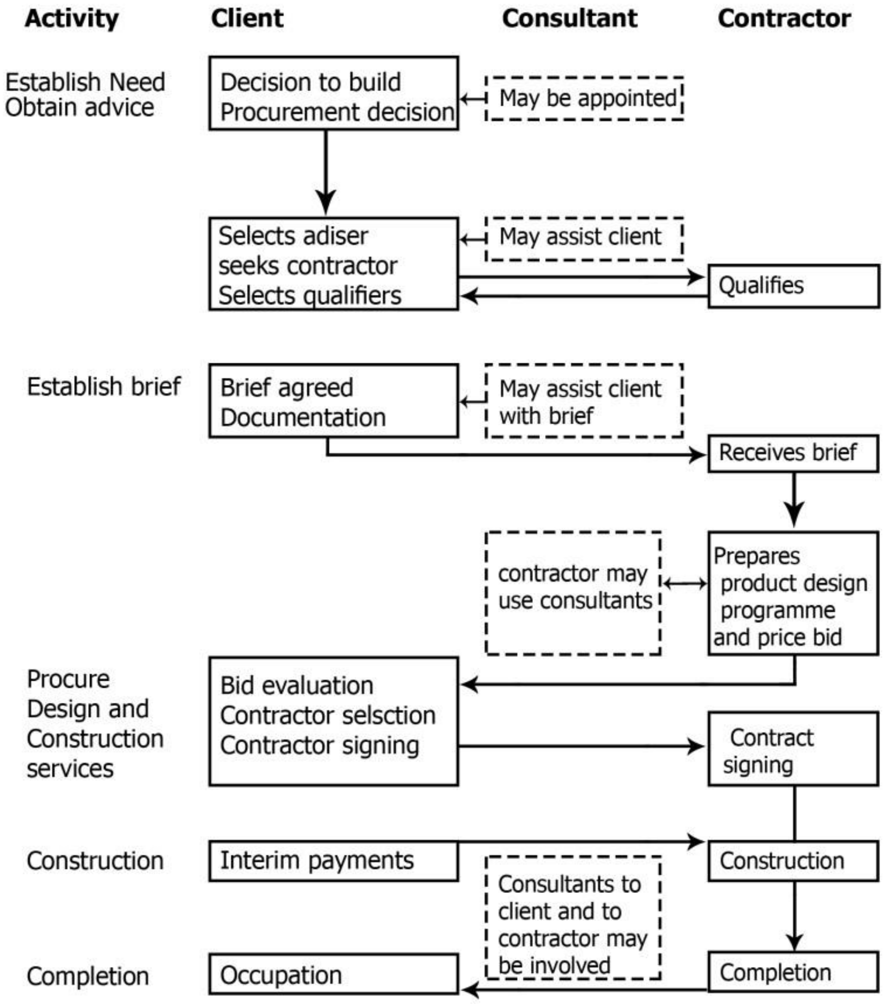

Figure 10: Main steps of the D&B method (Turner 1990).

The advantages and disadvantages of the D&B method have been stated in several studies (Molenaar, Songer & Barash 1999; Al Khalil 2002; Morledge, Smith & Kashiwagi 2006; Adnan et al 2011; Estman et al 2011; Takim, Esa & Abdul Hamid 2013; Chan 2014). Following are the main advantages of the D&B method:

- Reduces the time of project delivery and allows amalgamation of construction information during design.
- The client deals with only one firm, hence reducing the time for contracting with consultant and contractor separately.
- The single point of responsibility, where the selected contractor is responsible for the whole project.

- Flexibility in design, as the designer produces alternative designs in order to meet the client's needs.
- The client has an early knowledge about the financial commitments of the project.
- Improve the construction solutions, due to the communication enhancement.
- Less changes during construction.

The disadvantages of the D&B method are as follows:

- Less quality assurance, due to lack of checks and balances.
- Client might lose the control over the design phase, where the client is committed to the concept design before completing the detailed drawings.
- Difficulty to compare between bidders, due to each design being different and hence the price.
- Less competition, since fewer firms provide D&B service.
- Client cannot easily change the design in the later stages, as the cost of changes will be expensive.
- It requires the client to hire design staff to prepare the design brief and tender document.

The framework of D&B is structured to utilise BIM, as D&B is more integrated delivery method than the DBB due to early involvement of contractor team in a project (Hardin 2009). Therefore, in 2009, around 67.3% of BIM-based construction projects in the United States were delivered through the D&B method (Cao et al 2015). However, some of CAD documentation opposed BIM documentation, as it requires updating for newer platform to deliver superior project (Hardin 2009). In order to exploit BIM fully, it requires change in the process, roles and relationships, and all stakeholders need to update their work plan (Saxon 2013).

Typically, in the D&B method, the contractor receives client's requirements and based on this information, contractor then submits a tender including schematic design and price. Predominantly, this process leads to unsuccessful project delivery due to unclear requirements from client's design team, which either leads to the delivered project not matching the client's expectations, or multiple changes at a much higher cost. The implementation of BIM has the potential to address some of the shortcomings, where the clients can receive the design as 3D model and walkthrough to verify whether the proposal is suitable as per the client's needs, and any change can be done at a much less cost than any change on the site (Foulkes 2012). Therefore, the bidders have to submit the BIM model with tender documentation based on a set of well-organised BIM requirements provided by design team of the client to assist bidders in creating a model ready to be checked by client through Model Checking tools (Hopper 2012). It is an auditing tool that gives the possibility to review models for conflicts, potential problems and design code violation, and can be checked whether bidder's proposals are in compliance with client's needs (Khemlani 2012). Furthermore, it is required that the bidders submit their pervious BIM models along with their prequalification in order for the client to have an idea about their quality; it is one of the criteria to judge between bidders. Therefore, client has to hire a BIM consultant or a BIM manager to prepare the BIM project brief (New Zealand BIM Handbook 2014). Undoubtedly, the client's requirements may differ from client to client and from project to project; nevertheless, it should include indications related to:

- File format
- Coordinates system and units
- Level of detail, coordinates system and units of the model
- Conventions of objects-naming
- Model structure
- Identification of spaces

And the client has to provide a model for the existing site and buildings. Figure 11 shows an example for BIM requirements provided by client (COBIM 2012).

Structure	Building part	x/(x)	Accuracy
Facades	Exterior walls	x	• Examples of concrete wall element types are modeled accurately in terms of geometry and location, including connections, reinforcements and embedded objects. • Other elements and on-site concreting structures are modeled accurately in terms of geometry and location, so that collisions are avoided and information regarding the total amount of structures can be reported from the model.
		(x)	• Modeling of façade structures with light-structural frames is decided on a project-specific basis. For example, a wall can be modeled as a continuous for quantity survey. • Modeling of surface finishing of wall elements is decided upon on a project-specific basis.
	Special façade structures	(x)	
Exterior decks	Balconies	x	• Examples of concrete element types are modeled accurately in terms of geometry and location, including connections, reinforcements and embedded objects • Other elements and on-site concreting structures are modeled accurately in terms of geometry and location, so that collisions are avoided and information regarding the total amount of structures can be reported from the model.

Figure 11: BIM requirements at tender stage (COBIM 2012).

In order to create a BIM model properly, the contractor should hire sub-contractors in the early stage of the project so that they are able to add their inputs in the model (Porwal & Hewage 2014). It often happens that the selected design needs revision as per the client's changes and contractor's input. Therefore, Porwal and Hewage (2014) prefer to produce design in 2D documentation for tendering stage, and the selected design thus is developed into the BIM model including construction documents to local authorities and coordination among Mechanical, Electrical and Plumbing (MEP) drawings. Hardin (2009) states that BIM stands apart in this part of the delivery method, as it is constantly updated with the information from architects and engineers, and thus coordinates among their inputs.

The specifications and construction documents in the D&B method are saved in CAD files and PDF; these documents are thus readily shared among the participants as only one firm is responsible for design and construction (Hardin 2009). Implementing BIM with D&B delivery method will change the type of shared documents, as BIM models containing entire information such as specifications and bill of quantity will be shared (Hooper 2012).

On the other hand, implementing BIM with D&B will improve the facility management due to the level of detail in the BIM model and digital O&M manual with BIM components and particular information (Hardin 2009).

Utilising BIM with D&B is the first step for firms thinking to implement the full BIM process. Where, it introduces the idea of integration between project teams to achieve more targets and profits (Hardin 2009). However, it has been stated that implementing BIM with D&B is more effective when 80% of the work is electrical such as in substations, data centres and power generating stations. Therefore, 100% of electrical projects in many U.S. states are using D&B with BIM, including hospitals, data centres, biopharmaceuticals, stadiums, and high-rise residential or hospitality buildings (Gavin 2009).

Project team can utilise benefits from implementing BIM with D&B, where it allows the client to have reliable knowledge about the offers and all the information is located in one file instead of many (Foulkes 2012). Client can assess among the proposals with ease and accuracy and can check the compliance between proposal and his stated requirements (Statsbygg 2011).

On the other hand, for bidders and contractors employing BIM with D&B enhances the accuracy of bids in terms of price and construction capability, as the information can be realised from the BIM model and the calculation of the quantity is easier. Moreover, it allows the bidders to avoid errors and conflicts on their proposals before the final submission (Vianova Systems 2013). It also assists the selected contractor to save the time of preparation before starting the project, as an error-free shop drawing is prepared and a set of clear information is shared visually with the construction team. Furthermore, it enhances the integration and promotes consensus between the internal team, which leads to great management and accountability for a project (Gavin 2009).

Nevertheless, there are some drawbacks of applying BIM process with D&B, due to the lack of awareness among clients about the BIM potential; they usually do not have sufficient knowledge about meeting BIM requirements and controlling the BIM process. Subsequently, learning this approach is mandatory to reap BIM benefits (Kiviniemi 2010; Salmon 2012). Despite government's clear instructions on publishing BIM requirements clearly in the agreement, bidders often lack sufficient knowledge about BIM tender specifications (COBIM 2012). Therefore, the existing contract forms should be revised to be incorporated with BIM adoption (Gibbs et al. 2012). Furthermore, as preparation of the BIM model is costly and time consuming, the period of the tender will also be longer. Therefore, it is preferred that the bidders submit their CAD drawing at tender stage, and only the selected design is developed into the BIM model (Hooper 2012).

2.5.3. Construction Management

For several decades, the construction industry suffered from high level of fragmentation, inefficiency and high costs of inadequate interoperability due to diversity of culture in the industry. Construction management (CM) was established in 1960 to solve these problems and to add value to owners. However, it has not effectively changed the fragmentation among project participants (Kent & Becerik-Gerber 2010).

Under CM strategy, client hires construction manager (CMr) in addition to design team to manage project schedule, coordinate between design and construction process, expedite collaboration (Morledge, Smith & Kashiwagi 2006) and accomplish the project within a guaranteed maximum price (GMP), so that the project cost does not exceed GMP. The construction manager has two roles: firstly, in design phase CMr is consultant for owners to control development and design stage, and secondly, CMr acts as a general contractor in construction phase to ensure the project deliver is in compliance with the client's interest (Hardin 2009).

Owner signs separate contracts with designer and contractor, and CM supervises both contracts (Lahdenperä 2008). However, CMr has no direct contract with design team and general contractor and is not liable for any financial risk; thus, risk and responsibility are not allocated to a single main contract. Although the client is tightly involved in design and construction stages, he should maintain strong presence through hiring project management or administration to take the necessary actions towards the CMr recommendations. Nonetheless, this strategy is inappropriate for inexperienced clients. The main criteria of nominating CMr are the track record of cost forecasting and cost management (Morledge, Smith & Kashiwagi 2006). Figure 12 clarifies the organizational structure in CM.

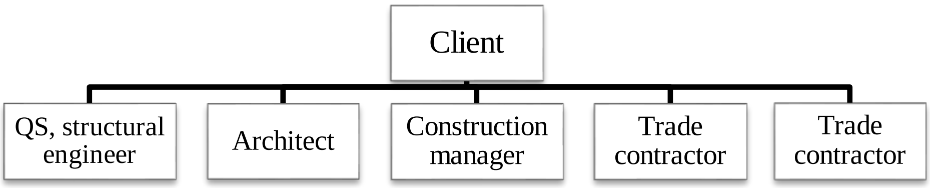

Figure 12: The organisational structure in CM (Morledge, Smith & Kashiwagi 2006).

In CM strategy, design and construction process can be overlapped in order to speed up the project. On the basis of several studies, there are two ways to implement CM as a delivery method (Koppinen & Lahdenperä 2004; Morledge, Smith & Kashiwagi 2006; Lahdenperä 2001; Eastman et al. 2011):

- **CM-at-fee/Agency CM:** CMr is hired to monitor and control cost, time, quality and safety without taking any responsibility. The main contractor is responsible for construction activities. Client pays CMr a fixed fee based on time. Often, large construction companies prefer to do construction work rather than being involved in CM-at-fee/Agency CM. Figure 13 shows the organizational structure in CM-a-fee.
- **CM-at-risk:** CMr is responsible for delivering the project including construction methods, quality and facility performance. In this case, all procurements are carried out by CMr based on the agreement between CMr and sub-contractors. However, the final decision for project delivery rests with the client. CMr is paid a fixed amount of fee based on time. Figure 14 shows the organizational structure in CM-at-risk.

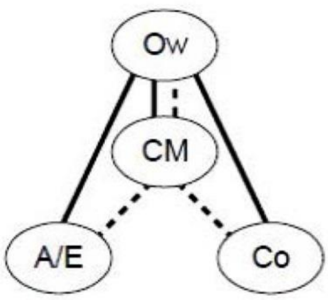

Figure 13: The organisational structure of CM-at-fee/Agency CM (Lahdenperä, 2001).

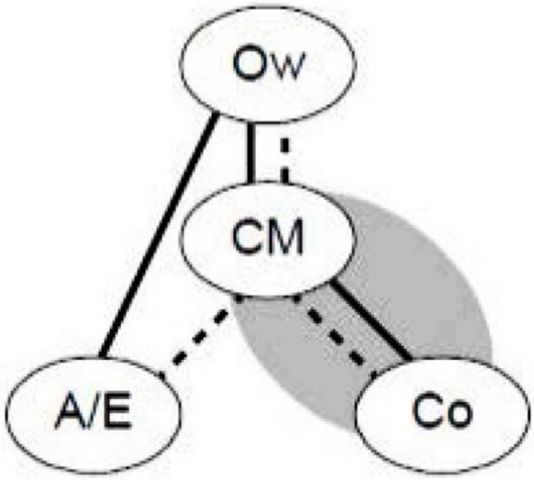

Figure 14: The organisational structure of CM-at-risk (Lahdenperä, 2001).

The main steps of implementing CM are as follows (Turner 1990):

- Determine the client's needs and requirements
- Hiring design team
- Nominate and select management organisation
- Evaluate the design proposal and programme
- Tendering and selecting the general contractor
- Starting the construction process

Numerous studies determine the advantages and disadvantages of CM strategy (Turner 1990; Koppinen & Lahdenperä 2004; Morledge, Smith & Kashiwagi 2006; Hardin 2009; Eastman et al. 2011).

The main advantages are as follows:

- The possibility of overlapping design and construction procedures offers time saving for project completion.
- Receive contractor input in early stage in design and project planning.
- Particularly in complex project, CM assists in more cost saving than other traditional delivery methods as the construction aspect is involved in design and price-oriented competition.
- Duties, risks and relationships for project team are obvious.
- Unlike other strategies, there is a possibility to alter design in the later stages.

- There is an improved cash flow because the owner has direct agreements with main contractor and pays them directly.

The main disadvantages of CM are as follows:

- Project budget is based on design team estimates, so the actual project cost is achieved after last trade packages.
- The client should be very active to operate such a strategy.
- It requires controlling close time and information more than quality.
- Risk of losing reputation is very high for CMr.
- Client takes more risks in CM than DBB, where he has to communicate and coordinate between more contracts and cost thereby adding fee-type contracting.
- The integration among separate organisations is not fully utilised.
- Flexibility of change in design and construction stage opens door for variations more easily.
- Client needs in-house skilled team to choose design team and CMr and define the requirements and responsibilities in the contracts.

Owing to the integration process, CM is considered to be the most effective delivery method that offers the best value as compared to other procurement methods. Where, the flow of information supports the integration among participants (Hardin 2009). As design team and CMr report directly to the owner, they can complement each other's work (Hergunsel 2011). Furthermore, contractor and sub-contractor are involved in the design stage itself, allowing them to add their inputs to the design and project documentation. Through a design-to-budget approach, contractor should inform design team about the cost based on ready documentation (Hardin 2009).

Application of BIM in CM requires architects and engineers to share their inputs early in the BIM model during the design stage in order to be used in preliminary estimation and coordination (Hardin 2009). Therefore, it is mandatory that CMr is a BIM expert who can manage, control and coordinate the information flow among participants. Therefore, CMr is acting as a BIM manager in D&B to prepare BIM design brief and asses the proposed models from design team (New Zealand BIM Handbook 2014). Likewise, an early involvement of a facility manager is recommended to define the requirements of documents and correspondences to assist in facility management. Unlike designers and contractors, facility managers are usually hired after project completion, thereby leading to their lack of familiarity with the project; consequently, disconnecting the flow of information (Hardin 2009).

Adopting BIM in CM delivery method has benefits for all project participants, Where, the quantitative information held by BIM model can be used in preparing cost estimation and coordination between project team. As BIM tools assist in the testing and coordination before construction work; therefore, BIM limits requests for clarification and provides prompt answers that are critical in CM due to the flow of ample information. The early involvement of contractor and sub-contractor allows CMr to deliver the project within GMP. Furthermore, implementation of BIM with CM allows project participants to sit on one table and share equal responsibility of the project (Hergunsel 2011).

On the other hand, complete information and documents supplied support the facility management to calculate the cost and resources. Thus, where the history of construction process and stages are well known, bringing a facility manager early in the picture makes O&M for facility much easier (Hardin 2009).

2.6. Implementation of BIM with Innovative Procurement Methods

The project delivery methods in the construction industry have faced vitriol in the past due to the fragmentation and lack of communication and coordination, which has considerably influenced the team dynamics and project performance. The need to improve the productivity of industry forces the research institutions to innovate new delivery methods so as to achieve project objectives and meet the client's expectations (Ibrahim, Costello & Wilkinson 2011). This section evaluates the innovative procurement methods and studies the effectiveness of BIM adoption within the new delivery processes.

2.6.1. Integrated Project Delivery

Integrated project delivery (IPD) is an innovative project delivery method and contractual language. It has been formed as an integration solution and aims to take the integration among the project participants to a new level (Hardin 2009). It has been introduced in the US construction industry to overcome the drawbacks in the traditional project delivery methods (Ashcraft 2011). The American Institute of Architects (AIA) defined IPD as "project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction " (AIA 2007, p. 2).

IPD is distinguished by efficient collaboration among clients, designers and contractor. This cooperation takes place in all the construction processes right from the design stage till the delivery of the project (AIA 2007). Raisbeck, Millie and Maher (2010, p. 1025) state that "However, under IPD there is no individual allocation and subsequent quarantining of risks between parties. From this perspective IPD can be defined as a procurement model in which risks are allocated jointly to all project parties and this joint allocation of risk is governed collectively"

In IPD, all project participants sign a single collaborative agreement in order to create a cohesive team by determining common and interconnected business interests, and defining the technical and social methods of communication and cooperation. The main aspect of IPD is how risk is allocated in terms of time and cost (Eastman et al. 2011).

Participants are required to adjust their behaviour in accordance with the new paradigm to deliver the project successfully (Ilozor & Kelly 2012). Therefore, the culture of participants needs to be changed and the presence of interpersonal dynamics such as respect, trust and well-working relationship is imperative (Kent & Becerik-Gerber 2010). Figure 15 shows the interpersonal dynamics between participants in IPD (Poole 2010).

Figure 15: The interpersonal dynamics among participants in IPD (Poole 2010).

There is an important change of architect's role in IPD, whereby designers and engineers are agreeing to prospective cost and benefits from the projects. This has provided a financial technique for architects to benefit from any involvement of design to construction performance. This change transforms architects in such a way that the design service becomes more articulated and sharpened (Eastman et al. 2011).

The main difference between IPD and traditional procurement is that the agreement is established on the basis of the negotiation process rather than the tender process as in traditional project delivery methods (Ashcraft 2010). AIA (2007) points out some of the differences between IPD and traditional project delivery methods, listed in Table 04.

Traditional Project Delivery		Integrated Project Delivery
Fragmented, assembled on "just-as-needed" or "minimum-necessary" basis, strongly hierarchical, controlled	**Teams**	*An integrated team entity composed of key project stakeholders, assembled early in the process, open, collaborative*
Linear, distinct, segregated; knowledge gathered "just-as-needed;" information hoarded; silos of knowledge and expertise	**Process**	*Concurrent and multi-level; early contributions of knowledge and expertise; information openly shared; stakeholder trust and respect*
Individually managed, transferred to the greatest extent possible	**Risk**	*Collectively managed, appropriately shared*
Individually pursued; minimum effort for maximum return; (usually) first-cost based	**Compensation / Reward**	*Team success tied to project success; value-based*
Paper-based, 2 dimensional; analog	**Communications / Technology**	*Digitally based, virtual; Building Information Modeling (3, 4 and 5 dimensional)*
Encourage unilateral effort; allocate and transfer risk; no sharing	**Agreements**	*Encourage, foster, promote and support multi-lateral open sharing and collaboration; risk sharing*

Table 04: Summary of major differences between IPD and traditional project delivery methods (AIA 2007).

Adopting IPD is more beneficial in social infrastructure and vertical buildings, where such projects contain uncertainty because of their complicated system, compatibility, functionality and incompliance with owner's needs (Lahdenperä 2012).

Scale and complexity of the project determine the organisation of an IPD team, the roles of each party and the way of coordination among participants. The basic pattern applicable for most of the projects is to form interdisciplinary team. The core team includes the owner's project manager, project architect and the contractor's project manager depending on the scale of the project; representative of facility management can be added to the core team (Ashcraft 2011). Figure 16 shows the basic pattern of the organization in IPD.

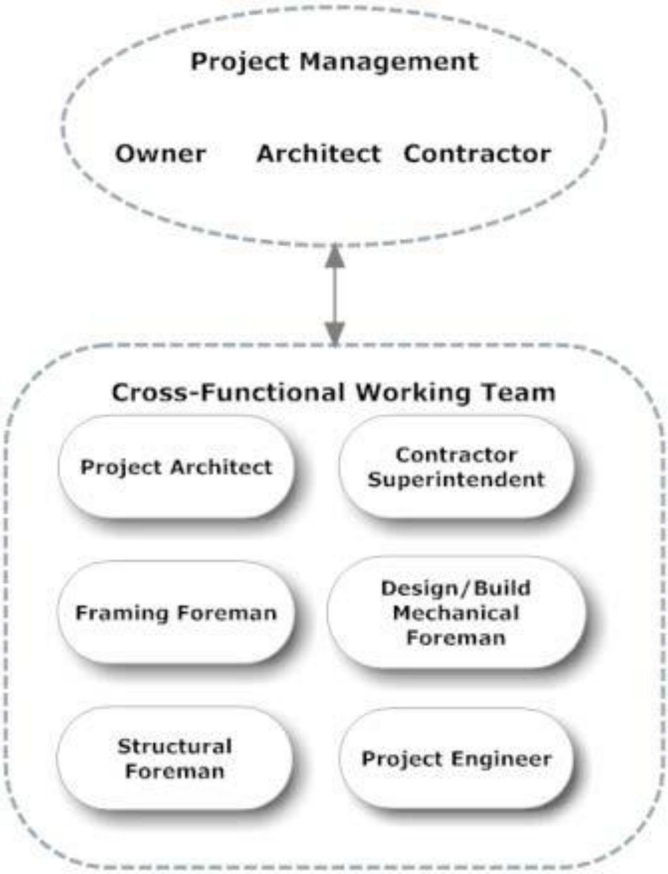

Figure 16: The basic pattern of the organisation in IPD (Ashcraft 2011).

In 2005, at AIA National Convention, "MacLeamy curve" has been presented by Patrick MacLeamy, CEO of Hellmuth-Obata-Kassebaum (HOK), one of the most known architecture organizations. MacLeamy curve is a universal graph illustrates the relationship between the cost of decision and the time of typical construction project. It is obviously observed that decisions made in early stages and during the design stage are costing less and more effective. Consequently, project will benefit by involving most of participants in the design stage, and value engineering decisions will progress timely, in particular, the decisions affecting the cost of project life cycle (Anderson 2010). *Figure 17* shows MacLeamy curve

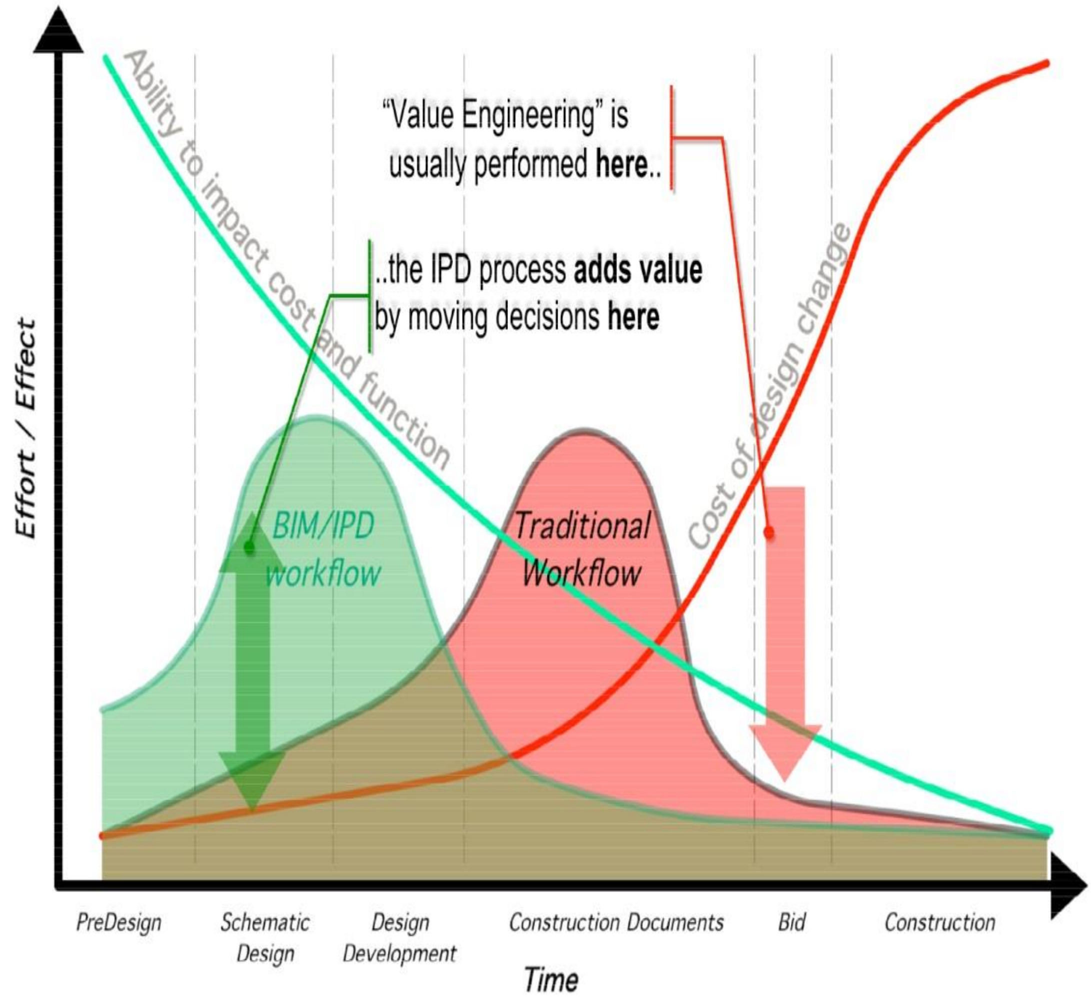

Figure 17: MacLeamy curve (Anderson 2010).

ConsensusDOCS, which is established by 22 leading organisations in the construction industry, has issued a consensus set of IPD contract documents. The onset of multiparty agreement was the ConsensusDOCS 300 and it was the first standard construction agreement to address IPD. Later, Integrated Form of Agreement (IFOA) was published as a relational IPD contract to address the financial and contractual framework to harness the efficient cooperation among project parties (Consensus DOCS 2009; Kent & Becerik-Gerber 2010). Ashcraft (2010) determines five major structural elements for IPD contracts as below; Figure 18 clarifies the relation between 5 elements in IPD:

- Early involvement of key participants.
- Shared risk and reward based on project outcome.
- Joint project control.

- Reduced liability exposure.
- Jointly developed and validated targets.

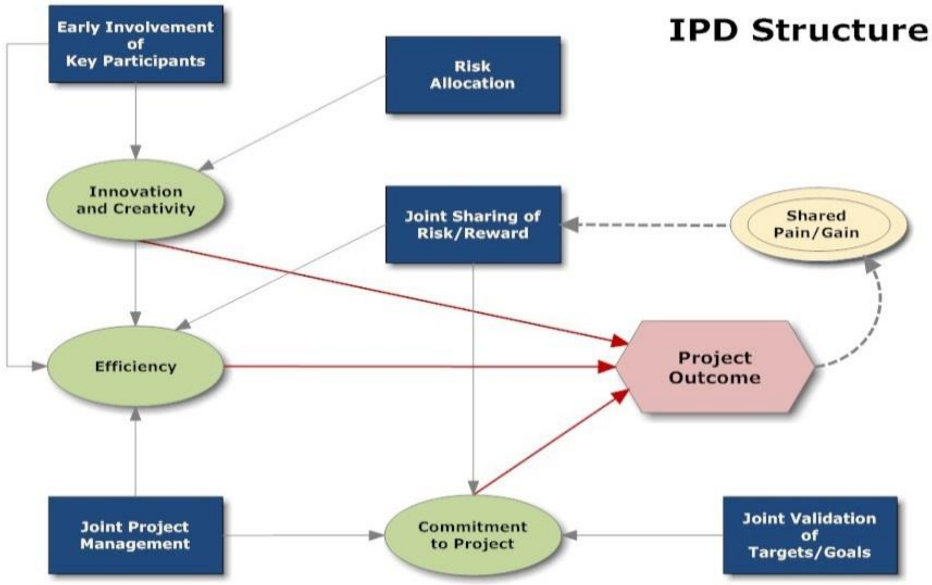

Figure 18: The relation among five elements in IPD contract (Ashcraft 2010).

There are three common principles of projects delivery through IPD. First, multiparty agreement – in traditional methods, client signs a separate contract with every major participant in the project, whereas in IPD, all parties who have major role in the project sign one agreement in order to maximise the integration and collaboration. Second, shared risk and rewards, the project parties are accustomed take steps to reduce their own risk, unlike in IPD there are elements designed to promote team work and enhance the success of the project, as IPD contracts share the risks and rewards among project participants. Third, early involvement of all parties , IPD allows all project participants to be involved from the design stage to add their inputs, thereby improving the collaboration and addressing the cause of fragmentation earlier (AIA 2007 ; Kent & Becerik-Gerber 2010).

O’Connor (2009) determines factors of successful IPD adoption as follows:

- **People: Selecting the Team,** the environment of IPD is different from other project delivery methods. It is mandatory to have highest degree of trust among parties. This requires change in the culture and behaviour. The entrants should be able to share risk and communicate openly and honestly. Furthermore, discouraging ‘no blame culture’ among team members to enhance the collaboration.

- **Process: Managing the Team,** controlling the relationships and collaborations among team members’ demands a Management Group to act as a decision-maker. This group comprises an authorised representative of the client, designer and contractor. In addition, there is a Collaborative Project Delivery (CPD) team which is responsible for facilitating the design, construction and commissioning of the project.
- **Promises: Motivating the Team,** intelligent incentives should be crafted in order to deeply instil the cooperation among project participants. Unlike traditional methods that always contain negative incentives, it is compulsory that IPD contracts contain positive incentives to promote the performance of cooperation and diminish the culture of ‘protect oneself on the expenses of others’. To enhance the economic incentives, social and moral incentives can also be created by boosting the environment to reinforce the collaborative behaviour.

Numerous studies determine the pros and cons of IPD (AIA 2007; O’Connor 2009; Duke, Higgs & McMahon 2010; Kent & Becerik-Gerber 2010; Eastman et al. 2011; Ashcraft 2011; Ilozor & Kelly 2012; Walker & Lloyd-Walker 2013). The pros of IPD are as follows:

- All the participants act as one.
- Risks and rewards are shared.
- Reductions of project cost by early discovery of the areas of conflicts as the participants add their inputs from the design stage.
- Diminishing the cost of O&M.
- Reduction in the wastage by efficient planning and shared cost.
- Changing the relationship among stakeholders from adversarial to collaboration.
- Increasing the opportunity to deliver the project in compliance with owner’s expectations in terms of cost, quality and time.
- Improving the facility management.

The cons have been stated as follows:

- It might be complicated to control and manage the participants as one firm.

- It requires a major cultural shift in participant's behaviour.
- The organisations need to create new legal frameworks to match new IPD approaches.

There are many constraints and limitations of applying IPD, such as the resistance to change in the organisations that are accustomed to traditional ways in terms of leadership and responsibility; the less experienced organisations require more efforts to apply coordination and integration; and evaluating the bidders based on low-bid award system, particularly in the public sector. Public institutions and agencies do not try to change their structure and procurement processes. Despite the existence of new contracts that are supporting IPD, they are not fully assured in places where they have not been tested appropriately. In addition, the insurance companies do not have coverage for IPD yet. In fact, there is a degree of concern about the relationship among participants in IPD (Kent & Becerik-Gerber 2010; Porwal & Hewage 2014).

Moreover, dispute resolution is still not developed appropriately in IPD, particularly in the specific obligations such as delay payments and duty indemnify. Nevertheless, the parties should have primary responsibilities to resolve such disputes (Ashcraft 2010).

Apparently, it is believed that IPD has materialised the most effective facility of BIM in the construction projects unlike the other project delivery methods. Where the parties are incorporated right from the early process, it creates the most efficient environment to implement full BIM methodology and to achieve all benefits of BIM, particularly for the end-user. It also enables a high level of participation to ameliorate competency and minimise errors. In addition, it opens the door for reconnaissance of the alternative approaches (AIA2007; Hardin 2009; Ashcraft 2010; Duke, Higgs & Mcmahon 2010; Kent & Becerik-Gerber 2010; Migilinskas et al 2013; Porwal & Hewage 2014).

Because the close connection between IPD and BIM has been realised early, hence ConsensusDOCS 301 BIM addendum has been issued to assist the participants to work collectively and in the best interest of all involved, and to allay the fear of the risk of moving to BIM approach (Duke, Higgs & Mcmahon 2010).

IPD depends on BIM not only for more collaboration and integration between participants but also to develop the project faster and efficiently. If in BIM the change occurs in one element, then the updated changes are executed everywhere and the tested information is transferred among parties faster than CAD. The project documentation while adopting IPD with BIM consists of a professional model, such as architectural and engineering model, and BIM documentation that can be used for estimating revisions, collision detection and site coordination (Hardin 2009).

- **Steps for Adopting BIM with IPD:**

Succar (2009) states that the implementation of BIM with IPD is passing with following stages and set of steps; it starts form pre-BIM towards IPD, and then he divides these sets as follows:

- Technology: contains software, networks and hardware that allow the shifting from drafting to object-based. This step starts from pre-BIM and leads to BIM stage 1.
- Process: includes leadership, infrastructure, human resources and products or services. It improves the collaboration and sharing information to allow model-based collaboration. This leads to BIM stage 1 maturing towards BIM stage 2.
- Policy: consists of agreements and regulations to create integration practice. This steps leads to BIM stage 3 and then IPD.

Figure 19 clarifies the aforementioned stages and steps.

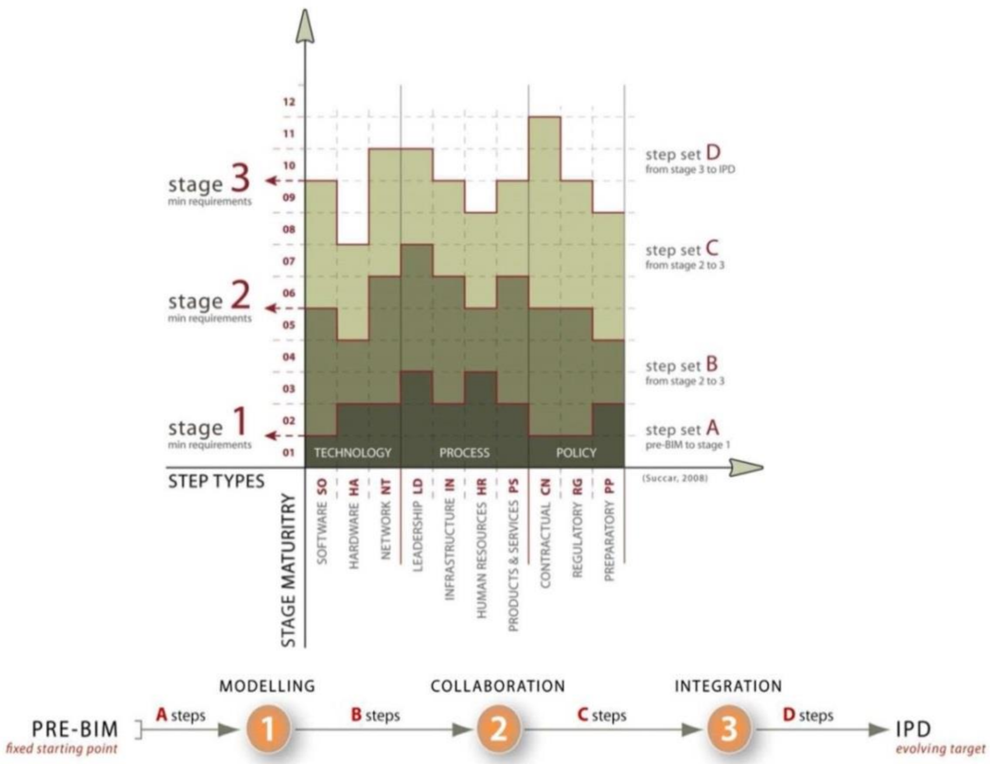

Figure 19: BIM steps and stages towards IPD (Succar 2009).

While Ashcraft (2010) proposes steps schematically for adopting IPD with BIM, the steps start after workshop explains IPD, how and why it works and the differences between IPD and traditional procurement methods. The aim of this workshop is to create a level of understanding among parties to achieve IPD agreement. The first step is that the participants have to come on one table to negotiate on an open discussion the legitimate discussion and concerns. This discussion should be documented to be referred later. It should be clear in this discussion that the goal of IPD is to create an integration environment and the risks and rewards are shared among parties equally to avoid project failure, thus all parties' concerns should be addressed in this discussion.

The next step is to determine the commercial terms and it is mandatory to be compliant with party's interests that have been determined in the previous step. In this step, parties develop the BIM execution plan, its workflow, and the requirements of each party to create a BIM model and determine the standards of information in terms of assembling, portraying and names. This information influences the data entry at later stages.

Based on the scale of the project, BIM responsibilities are determined in the main contract as an amendment or as an introduction in the project manual. The final step is to produce a final agreement in compliance with parties' interests that have been documented in earlier steps. Figure 20 explains the steps of workflow.

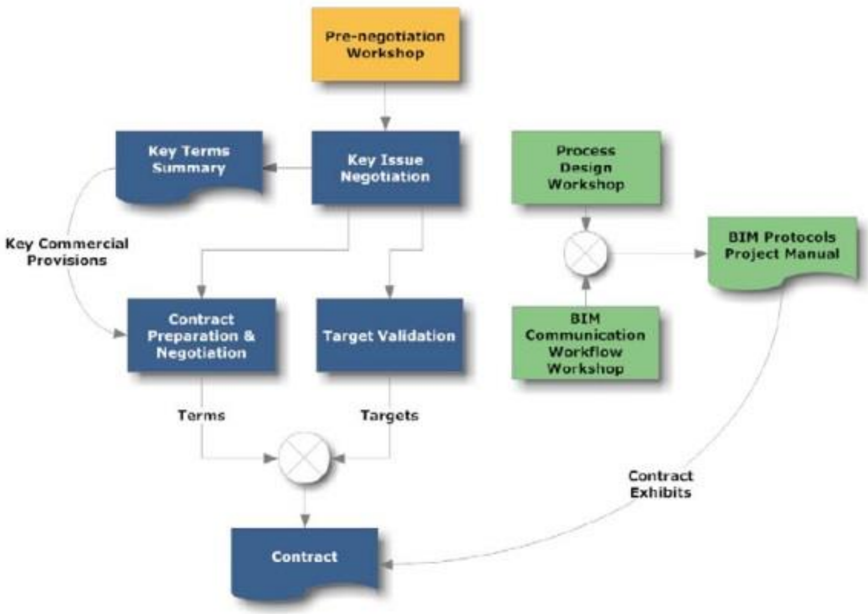

Figure 20: Schematic representation of steps of adopting BIM with IPD (Ashcraft 2010).

Anderson (2010) argues that owners and operators are likely to drive the adoption of process, where they are controlling the payments and investments. Therefore, this approach should have motivations for the sponsors. The main motivation of IPD with BIM process adoption is cost reduction, where well-planned IPD projects using BIM present cost reduction through design and construction stages as a result of:

- 3D model and simulation increase design quality and reduce errors and conflicts.
- Proper cost prediction due to accurate inputs and BOQ.
- The site condition is known that improves potential for prefabrication.
- Efficient plans and construction schedule due to early involvement.
- Transfer the BIM model to facility management in order to improve O&M.

On the other hand, the adoption of IPD with BIM might face barriers, such as, requiring all project participants to obtain the same IT capabilities, which in reality might be difficult to achieve, and the selection of participants with similar IT capabilities might take long time. Because of this the negotiation process might fail, and hence the selection should depend on parties that have similar interests or they have already executed projects as a team (Raisbeck, Millie & Maher 2010).

2.6.2. Project Alliancing

Several relational contracting approaches were introduced to the construction industry in the 20th century to promote collaboration. Project alliancing (PA) is one such approach (Rowlinson et al 2006).It is also considered as the notion of collaboration process (Raisbeck, Millie & Maher 2010). It has been used for number of infrastructure projects and building sectors in Australia while the construction industry in United States was developing the DBB. Although PA has been growing in the US construction industry by approximately 20% per year from 1980s; however, 25% of firm revenue from PA has been accounted in the 21st century (O'Connor 2009).

PA is a project delivery method that seeks to ameliorate project outcomes through consolidating the integrated approach by sharing the negative and positive risks of project among team participants (Kent & Becerik-Gerber 2010). In 2003, Hutchinson and Gallagher (cited in Rowlinson et al 2006, p.79) defines PA as "an integrated high performance team selected on a best person for the job basis; sharing all project risks with incentives to achieve game breaking performance in pre-aligned project objectives; within a framework of no fault, no blame and no dispute; characterized by uncompromising commitments to trust, collaboration, innovation and mutual support; all in order to achieve outstanding results".

PA is a multiparty agreement among key project participants to carry the responsibilities of design and construction process, sharing risks and rewards in order to persuade the close collaboration, fostering the innovation and delivering ventures successfully. Where, each player considers the point of view of other parties (Petäjäniemi & Lahdenperä 2012). Successful PA implementation will lead to 20% of the estimated gross budget savings and it will play a significant role in the emerging commercial, political and social dynamics of the 21st century (Rooney 2009).

PA has been used significantly in last decades, particularly in Australia, and it has also been applied in the renovation of the Lielahti–Kokemaki railway and in Tampere lakeshore road tunnel, both in Finland. Such approaches rely on negotiation process and team selection criteria (Petäjäniemi & Lahdenperä 2012). In order to ensure efficient implementation of PA, a proper selection of teamwork is required, where the participants should be able to solve all confusions internally without recourse arbitration, and have the capability to improve teamwork and can work with "no blame" culture (Rooney 2009).

- Process of PA:

The process of PA starts by sending 'Request for Proposal' for selected team, and then, who has the desire to participate, will submit tender narrative, that includes a potential plan of managing the relationships among participants, the quality of their staff, and the contractor presents his capability to deliver the project. Whereas, the price is not indicated in the tender documents because it is not part of selection basis. Depending on the assessment, which includes interviews, two or three competing teams will be selected for next stage (Petäjäniemi & Lahdenperä 2012).

The interview is usually conducted in workshop format to give sponsors an opportunity to assess the performance and capability of each workgroup and determine which workgroup has the efficient relationship in compliance with the project type. The bases of selecting the best tenderer are evaluation of workshop tasks and combined team fee (Rooney 2009).

The selected team will sign "development agreement" with client for design of the project, then the expected project cost will be set, and after agreement is reached the participants will sign implementation contract. Once the agreement is signed, the workgroup develops the Target Cost Estimate (TCE) and the Target Outturn Cost (TOC). TOC is an engineered cost estimate that the integrated delivery team calculates. All variables have to be mentioned on the final cost, where once it is set, cannot be changed (Rowlinson et al 2006; Rooney 2009; Petäjäniemi & Lahdenperä 2012). *Figure 21* explains the process of PA from the time owners decides to adopt PA

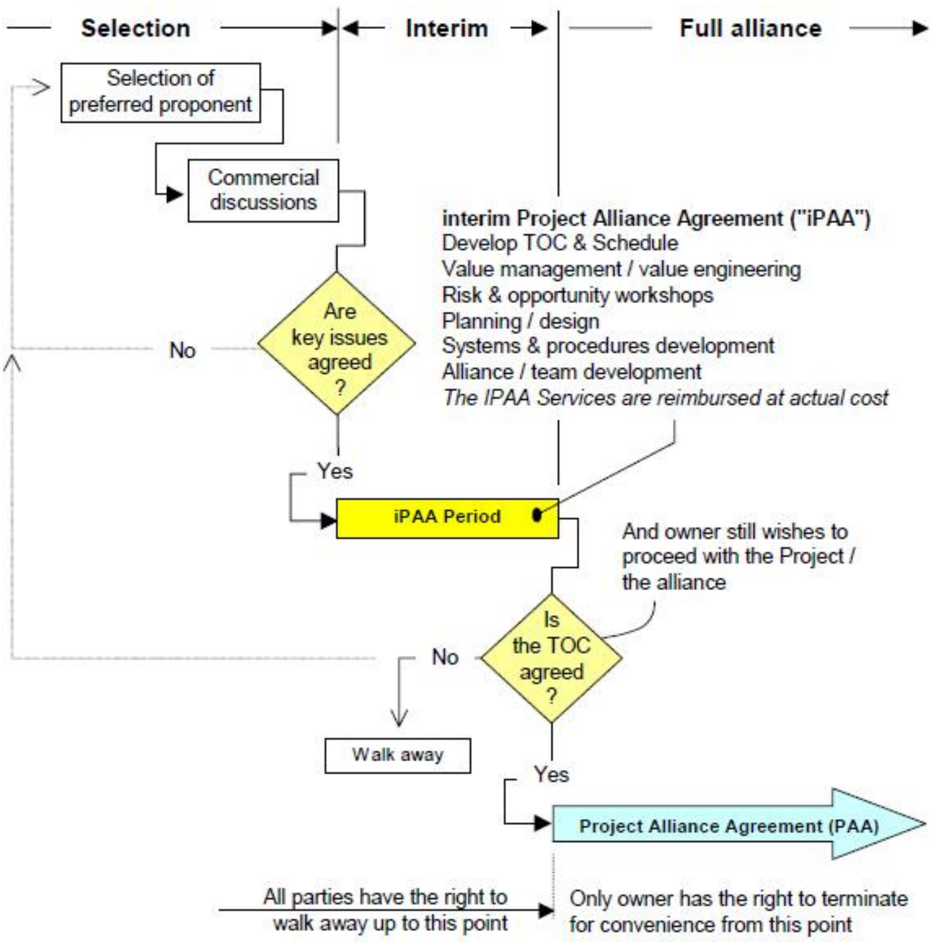

Figure 21: The process of PA (Ross 2003).

The core principles of PA which are common in most projects have been stated in Ross (2003) and Rooney (2009) as follows:

- Cultural change from adversaries to cooperation and integration relationship with 'no blame' culture.
- Rewards and risks are shared equitably.
- All parties are involved in decision making to result in the best decision for the project.
- A philosophy of bringing the optimum financial benefits.
- Promote the innovation to produce high performance.
- Honest and open communication without hidden agenda.
- Prompt reply for all conflicts and collisions without recourse to litigation.
- Assistance from participant top management.

Before the project starts, all parties have to agree to a set of standard benchmarks to measure the performance in different categories, such as project delivery within the agreed budget and schedule, ensuring less environment damage, maintaining health and safety and checking that the cooperation relationship is improved. The agreement will mention that while the parties will gain extra rewards if they improve the performance and deliver the project earlier, they will lose part of their rewards if they do not deliver the project successfully (Rooney 2009).

Roos (2003, p. 4) argues that "The non-owners participants are typically compensated in accordance with following 3-limb model:

- Limb 1: 100% of what they expend directly on work including project-specific overheads;
- Limb 2: A fee ("Fee$") to cover corporate overheads and profit;
- Limb 3: an equitable sharing between all alliances participants of gain/pain depending on how actual outcomes compare with pre-agreed targets in cost and various non-cost key result (KRAs)"

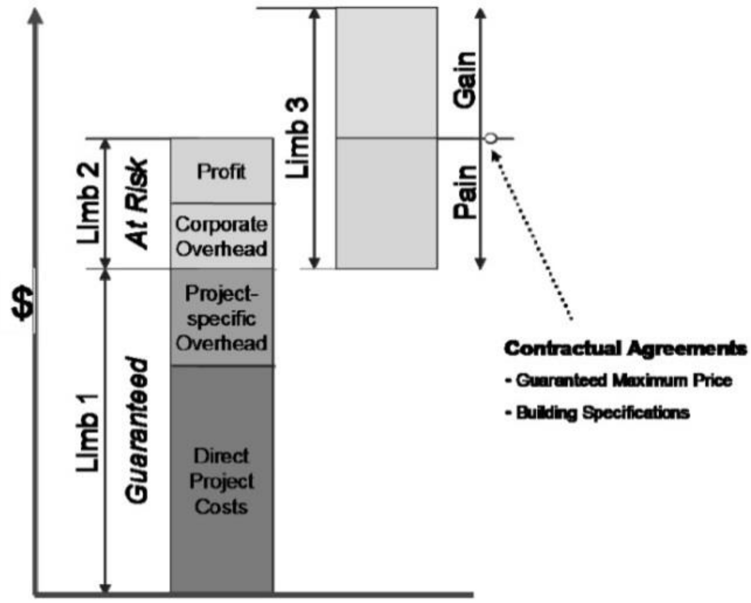

Figure 22: Demonstration of 3-Limb model (Raisbeck, Millie & Maher 2010).

The organisational structure of PA consists of three levels: first is project alliance board that leads the direction till the end of the project with overall support to alliance team. Second is Alliance Management Team that gives support and manages the collaborative approach. Third is Integrated Project Team that comprises project staff at operation level (Rowlinson et al 2006). *Table 05* clarifies the organizational structure of PA and the members of each level.

Project Alliance Board (PAB)	○ Senior executive from all alliance partners	• Provide governance • Set policy and determine delegation • Monitor performance of the AMT • High level leadership/support
Alliance Management Team (AMT)	○ Alliance Manager* ○ Deputy Alliance Manager ○ Project Managers from each site ○ Design co-ordinator ○ Alliance communication co-ordinator ○ Environment manager ○ Risk/Opportunities and Innovation Manager ○ Alliance Coach ○ Alliance Psychologist ○ Services Manager	• Provides overall management for all three projects • Ensures effective integration into public sector organisation operations • Performance management
Integrated Project Team	○ Project staff at operational level	• Individual project work

Table 05: The organisational structure of PA (Rowlinson et al 2006).

There are numerous constraints that may hinder PA implementation. The constraints can be divided according to team selection, collaborative culture and value for money as discussed below (Rowlinson et al 2006; Rooney 2009; Kent & Becerik-Gerber 2010; Petäjäniemi & Lahdenperä 2012; Bolpagni 2013):

- In the early stage there are many uncertainties, so it is difficult to estimate the reliable cost; this makes client very wary.
- Select the team before design proposals. Selection is based on competence that creates challenges.

- The design proposals that are not ready might limit the interests of organisations to participate.
- Changing an organisational culture to trust and open relationship is a challenge, especially for organisations accustomed to traditional method where the rivalry relationships are prevalent.
- Sharing the risks will not be acceptable to some parties, as parties will not accept to bear the faults of other parties.
- The decision making is unanimous; this cannot be attained as long as there is difference in fundamental interests of the parties.
- The lack of skilled staff in organisations is a challenge to form alliance.
- Lack of competition and probity auditing hinder implementation of PA in public sector. This reason drives EU legislation (European Parliament, 2004) to adopt the price and economic viability to be in the PA selection criteria.

The advantages and disadvantages of PA have been stated in several studies (Ross 2003; O’Connor 2009; Kent & Becerik-Gerber 2010; Petäjäniemi & Lahdenperä 2012). The advantages are as follows:

- Sharing the risks and rewards among participants improves the cooperation, wherein all stakeholders are in gain/pain equality.
- The integration environment forces the participants to direct their energies to mitigate the errors.
- The owners have a clear knowledge about the project cost, where the variation process does not exist.
- Effective management of stakeholders.
- PA allows skills transfer among participants that lead to develop project staff.

The disadvantages are as follows:

- The success of delivery is linked with cooperation form, so any lack in cooperation will lead to failure.
- The collaboration performance is associated with partners’ performance; it is necessary that it consists of firms with similar performance, which is difficult to achieve due to quality benchmarks not been clearly defined.

- PA requires absolute dedication from partners to change firms' behaviour towards project participants. That requires more efforts from managerial level and the result is not guaranteed.
- Many firms and clients particularly will hesitate to adopt such an approach, where the cost is not defined from beginning and the risk is shared.
- The risk might be too great for participant who has a little role.

There are obvious similarities between IPD and PA. However, there are clear points of difference between IPD and PA. For instance, the relationship among participants is shared in PA unlike IPD in which there are several shared commitments among participants. Furthermore, adopting BIM in PA is based on the discretion of stakeholders and the project type (Raisbeck, Millie & Maher 2010).

However, BIM implementation has mutual goals in IPD and PA (Halttula, Aapaoja & Haapasalo 2015). Adoption of BIM promotes the collaboration among stakeholders in PA through aligning the projects goals and incentivising them to work in integration environment (Kent & Becerik-Gerber 2010). BIM 3D models can be utilised to combine all sub-designs in same model. This allows the parties to predict to what extent the current designs will influence their role in the project, and provide information for stakeholders equally to do analysis for problem prevention. It promotes co-operation, facilitates stakeholders to understand the current situation of the project, and enhances the culture of resolving the problem rather than finding the guilty. In addition, it guarantees that the decision taken is appropriate for the project objective (Halttula, Aapaoja & Haapasalo 2015).

The implementation of BIM process is similar in all relational project delivery arrangements (RPDA), such as IPD and PA (Halttula, Aapaoja & Haapasalo 2015). Where, the main step is conducting a workshop among participants before project starts to determine the project goals, the roles of each stakeholders and BIM model standards in terms of input information required, portraying and names (Ashcraft 2010).

The Heathrow Airport Terminal 5 is an optimum paradigm of an attempt to adopt BIM with PA, where selected contractor, suppliers and sub-contractors were integrated on all project stages including project design, project planning and delivery activities.

Consequently, their inputs created a highly sophisticated BIM model and efficient integration of many components. In addition, there was conscious knowledge sharing to improve the collaboration environment (Walker & Lloyd-Walker 2013).

2.7. Summary of Literature Review

Recently, the adoption of BIM in the AEC industry has been widely advocated. It has been developed to improve the productivity of the construction industry through elaboration in the integration among participants. BIM is a 3D model simulating the building and containing most of the physical and functional characteristics of the building, thus being a central platform of information. In addition, BIM is a process starting from the design stage till the operation of the facility.

The benefits of BIM have been realised by all stakeholders. It facilitates the life cycle of the project from design stage to construction process and then operation and maintenance of the building till its demolishing.

Realising the benefits of BIM in improving the construction industry forces many governments to mandate BIM as a compulsory requirement, such as the United Kingdom, the UAE and Finland. Furthermore, clients have realised the benefits of BIM in reducing the cost and duration of the project, so they have imposed the implementation of BIM in the agreements.

However, many firms have implemented BIM even before being asked by their government or client to do so in order to be distinguished in the market and get a competitive advantage, thus force other firms also to adopt BIM in order to bridge the competition gap. Moreover, the complexity of projects is increasing owing to the multi-disciplined participations in one project, which compels the firms to implement BIM so as to improve the level of coordination among participants.

Nevertheless, there is a counterforce that prevents the implementation of BIM, which is the current procurement method, due to the drawbacks in its process that influence the implementation of BIM process. The current project delivery methods have a low level of communication and collaboration among participants and lack of coordination and sharing of the information. Moreover, the current contractual agreements are not convenient with BIM adoptions, as the contracts do not clearly define the numerous risks, uncertainties, responsibilities and intellectual property rights.

Therefore, there is an urgent need to change or reform the framework of the current project delivery methods to implement BIM efficiently. The substantial issue requires reform in the relationship among participants. The level of cooperation should be improved and the adversarial relationships be avoided. In order to promote the relationship among participants, the procurement methods should allow sharing the risks and rewards among stakeholders. Moreover, the procurement methods should authorise the stakeholders to be involved from design stage in order to reduce the cost and duration of the project.

Meanwhile, the contractual agreements demand essential modifications in order to determine the liabilities, LOD, required inputs of each stakeholders and the ownership of the model. Whereas, implementation of BIM demands involving new participants, such as BIM consultancy and BIM manager, the procurement methods should identify the roles and the position of new stakeholders in the process hierarchy.

Most of these changes should be applied in DBB and CM procurement methods, as it is the most inconvenient method with BIM adoption. The adequate level of integration in D&B makes it convenient with BIM implementation. However, it is recommended to change the tender process of D&B to add BIM model specification.

On the other hand, it has been emerged recently that innovative procurement methods participate effectively in implementing the BIM process, such as IPD and PA. The essential matter in the innovative procurement methods is allowing the participants to be involved from the early stage through single or multi-party contract containing common and interconnected business interests, and improving the integration and collaboration among stakeholders through sharing risks and rewards. Hence, the innovative procurement methods are considered the most effective delivery methods that facilitate in the adoption of BIM by creating a collaborative environment, thereby assisting in reaping the full benefits of BIM.

CHAPTER THREE: THEORETICAL FRAMEWORK

3.1. Introduction

Theoretical framework is the organisation of concepts, hypothesis, beliefs, expectations and notions that support the research based on conducting literature review, and it can be clarified either graphically or in narrative form – the main factors to be studied and presumed to have a relationship between them (Miles & Huberman 1994).

Based on the extensive literature review conducted in the previous chapter, this part of the research aims to highlight the variables indicated in the study, elucidating the relationships among the variables and elaborating the significance and the reasons of having such a relationship. This leads to creating a graphical diagram of theoretical framework to visualise the relationship among the variables.

3.2. Study Components

The main catalyst for this study is the global trend to adopt BIM in the AEC industry in order to improve the construction process and raise the level of integration among project participants. Although the procurement processes have a significant impact and they shape the outcomes of the project (Naoum & Egbu 2015). The main aim of this study is to recognise the required modification for the procurement framework to ensure a proper implementation of BIM in order to assist the stakeholders in the UAE AEC industry to utilise the maximum benefits of BIM.

In order to achieve the main aim, study components have been developed based on conducting the literature review. The sequence of the components starts by exploring the driving forces required to impose BIM in the construction industry, then addressing the roadblocks in the current procurement methods that might hinder the implementation of BIM, thereafter determining the common elements in delivery methods that require change or reform and then finally testing whether the required modifications will lead to harnessing the maximum benefits of BIM.

The graphical model in Figure 23 has been developed to illustrate the study components and the direction of the relationships among the components that have been elaborated as follows:

3.2.1. Driving force to implement BIM

This study starts with this key component to clarify that the implementation of BIM became or will become imperative in the AEC industry, especially in the UAE market due to several factors; the most important being the government strategy to implement BIM widely in the coming years and to make it mandatory for the projects depending on their scale.

In the same context, the current construction process lost its ability to cater client's needs, which are growing rapidly in terms of developing products with higher standards with accurate schedule and cost, and with less risk and errors.

On the other hand, the construction market is pressurising to impose the new process due to the complexity of the projects, which requires a high level of coordination between multi disciplines. In addition, for an organisation to remain competent in the market, it has to be distinguished and remain updated by adopting new processes to gain competitive advantage. Moreover, the development of technology influences every industry in order to improve the productivity, and hence the construction industry has to utilise this evolution in technology in order to improve the productivity, since it has less productivity as compared to other industries.

This research will check the validity of first hypothesis: *H1: project complexity and external pressure from government, client and market force the firms to implement BIM in the AEC industry.*

3.2.2. Implementing BIM with current procurement methods

The aim of this component is to explore the key points in delivery methods that might prevent the proper adoption of BIM and which consequently diminish the utilisation of BIM benefits. On the basis of the literature review, the procurement methods have been divided to two categories. First category is the traditional procurement methods, such as DBB, D&B and CM, which have been used for many decades and are still being used. Second category is innovative procurement methods, such as IPD and PA, which have been developed to solve the problems found in the traditional procurement methods.

It has been gathered from the literature review that the traditional project delivery methods have some drawbacks that hinder the AEC industry to reap benefits from BIM; the common weaknesses are low level of integration among participants, lack of coordination and sharing information and the risks and uncertainties of which are not quantifiable at the outset.

Adopting BIM is successful with the innovative procurement methods, as it promotes the cooperation among participants and is able to share the risk and rewards of the project among the participants. Through the interviewees and case studies, this study will investigate the success of innovative procurement methods to utilise the maximum benefits of BIM adoption, and the ability of the UAE construction market to implement these innovative procurement methods.

The research will check the validity of second hypothesis: *H2: innovative procurement methods more convenient with BIM implementation rather than current procurement method.*

3.2.3. Reforming the Procurement Framework

The literature review in this study provided the evidence that to ensure adoption of BIM appropriately, changes are required in the procurement framework. Wherein, implementation of BIM requires drastic change in organisational culture with an increase in the level of integration among stakeholders and improvement in the teamwork culture. Subsequently, the organisational culture towards the project stakeholders should be transformed from adversarial to cooperation, and eliminate the blame culture in order to improve communication among participants.

Another required change is determining the roles and responsibilities of new participants that are engaged in BIM adoption process, for example, BIM manager and BIM consultant. Involving new participants will redefine the roles and responsibilities of all the participants, which necessitates improvement in the current procurement methods to determine the role of the participants and control the relationship between them.

Definitely, the new relationships, roles and responsibilities must occur within a legal framework to avoid disputes and save rights. Consequently, the contractual agreements have been updated by adding new clauses to determine responsibilities, intellectual property rights, defects liability and interoperability issues. Moreover, with its implementation, BIM introduces the new risks that should be settled legally at the onset of the project, and its adoption requires even distribution of risks and awards among stakeholders.

It will be investigated further in the interviews and case studies that to what extent reformation of the aforementioned elements have ensured proper BIM adoption that has allowed the stakeholders to avail the maximum from BIM benefits.

The research will check the validity of third hypothesis: *H3: making changes in the framework of current procurement methods will facilitate the implementation of BIM.*

3.2.4. Realising the BIM Benefits

On the basis of the previous overview of the study core, this refers to the target of this study. The aim is to assist the organisation and the entire AEC industry to avail benefits offered by BIM. It has been concluded that the current procurement methods in their current state prevent the utilisation of BIM. However, the procurement methods are susceptible to evolve in order to perceive the benefits of BIM, and the evolvement necessitates reshaping of the elements that have been discussed previously in this study.

It has already been discussed in the literature review what are the anticipated benefits of using BIM for each stakeholder in order to explore the importance of the study, and encourage the organisation to accept the changes in the construction process.

This study investigates the practices to reform the procurement methods in order to achieve the aim of this study, and to what extent it is required to utilise the benefits of BIM.

The research will check the validity of fourth hypothesis: *H4: the innovative procurement methods and amending current procurement methods will assist firms to maximise the utilisation of BIM.*

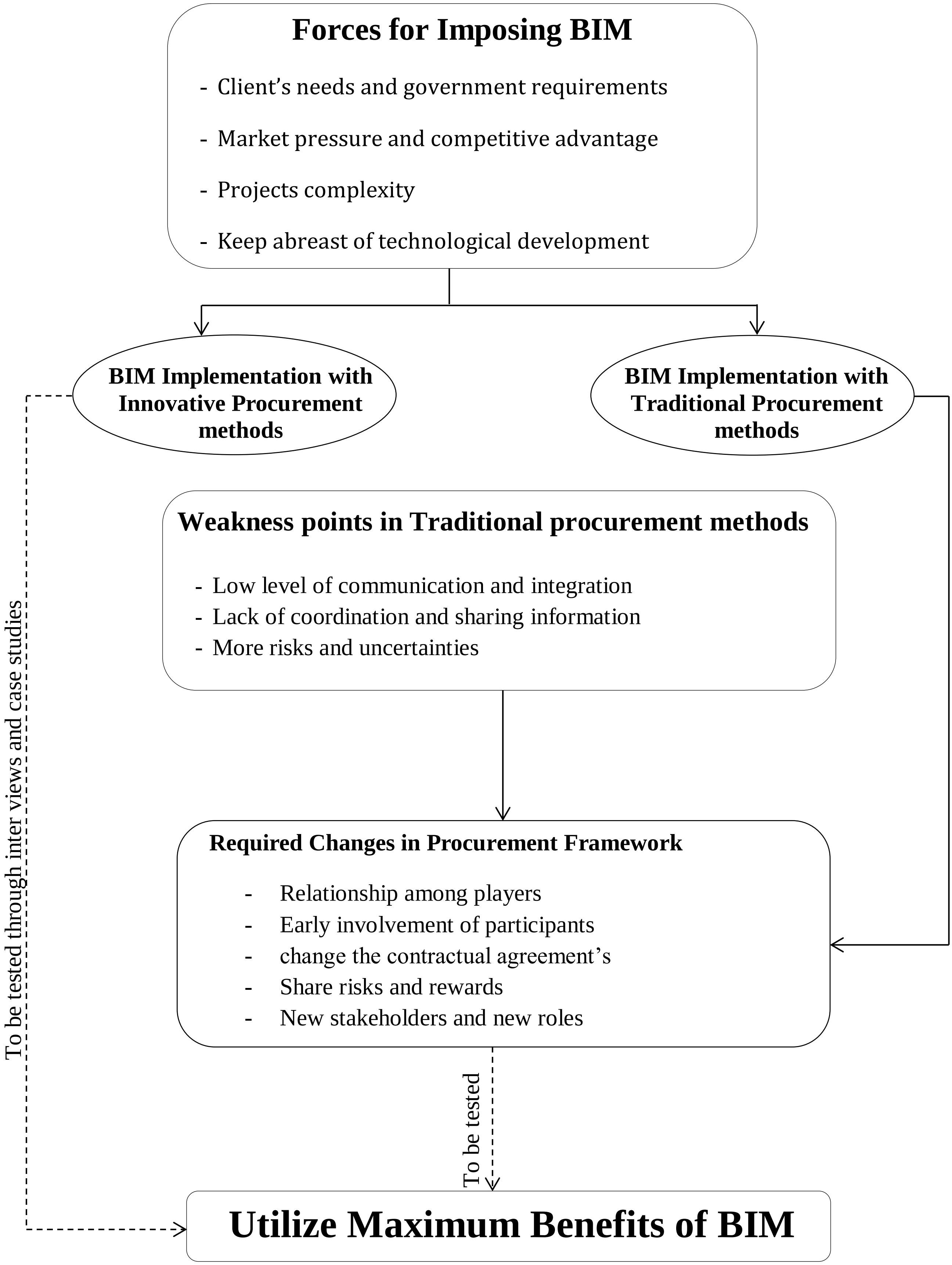

Figure 23: Theoretical framework of BIM.

CHAPTER FOUR: RESEARCH METHODOLOGY

4.1. Research Methodology

Before digging into practical issues, this chapter clarifies the adopted methodology to achieve the aim and objectives of this study and investigate the validity of the hypotheses extracted from the literature review and conceptual framework. As can be understood from the literature study, there is pressure on the firms to use BIM in the construction projects. Thus, its adoption is facing many obstacles, one of being that the current method of procurement is not designed for the adoption of BIM, so the adoption of BIM demands modification of the current procurement methods to ensure the adequacy of implementing BIM in the UAE market.

This profound understanding concludes that there are variables that have to be changed in the framework of current delivery methods so as to ensure a proper adoption of BIM which allows vendors to avail benefits of BIM. The discovered variables can be categorised into two groups: the first group is related to the behaviour like culture of the organisation and relationship among participants, the second group is related to legal issues for instance contractual agreements and new roles and responsibilities.

The research is contemplating to answer the questions with type 'what'. The research questions illustrated earlier are: what are the driving forces for imposing BIM? What are the implications of adopting BIM in the current procurement methods? What modification is required in the framework of current procurement methods? Therefore, this research can be considered as descriptive, interpretive and process-oriented.

The qualitative approach is based on the type of research intending to study the relationships, behaviours and processes. Therefore, such an approach is convenient to the research aim and objectives. The qualitative research demands collecting qualitative data from face-to-face interviews in order to analyse and test the extracted information from literature review, leading to the final conclusions and recommendations (Flick 2009).

Case study is a qualitative methodology that is widely used for exploratory, descriptive and explanatory research such as management information (Yin 2013). Therefore, the case study methodology has also been selected for this paper to cross-check analysis in order to investigate research objective and produce reliable findings.

Consequently, a set of semi-structured questions have been prepared for face-to-face interviews in order to create case studies and verify the data drawn from the literature review. The interviews have been conducted with six experts participate in managing BIM projects in the UAE market, leading to four case studies based on four projects in which BIM was adopted. Basically, interviews provide explanatory answers for the current practices that give a chance to improve the current procurement methods and provide adequate information about implementing BIM with the innovative procurement methods.

The aim of face-to-face interview is to involve personal contact with the respondents to receive explanatory answers to multiple questions based on fact, knowledge and opinion.

The selection of case studies has been done on several following criteria:

- BIM is used in the life cycle of project as a process and not as a drawing tool to investigate the modification in the project delivery method.
- Each case study is based on different project delivery methods to draw a comparative chart between them and deduce the most efficient procurement method that maximises the benefits of BIM.
- The projects have been conducted in the UAE construction market.

With BIM still being in its naive stage in the UAE market and most of the projects still using BIM as a drawing tool and not as a process, the selection of case studies was an arduous task. Lately, many projects in the UAE started with the BIM process but for various reasons they discontinued the process midway and stakeholders reverted to the old process, for instance, Cleveland Clinic Abu Dhabi – owing to the involvement of many suppliers of particular medical equipment in the construction stage, their demands kept fluctuating in the design stage and the contractor was not able to make amendments in the BIM model as fast as he could do in the 2D CAD; therefore to meet the deadline of the project delivery, BIM was discontinued.

Similarly, project of W Hotel & Residence in palm Dubai adopted the BIM process at its onset but at the construction stage the client on the advice of investment advisers demanded changes in the design, as participants were not very expert in BIM they preferred to discontinue the BIM process.

Therefore, there was keen interest in choosing those case studies that adopted BIM process from design stage till the completion of the project, and selection of interviewees was also carefully done to ensure that their roles and responsibilities are related to BIM and procurement method. The respondents were project managers, contract managers or equivalent with minimum 15 years of experience in BIM projects. Moreover, respondents were carefully hand-picked from various participants so as to investigate the perspective of diverse stakeholders.

The interview questions have been developed to explore the driving forces of imposing BIM, the ability to reform the current procurement methods, examine the ability of the UAE market to implement BIM with innovative procurement methods and test to what extent the transformation of procurement methods will improve the BIM implementation to utilise the BIM benefits.

4.2. Data Analyses, Findings and Discussion

The case studies have been adopted via a qualitative approach in order to build profound grasp of the practical perspective and investigate the efficient solutions to the problems encountered by the stakeholders in implementing BIM with the procurement methods. It has been argued, “case studies are used when the researcher intends to support his/her argument by in-depth analyses of a specific problem based on interview with a person, a group of persons of a particular project” Naoum (2013, p.46).

The case studies have been developed on the basis of face-to-face interviews with carefully selected experts in BIM projects, and the questionnaire of the interviews has been elicited from the extensive literature survey. The duration of interviews lasted between 60 and 90 minutes and the responses were recorded or carefully transcribed.

Each case study presents the implementation of BIM in a construction project with different project delivery method. First case study is a project in Abu Dhabi in which the DBB method has been adopted as a project delivery method; second case study is also a project in Abu Dhabi and in this case the BIM process has been implemented with IPD; as well third case study is a project in Abu Dhabi where DBB has been used to deliver the project with quite difference in the framework from first case study; and the fourth case study is a project in Ruwais that has been conducted through the D&B procurement method.

Two interviews have been conducted with two participants, each representing different stakeholders in order to build the first case study. Interviewee (A) is a BIM project manager representing one of the main contractors, wherein the project is a joint venture among three main contractors. His responsibilities are managing the accessibility to the BIM model, coordinating among the project stakeholders and managing the time and cost of his firm's part of the project.

The interviewee (A) is one of the pioneers in implementing the BIM process in the Middle East. His passion about BIM arose since 1988, and he believes that BIM will be the prevailing in the construction projects in the nearest future. Because of his expertise, Dubai and Abu Dhabi municipalities are employing him to evolve the implementation of BIM. He works in a firm that has an open-minded management and is passionate for innovation. Therefore, they entrusted him and with team support they successfully implemented BIM in the firm. This firm is considered as a one of the first organisations that has implemented BIM in the Middle East, and has developed their own registered software and system, which remains exclusive for the firm

Interviewee (B) is a commercial manager and represents the consultant firm of the same project. His experience is more than 17 years and is responsible for the contractual agreements between his firm and others stakeholders.

Case study 2 has been built through interview with Interviewee (C), who is a contract manager and a representative of the contractor; his experience is more than 23 years.

The third case study has been built around two interviews: first one is with interviewee (D) who represents the main contractor and is working in the project as a BIM project manager with experience of more than 24 years. He has a passion for BIM. Where, he started his trip with BIM from 1994, he has made many attempts in implementing BIM in many firms, not all of them successful though. Furthermore, he has written many articles and delivered many lectures and seminars in famous official events about the BIM and its management; last one was in the Big 5 – International Building and Construction Show in Dubai.

Next interview has been conducted with interviewee (E) who is representing as steel structure sub-contractor and has played a significant role in this project where steel structure was the main element in the project.

The fourth case study has been created from interviewee (F) who is a project manager with a very long experience in BIM projects and has participated in successful BIM implementation in several firms.

The key objectives of this dissertation were explained to the interviewees at the beginning and all the interviewees were very open, their answers were insightful and have since contributed significantly in building profound grasp about research topic. Table 06 illustrates the case studies and qualifications for the selected interviewees

	Case Study 1		**Case Study 2**	**Case Study 3**		**Case Study 4**
	Interviewee (A)	**Interviewee (B)**	**Interviewee (C)**	**Interviewee (D)**	**Interviewee (E)**	**Interviewee (F)**
Company type	Contractor	Architects/ Consultant	Contractor	Contractor	Sub-contractor	Contractor
Company Market	International	International	International	National and Middle East	International	International

Position	BIM Project Manager	Commercial manager	Contract Manager	BIM Project Manager	Project Manager	BIM Project Manager
Years of experience	30	17	23	24	15	24
Experience in the UAE	6	4	20	9	7	9
Interview duration	90 mins	60 mins	75 mins	90 mins	60 mins	90 mins

Table 06: Demographic for the case studies.

4.2.1. General View of BIM

The questions for interviews have been divided into two sections. First section is about the required reformation for the current procurement methods in the UAE in order to verify the validity of hypotheses derived from literature review. Second section aims to build a profound grasp of the changes that have occurred to the current procurement methods due to the implementation of BIM through case studies of projects that have adopted BIM in the UAE in order to build knowledge about the practical practices.

All the interviewees shared the view that the AEC industry suffers from a low level of development as compared to other industries, and that in coming times BIM will play a significant role in improving the performance of the AEC industry. Evidently, BIM creates an integrated environment for the AEC processes and activities in order to gain profits for all the participants and improves the level of collaboration and communication among participants, thereby saving time and cost. Furthermore, BIM develops the coordination in various disciplines of the same firm which leads to error-free design, accurate pricing and archive for the project activates.

Therefore, the interviewees confirmed that BIM will be mandating in all construction projects, and there are many factors driving forces to impose implementation of BIM. The strongest factor is the pressure from client and government. It is generally believed that the enforcement of the BIM in the contract is either due the local authority's requirement or due to the client's need; however, often firms have been known to adopt BIM without any pressure just to have a competitive edge over others in terms of technological development and finding a solution for the poor coordination resulting from the complexity of the project. The interviewees ranked the driving forces extracted from the literature review as shown in Table 07.

Driving Forces	A	B	C	D	E	F
Government and client pressure	1	1	1	1	2	3
Market pressure and competitive advantage	4	4	3	3	1	1
Projects complexity	2	3	2	2	3	2
Reply to the technological development	3	2	4	4	4	4

Table 07: The interviewees' ranking of driving forces.

The interviewees stated that there are some strong forces preventing the proper implementation of BIM in the current procurement methods in the UAE such as low level of communication and integration, lack of coordination and sharing information and involvement of stakeholders at a very late stage (i.e. after the design stage).

Furthermore, another major factor holding back the implementation of the BIM process is the adversarial relationship among the project stakeholders as bitter the relationship among project stakeholders, poorer the collaboration among them, and thus failure in the implementation of the BIM process. In order to improve the relationship among project stakeholders, an overall change in the mind-set of the organisation is required, a change that inculcates a feeling of taking another firm as a partner in successful project delivery and not as a competitor.

While on the one hand, some of the interviewees are of the opinion that overall framework of the current procurement methods in the UAE needs transformation in order to harness the benefits of the BIM process. On the other hand, other interviewees feel that for effective implementation of the BIM process, the projects need to be procured through the D&B method, which though is already used in many projects in the UAE but on lesser range than the DBB method. Where, the level of communication and collaboration in the D&B method is much higher than the DBB method, but the firms in the UAE are not yet ready to carry the responsibilities of designing and construction at the same time.

Nevertheless, for effective implementation of BIM, still many changes are required in the D&B and DBB methods such as amending the contractual agreements so as to control the liabilities, saving the intellectual property rights and distributing the risks equally

All the interviewees agreed that soon there will be a third party, such as BIM management firm or BIM consultancy, in order to look after the implementation of BIM in all stages of the project and control the accessibility to the BIM model. The interviewees ranked the required factors needing a change in the current procurement methods, as listed in Table 08.

Required changes	A	B	C	D	E	F
Relationships among player	1	1	3	4	2	1
Contractual agreements	2	2	1	2	5	2
Shared risks and rewards	4	4	2	5	3	4
Involve new stakeholders and new roles	5	5	5	1	4	5
Early involvement of stakeholders	3	3	4	3	1	3

Table 08: The interviewees' ranking of required changes in the current procurement methods.

All interviewees unanimously confirmed that by far IPD is the most convenient procurement methods for implementation of the BIM process. This is primarily because of the high level of integration, communication and collaboration in this method. In addition, this method involves all the stakeholders at an early stage of the project, thus improving the coordination and reducing the conflicts throughout the project life cycle. Not to mention that sharing of the risks and rewards among participants in this method promotes the cooperation wherein all the participants earn profits on the successful delivery of the project.

4.2.2. Case Study 1: Midfield Terminal Building (MTB)

One of the significant components in delivering Plan Abu Dhabi 2030 is developing Abu Dhabi's International Airport, and the key milestone in this developmental plan is Midfield Terminal Building (MTB) that will allow Abu Dhabi International Airport to handle additional 7 million passengers. Therefore, it is one of the most important and largest projects not only in Abu Dhabi but also in the UAE (ADAC 2011).

The project has been launched in 2011 with contract value around 3 Billion US dollars (11.04 billion AED) to build five buildings with built-up area around 7000 m². The site activities of the project started in 2012 and the duration of the project is 49 months, thus expected project completion date is July of 2017. The project has been procured through DBB contract type. The design and engineering of the building has been carried out with the utmost diligence. The project was awarded to a joint venture (JV) contract consisting of three international companies with very high reputation in airport projects.

This project has been chosen as a case study in this dissertation because of its implementation of the BIM process in the life cycle of the project, and also because the main stakeholders in this project have a vast experience in BIM projects.

Representatives of two participants of the project have been interviewed separately in order to develop this case study. Interviewee (A) is a BIM project manager representing one of the main contractors, and Interviewee (B) is a commercial manager representing the consultant. Both interviewees are from very well-known firms that are among the world's top 100 firms in the AEC industry.

4.2.2.1. Factors Responsible for Implementing BIM in (MTB):

This project commenced in 2011, at a time when implementation of the BIM process was not mandatory. However, BIM was implemented in MTB project because of the pressure from the client who is a governmental entity.

The client has imposed the implementation of BIM in the contract on the recommendation of the project management firm and consultant. Since its formal implementation in the project, countless meetings have been held between architects, engineers and client in order to increase the awareness about BIM benefits for the project.

In contrast, the client was not at all enthusiastic in the beginning of this project, owing to various reasons. First, client has to pay an extra fee to the consultant. Apparently, the consultant fee for BIM projects is far more than normal projects because the wages of engineers and draftsmen who are working in the BIM projects are more than those working in the normal projects. Furthermore, the firms using BIM in the UAE market in 2011 were very rare, thereby providing a monetary advantage of the consultant. Second, there is always a resistance to change. Owing to their familiarity with the old processes and lack of qualified staff, the client is susceptible of using new processes and technology – especially in a crucial project like MTB – that might lead to project failure.

The project management firm played an important role in convincing the client for the use of BIM in this project. It is a universal fact that the most important factor for the client in any project is the cost; therefore, the project management firm in this project proved to the client that the implementation of BIM will absolutely reduce the project cost due to the accurate BOQ extracted from the BIM model, and the project duration will also be reduced by improving the coordination and collaboration among stakeholders.

In the contractor’s point of view, the main factor that influenced the client to impose BIM in the contract is the cost reduction. Where, BIM was able to reduce the cost of the project by around 460 million US dollar (1.7 billion AED) which is around 14% of the project cost.

In addition, the complexity of the project was one of the main factors that assisted the consultant for convincing the client to adopt BIM in the project. As the design concept of the project was inspired from the desert dunes, it is a very sophisticated project and has an iconic shape, and old processes cannot be relied for accurate drawings for the execution. Furthermore, the project contains of tremendous disciplines and sub-contractors and it is very difficult to coordinate among them and detect the conflicts by the old methods.

Moreover, the BIM process plays an important role in O&M of such a critical project. Subsequently, delivering the final BIM model will improve O&M of the project and is very beneficial for the facility management.

Finally, the client imposed BIM in the contract and tendering documents, and the implementation of BIM was kept as one of the main criteria in selection of the contractor.

The selected contractor has realised the benefits of BIM long back, and has already adopted BIM since 2000 in response to technology development, and since then they have been implementing BIM in all projects, irrespective of the preference of the client or the government.

The contractor confirmed that imposition of BIM in the tender and contract documents forced the adoption of BIM in the MTB project. In addition, the complexity of the project obliged the participants to implement BIM. It was eventually realised that issuing shop-drawings of this project through 2D CAD would take a long time and would not do justice to such an iconic design. Furthermore, in a project where around 79 sub-contractors and around 40,000 site activities were to be executed, the coordination among the tremendous disciplines and sub-contractors with 2D CAD would be impossible.

Therefore, the contractor enforced sub-contractors to implement BIM and issue the shop-drawing from the BIM model so as to improve the coordination and deliver accurate BIM model for the facility management. Obviously, coercing sub-contractors to work with the BIM model was not an easy task, particularly the small firms where most of them did not have sufficient knowledge about the BIM process. However, the support that they have received from the main contractor made them realise the benefits of implementing BIM and its effects on the life cycle of the project. Furthermore, the main contractor's imposition in the contract to issue the shop-drawings through the BIM model prompted them to hire BIM specialists.

The large sub-contractors of this project, like the steel structure sub-contractor, have already experienced implementing BIM in their previous projects and have participated in many BIM projects that added to their resume and gave them preference to be awarded this project.

Undoubtedly, the collaboration from all stakeholders participated efficiently in improving the coordination and communication that has been duly reflected in the project performance.

4.2.2.2. Reforming the Procurement Method to Implement BIM

This project has been procured through the DBB method. However, the interviewees confirmed that the DBB is not an exemplary procurement method to be used in BIM projects, as it lacks coordination, communication and confidence among participants. Furthermore, many firms require a protocol between their information technology (IT) departments to work on one model.

Nevertheless, DBB was the chosen procurement methods due to the type of this project and the environment of the construction industry in the UAE that is mostly adopting the DBB method in the public sector projects. Furthermore, there are very few firms in the UAE that can design and construct a project of such a scale.

Thus, few modifications are required in the DBB method to make it suitable for the BIM adoption in order to ensure high level of communication, coordination and collaboration among stakeholders, thereby ensure successful project delivery. The modifications have been done as follows:

- **Tender Stage:**

The architect for this project was hired by the client after stiff competition between four pre-qualified firms, and the selection was based on the pre-qualifications on the airport and BIM projects.

Usually, the architect prepares tender documents including 2D CAD drawings; however, based on the contractual agreement of this project, the architect was asked to prepare the BIM model of the site and proposed buildings in an IFC format with LOD 200 along with the tender documentation. It was mentioned in the tender document that the consultant is not responsible for the extracted data from the model, which was a very weird clause though. Because the profit of the consultant is very low as compared to the contractor, consequently he has to carry the lowest risk.

The client then issues the model with tender documents to a list of selected pre-qualified firms with prior experience in constructing airports and handling BIM projects. It is duly mentioned in the tender documents that the contractor is responsible to submit a built model at the end of the project to the operator for O&M in order to impose the BIM process in all the stages. Therefore, the contractor forces the sub-contractor in turn to issue the shop- drawing through the BIM model.

In fact, as the awarded contractor was more experienced in the BIM projects than the consultant, the contractor was not satisfied with the quality of the BIM model which has been created by the architects, because the data could not be extracted out of it clearly and contractor simply did not want to take any responsibility about the data based on a model created by others. Therefore, the contractor created a new model in the tender stage before being awarded the project. It took the contractor around 6 months to accomplish this, which was indeed a very risky step as engaging architects, civil and MEP engineers for a long period with a project still not awarded is not intelligent.

The contractor illustrates that the cost of risk of working on the BIM model for 6 months is lower than the risk of relying on the data extracted from an improper model, because it might cause submitting a higher price than competitors or a price less than it deserves, thus anyways affecting the ultimate profit. Furthermore, if the contractor wins the bidding, which happened in this case, it saves him a long time in the construction stage.

- **Relationship:**

The relationship among participants in the DBB method is stratified and contentious, and has a lack of collaboration and confidence, which is not convenient with BIM implementation. That is demanded reformation to the relationship to be more collaborative and increases the level of confidence.

The discussion revealed that improvement in the relationship among participants in the beginning was not an easy task, and that required a change in the culture of the organisation. However, the participants have been convinced lately that improvement in the cooperation will reflect on the project performance, thereby leading to a successful project delivery.

Two factors have played a significant role in bringing about a change in this relationship. First, the participants gain experience in the BIM projects and they believe that the collaboration is the main factor to deliver any BIM project successfully. Second, the model is created by a contractor and the information rests exclusively with the contractor, so the stakeholders in the beginning called the contractor as a '"Black Box". Thus, it was worthwhile improving the collaboration among stakeholders to ensure smooth data exchange.

- **New responsibilities:**

The discussion also revealed that the role of stakeholders in DBB methods has not changed with the BIM implementation. While, new responsibilities have been added to some stakeholders, for instance the contractor is responsible for controlling and managing accessibility to the BIM model, it is not mandatory that the contractor has to execute this responsibility, as it might be transferred to another stakeholder in another project based on the agreement and the type of the project.

On the other hand, in addition to the usual responsibilities, the consultant has to check the possibility of using data transfer to check the compatibility of the model, ensure that the contractor is issuing drawing from the BIM model that has been created with LOD as per the contract, and the created model is convenient with the design requirements.

- **Contractual agreement:**

The interviewees stated that the contract of this project was issued according to FIDIC (1st Edition, 2000) that did not contain exclusive clauses for BIM. Therefore, some clauses were added by using ConsensusDOCS 301 in order to determine the liabilities, workflow of the information and intellectual property rights. Although the model has been created by the contractor, but as stated in the contract the final model will be owned by the client to be used in O&M, and will pay for that.

Moreover, LOD of the model at each stage and the required inputs from each stakeholder in order to deliver a successful model for the facility management were determined in the contract itself.

4.2.2.3. Challenges and Obstacles

Implementation of BIM in MTB projects faced many challenges as both the client and the facility management has a lack of knowledge about BIM, thereby failing to realise the requirements of the BIM process. Furthermore, government authorities are not yet familiar with the BIM process, to issue the work permissions like 'No Objection Certificate', the concerned firms have to transfer the issued drawings to 2D CAD format which is a huge waste of time. Even though the BIM implementation is a mandatory requirement from government, its requirements are not yet clear and the reviewers are not well qualified.

On the other side, many stakeholders, particularly sub-contractors, are not yet ready to implement the BIM process due to lack of awareness and lack of BIM operators, because of which there are delays in submitting the shop-drawings which cast their shadow on the project schedule. Nevertheless, they have been pushed and supported by main contractors to implement BIM. In some cases, the main contractor accepts 2D CAD shop- drawings, to avoid delays, on condition that the model to be updated after that with the approved shop-drawings.

Moreover there is no standard contract for the BIM projects to determine the liabilities and ensure transfer of the data and collaboration among project participants. The interviewees stated that the risks and uncertainties of the DBB contract need modifications to be distributed equitably where still the contractor is carrying the maximum risk.

4.2.3. Case Study 2: Automated Passenger Mobility (APM)

This project is a part of the plan to increase the current and future capacity of the anticipated growth of passengers and aircraft movements through Abu Dhabi International Airport. APM project aims to provide the highest levels of service and develop the current infrastructure of the airport. As a result of the monitoring and studying the constant growth of passengers, it is forecasted that a 30% increase in passengers will occur by 2017 (Al Mansouri 2014).

The APM project is designed to transport passengers between MTB and its future satellite terminals. Where, Abu Dhabi Airports is planning to build new terminals after opening of MTB. Hence, they have foreseen the practicality of building the APM simultaneously with the construction of the MTB, rather than interrupting its operations after it opens in 2017. The project has been launched with a total cost of around 450 million US dollar (around 1.656 billion AED) and the site activities started practically in 2013 to be accomplished by 2017.

The project is considered to be the first attempt of the UAE in using IPD as a procurement method. Moreover, involving the participants from the design stage was a smooth process because of using expertise of some of the participants already involved in the MTB project.

The implementation of BIM with IPD in this project makes it ideal to be selected as a case study in order to investigate the compatibility of BIM with the innovative procurement method.

This case study has been developed by conducting an interview with Interviewee (C), who is a BIM manager representing the main contractor which is very well-known firm, has a vast experience in BIM projects and is one of the world's top 100 firms in the AEC industry.

4.2.3.1. Factors Responsible for the Implementation of BIM in APM

The client has realised the benefits of BIM and its impacts on the project performance and the awareness about BIM has been increased in MTB project. Hence, the client imposed the implementation of BIM in the APM project in order to achieve a high level of productivity and save cost and time.

Undoubtedly, the participants working together in the current project contributed significantly to facilitate the adoption of BIM and influence the client's decision to impose BIM in the contract. Furthermore, it improved the collaboration among the participants and their experience in the BIM projects.

Furthermore, the project complexity played a crucial role in forcing the stakeholders to adopt BIM in this project, as there were numerous disciplines and participants in this project, in addition to the local authorities' requirements. Therefore, a high level of coordination is required among the disciplines so as to meet the requirements of the local authorities.

4.2.3.2. The Adopted Procurement Method

The project participants are already working together in the MTB project which instigates the client to use them in the APM project and adopting IPD as a project delivery method. Actually, the contractor for this project is a very experienced firm in BIM project, so he was the adviser to adopt IPD for this project and involving key participants, such as designers, contractors, suppliers, sub-contractors and manufacturers, right from the design stage, thereby reducing the possible amount of time needed for project accomplishment.

All participants were appointed by the client and all have been invited to one table and have been asked to deliver the project at the exact time, thus demanding an increased level of collaboration and integration. The interviewee stated that the efficient method was to make stakeholders working as partners in the project by sharing the rewards, and this can be achieved through IPD.

The viewpoint is that in traditional procurement methods, each participant earns from the mistakes of others that ultimately reflects on the performance of the project. For instance, if the contractor asks for extension of time, the consultant will earn where his staff will stay for longer time. On the contrary, in IPD, the rewards are shared among stakeholders; if the project is delivered earlier with cost saving, the saved amount will be returned to stakeholders equivalently.

The interviewee also stated that by far IPD is the most effective procurement method for implementing BIM due to the early involvement of key stakeholders that reduces the duration of creating a BIM model and hence reduces the overall cost to client. Where, each stakeholder is adding his inputs from the beginning and in one model which improves the level of coordination and assist in early detection of the conflicts.

In traditional procurement methods, usually a client is paying an extra fee to consultant for creating a BIM model and usually the model is created by consultant is used for clarification in the tender stage only. After this, the selected contractor creates another model from scratch for the same project and client pays for that again due to lack of information in the BIM model that is created by consultant. On the contrary, in an IPD method, a model is created only once and the client is paying for one model only.

Moreover, implementing BIM with IPD ensures high level of collaboration and executes project design model with a higher completion rate before construction phase which is highly beneficial to a project's budget and schedule. Therefore, adopting BIM with IPD in the APM project plays a significant role in reforming the relationships among participants, where it has moved towards the collaborative relationship rather than the adversarial

Sharing the rewards enhanced project members to collaborate, communicate and be more innovative, which increased the efficiency of the construction phase and possibly decreased the amount of time needed for construction. Undoubtedly, sharing the rewards accompanied with sharing risks where stakeholders are not working in the hierarchical structure, like in traditional procurement method, but they are working in same line in order to deliver the project successfully. However, in the AMP project, contractor has carried far more risks than others because contractor was responsible for the quality and productivity of particular sub-contractor as well due to lack of capability of the client to inspect their work.

4.2.3.3. Challenges and Obstacles

IPD is an innovative method and thus there were few challenges in adopting IPD in this project; the most significant barrier is the unfamiliarity of participants with such a type of procurement methods in terms of collaboration and communication. This is unlike the general practice in the construction industry where professionals are accustomed to strict lines of communication within the hierarchical structure of traditional delivery methods. Hence, to convince stakeholders to work in the same line as partners was not a smooth task, especially when responsibilities will also be changed. However, the client has forced project team to adopt IPD with BIM in order to achieve high level of performance.

Another major challenge is the contractual agreements that are not consistent with the adoption of BIM and IPD together. In the current procurement methods, owner has separate contract with designer and contractor; whereas, IPD demands that the project stakeholders develop common procedures and performance requirements, wherein the client needs to ensure that the contract language is consistent among all agreements and the general conditions.

Moreover, the clauses of sharing the rewards and risks were not clear in the agreements and there is no clear guarantee for sharing the rewards in case of the project has been delivered earlier. Nevertheless, stakeholders agreed to participate in such a type of project because of the owner is one of government authorities.

4.2.4. Case Study 3: Louvre Abu Dhabi Museum (LADM)

Part of Abu Dhabi 2030 plan is to set Saadiyat Island as a home to iconic cultural institutions. Therefore, government has decided to construct unprecedented museums on the island, starting with Louvre Abu Dhabi, followed by Zayed National Museum and Guggenheim Abu Dhabi.

The notion of Louvre Abu Dhabi was born out of an intergovernmental agreement in 2007 between the emirate of Abu Dhabi and France. The museum contains a complex network of pavilions, plazas, alleyways and canals, evoking the image of a city floating over the sea. The huge geometric dome, which is 180 m in diameter, will hover over the complex.

The contractor for this was awarded in the first quarter of 2013 to build the museum in 64,000 square meters with built-up area of 24,000 square meters. It was aimed to be accomplished in the fourth quarter of 2015 with contract value of 653 million US dollars (2.4 billion AED). The design and engineering of the building has been carried out with utmost precision. The project was awarded to a joint venture (JV) contract consisting of two firms with very high reputation in mega projects.

The BIM process has been adopted in the project life cycle, and the project has been procured through the DBB method, so it has been selected as a case study in order to investigate the change occurred in the procurement method to ensure the proper implementation of BIM.

In order to construct a profound grasp about the required changes required in the procurement method to implement BIM properly, this case study has been constructed through two separate interviews conducted with a project manager representing one of the main contractor Interviewee (D) and an operation manager representing the steel structure sub-contractor interviewee Interviewee (E).

Conducting an interview with a representative of the steel structure sub-contractor was very beneficial for this study due to his firm was one of the main stakeholders in this project and it was involved in the design stage under certain conditions that will be illustrated later in this study.

4.2.4.1. Factors Responsible for the Implementation of BIM in LADM

It has been gathered from the interviews that the pressure from the client was the main force behind the adoption of the BIM process in the LADM project, as the client had sufficient knowledge about the BIM process through extensive experience in prior projects. Besides, the contractor is also one of the pioneers in implementing BIM in the UAE and the Middle East, as they had been adopting BIM in all their projects since 2009 even if it is not obliged by the client.

The top management of the contractor has realised the perceived benefits of BIM in terms of high level of coordination, accurate pricing and market advantage to win more tenders with less cost and more profits.

On the contrary, the steel structure sub-contractor adopts BIM only if there is a compulsion in the contract and for this they usually employ organisation that is specialist in BIM. However, they have a plan to create an in-house BIM department in the next two years due to an increasing pressure of the market.

4.2.4.2. Reforming the Procurement Methods to Implement BIM

This project is carried out through the most popular procurement method in the UAE, which is the DBB, with BIM implementation in all the stages. However, the interviewees confirmed that DBB is not the proper procurement method for implementing BIM, as one of its most critical defects is that the stakeholders are not involved from the design stage.

In the LADM project, this shortcoming was overcome to some extent. Where, the concept design of the LADM contains a huge geometric steel dome with 180 m diameter. Therefore, it was necessary to involve the steel structure sub-contractor from the design stage in order to create a BIM model with high level of coordination and free of errors before sending it to the bidders. Figure 24 shows the geometric dome.

Figure 24: The steel geometric dome in LADM.

In light of this, the DBB procurement method has been modified to ensure proper implementation of BIM as follows:

- **Early Involvement of Stakeholders**

The interviewees stated that the implementation of BIM requires involvement of main stakeholders in the design stage so that they can add their inputs in the beginning of the creation. However, the traditional procurement method DBB does not allow it, thereby frequently creating a BIM model for a single project twice, once in the tender stage and once in the construction stage, which anyways is a huge wastage of time and multiplication of the cost.

Therefore, it is mandatory to involve the main stakeholders in the earlier stages. In this project, the steel structure sub-contractor was appointed in the design stage so as to create a proper BIM model that can be developed in the next stages as well, and it has been well agreed upon in the contract too that the sub-contractor will work under the main contractor in the construction stage.

The contractor’s point of view that implementing BIM with DBB requires changes in the process so as to allow most of the stakeholders to be involved in the design stage, especially sub-contractors. Evidently, their input changes the design of the project, for example, installation of an AC machine demands special conditions in terms of size, location and the surrounding environment; consequently, if stakeholders are hired in the design stage itself, many efforts and rework will be saved and higher level of coordination will be achieved.

The protocol of hiring the steel structure sub-contractor in this project can be applied on all sub-contractors. This can be achieved by hiring them and obliging the main contractor to work with them through certain percentage of the agreement between sub-contractors and the client.

Even the sub-contractors pointed out that their involvement in the design stage was very beneficial for the whole design, and it allowed them to detect the conflicts between their design and the different disciplines earlier before commencement of the construction stage.

- **Tender Stage:**

The representatives of the contractor confirmed that they received a very developed BIM model, much advanced than 2D drawings and prevalent tender documents, in tender stage. The model was in an IFC format with LOD 200 as per the agreement between the consultant and the client.

Nevertheless, the contractor stated that to prepare their proposed bid they relied only on 2D drawings and used the BIM model for clarification. Because the implementation of BIM in the UAE is still in its preliminary stages and there is still a lack of trust among stakeholders, so they cannot depend on the data extracted from a model created by another organisation. Furthermore, there is no official registration for BIM models such as a stamp on 2D drawings.

However, the developed model was beneficial in pricing stage and has been evolved since winning the project in order to be used in the construction stage and delivered at the end of the project for the operation and maintenance. Undoubtedly, the early involvement of several sub-contractors participated significantly in developing BIM model, which assisted in time saving and detecting the clashes earlier.

- **Contractual Agreement:**

The agreement of this project was issued on the basis of the FIDIC (1st Edition, 2000), and particular clauses for BIM were added in order to determine the liabilities, relationships, workflow of the information and LOD of the model in each stage till the delivery of the final model to the operator.

The early involvement of some sub-contractors imposed particular clauses in the contract. Where, those sub-contractors are hired by the client and they will work under main contractor umbrella, and 10 % of the agreement between client and sub-contractor will be paid for the main contractor to inspect the work of sub-contractor.

Regarding the intellectual property rights, it has been stated in the contract that the final model will be owned by the client in order to be used in O&M. However, the interviewees argued that it is very unimportant clause and the concerned persons about BIM have a lot of discussions about this point, whilst it is settled that the client owns the final model, because he is paying for all the participants, and such a point might restrict sharing the information between participants. Moreover, the libraries of BIM objects are available now online with very low price and some suppliers are creating their products in IFC format and putting it on their websites for free.

- **Relationship:**

The interviewees argued that the relationship among participants in the DBB is not convenient with BIM adoption owing to lack of confidence, communication and cooperation.

However, in the LADM project, the main stakeholders have adequate awareness about the BIM process and they have ample amount of prior experience, hence they know that it requires high level of collaboration and trust and sharing of the information to deliver the project successfully. Therefore, in this project the relationship among stakeholders had sufficient level of collaboration, though not optimum.

Moreover, involving sub-contractor in the design stage improved the cooperation among stakeholders and assisted in sharing the information. As the sub-contractor was hired earlier, the sharing of the information with the consultant improved the design and assisted in avoiding the clashes.

4.2.4.3. Challenges and Obstacles

The contractor highlighted that owing to lack of awareness about BIM in some stakeholders particularly sub-contractors, the LADM project faced many challenges, which resulted in delay of submitting shop-drawings and hence delay in the execution of the project. Because most of the sub-contractors, particularly local sub-contractors, were not familiar with the BIM process and had lukewarm response towards BIM adoption. Therefore, the contractor accepted 2D CAD shop-drawings so as to remain within the timeline of the project, thereby hindering the full utilisation of BIM.

Moreover, there are no obvious clauses in the contract to oblige all stakeholders to work through BIM process. The interviewees claimed that the current agreement demands amendment to make it compatible with the BIM adoption in terms of determining the responsibilities, LOD of each stage and the required inputs from each stake holders, and most of the current contracts are copied from prior projects due to lack of awareness from client about the essential requirements from each stakeholders in each stage.

The contractor expects that in the near future client will hire a third party, like BIM specialist or BIM management, to control the BIM model in all processes and ensure that each stakeholder is adding the required data. Furthermore, it would control the accessibility to the BIM model and manage the workflow of the information.

In addition, the contractor confirmed that the critical problem faced in this project and all the other projects that are implementing BIM with DBB is that all the stakeholders are not hired from the design stage, so a design which otherwise should be final goes through various changes over a span of time after the stakeholders come into the scene. Consequently, the tasks are repeated and there is wastage of time that is ultimately reflected on the cost. Therefore, it is necessary to transform the DBB procurement method to allow an early involvement of the stakeholders in order to elaborate the transparency and collaboration.

The interviewees rightly stated that though the main aim of implementing BIM is to save the cost, but by implementing BIM with DBB, the model is recreated at every stage at the cost of client's money and stakeholders' time, thereby costing all the stakeholders far more than executing a project without BIM.

In addition, the relationship among stakeholders needs to be more collaborative than adversarial through sharing the rewards among stakeholders, thus promoting the cooperation and reducing the risks and uncertainties.

The representative of the contractor stated that the stakeholders can work in a cooperative environment and can save a huge amount of fund; this saved fund can then be shared at the end of the project in order to improve the collaborative environment.

4.2.5. Case Study 4: Borouge III Ethylene Plant (EU3)

EU3 is the latest expansion of the petrochemical plant in Ruwais, about 250 km west of Abu Dhabi city. The client aimed to build one of the world's largest ethane crackers with total cost of 1.075 billion US dollar (4 billion AED) and using 5,100 ton/day of Ethane feedstock and producing 1.5 MM ton/year of Ethylene, propylene and hydrogen.

The contractor was nominated in the last quarter of 2010 to design and build the project, which includes an ethane cracker, two polypropylene units, and a low density polyethylene unit, with duration of 29 months and to be accomplished by mid of 2013.

The client selected the contractor through a close tender between three firms that had well reputation in oil and gas projects. The project was delivered through most popular procurement method in gas and oil projects which is D&B.

This case study proves very beneficial for the research because it helped in investigating the required modifications for the D&B procurement method to ensure BIM implementation properly and to utilise the benefits of BIM.

A face-to-face interview was conducted with one of the contractor's representative in order to develop the case study. The Interviewee (F) is a BIM project manager and is one of the pioneers in adopting BIM in the Middle East, as he has been adopting BIM since 1999 and has created a BIM department in the firm which is one of the world's top 100 firms in the AEC industry.

4.2.5.1. Factors Responsible for the Implementation of BIM in (EU3)

The project commenced in 2010 at a time when BIM implementation was not mandatory. In addition, most of the clients were not aware of enforcing BIM in the contract. However, the top management of the main contractor realised the benefits of BIM long back, such as reducing the duration and cost of a project so that they could propose the best bid, and improving the coordination among the internal departments. Thus, they have been using BIM since 2000 in every project in order to stand out in the market.

Moreover, the interviewee confirmed that as the complexity of the project is increasing day by day in oil and gas projects particularly, and tremendous disciplines and sub-contractors are getting involved in the project, BIM was the sole efficient solution to coordinate and integrate among these disciplines. Based on all these facts, the top management imposed the BIM process in the EU3 project.

4.2.5.2. Adopted Procurement Method

This project had been conducted through the D&B method (lump sum turnkey basis). It is by far the most popular procurement method in oil and gas projects as the nature of such projects demand high level of coordination and integration in order to achieve the required level of health and safety. Furthermore, the clients usually do not have sufficient experience in the construction project, so it is preferable to hire a single firm that can manage all the processes of the project.

Therefore, the responsibilities of design and construction of this project transferred to the main contractor. Consequently, it is required from the main contractor to collect the required information in order to combine it in the demanded model.

Usually, the contractor in the D&B procurement method hires a consultant for the design phase and the local authorities' permissions. While, the contractor of the EU3 project had already executed numerous projects based on the D&B method, so the top management decided that this project be designed in-house by creating a design department in order to improve the level of coordination and collaboration. Hence, the EU3 project had been designed and constructed by a single firm.

The representative of the contractor argued that the D&B method is the best method for BIM implementation du to it allows the main stakeholders to be involved from the design phase, hence achieving a high level of coordination and early detection of conflicts. The EU3 project is of a substantial size and complexity due to the nature of the facility, and there are multiple disciplines contributing to deliver the project. Subsequently, an early involvement of main stakeholders was required so as to combine their information in one model which can be carried from design stage to construction stage and then to the facility management, also ensuring the high level of interoperability within the project in the meanwhile.

Moreover, an early involvement in D&B contributed in saving time and cost, as the BIM model created once and being developed later in each stage. This is in stark contrast with the DBB method in which the model is created from scratch at every stage and changes are incorporated per the requirements of the participants; this ultimately reflects on the cost and time of the project.

Certainly, not all stakeholders, particularly sub-contractors, have the same experience in adopting the BIM process, and the contractual agreements too do not include any standards for the BIM model in a predefined format. Thus, in order to achieve the suitable level of the interoperability, the main contractor receives the information and combines it in one model that is created by their BIM department.

On the other hand, the interviewee revealed that implementing BIM with D&B in this project contributed in achieving the high level of collaboration among the participants and efficient flow of information. In D&B, the budget is fixed right from the onset of a project, thus any delays caused eat away a piece of profit from the participants' pockets; thus, all stakeholders aim to accomplish the project on time. In addition, D&B promotes the integration among participants due to the high level of trust, thereby transferring the data smoothly.

Furthermore, designing the project in-house allowed the contractor to have a control over all the design processes, which assisted in promoting the coordination, communication and the flow of information. Because the collaboration among the internal departments is easier than the collaboration between diverse firms, the contractor can deliver more accurate and reliable design with less risk.

The interviewee confirmed that the main change undertaken in the D&B method to ensure proper implementation of BIM in the EU3 project was that the main contractor carried a new set of responsibilities, such as controlling the workflow of data among participants in terms of the required information of each player, deciding how the information will be added to the model and when is the exact time to be added. Where there are several clusters of information based on each other, all such tasks are taken care of by an information manager.

On the other hand, according to the representative of the contractor, there have not been substantial changes in the contractual agreements due to the lack of awareness of client about BIM, and that too at a time when there were no clear instructions from the local authorities on the BIM model. Even the clients were not aware about the clause of 'ownership of the BIM model' had to be imposed in the contract.

4.2.5.3. Challenges and Obstacles

It has been gathered from the discussion that the lack of awareness from the client about BIM added more pressure on the BIM department of the contractor, because the client is required to provide the Employer Information Requirements (EIR) to determine the required specifications of the demanded model which will be delivered to the facility management. However, the interviewee believed that all the facility management and operators in the UAE do not have sufficient awareness about the BIM process, and they did not upgrade their software to make it compatible with BIM implementation.

Indeed, the most important obstacle in this project was the lack of knowledge of sub-contractors pertaining the BIM process, so they were not able to play their part in the BIM model. Furthermore, the contract was free of any clauses to oblige sub-contractors to implement BIM, the contractor was forced to accept the shop drawings from sub-contractors in 2D CAD format and thereafter converting it to the BIM model; thus adding more tasks and responsibilities on the main contractor's shoulders.

The interviewee believed that the main contractor should have imposed the implementation of BIM with predefined specifications in the contract with sub-contractors in order to ensure the interoperability, and thus forcing the sub-contractors to implement BIM, which have been addressed in the later projects.

4.2.6. Cross Case Analysis

This section aims to facilitate the comparison of commonalities and variances of aforementioned case studies in order to produce reliable findings that can be used in broader purposes (Khan & Van Wynsberghe 2008).

Referring to the analysis of earlier case studies, it is significant that there are forces imposing the implementation of BIM, and the strength of these forces is varying from project to another. However, it is obvious that the pressures from clients and government requirement are the main common forces in the first three case studies, where it stems from perception of the BIM benefits from client.

Furthermore, the level of complexity of the project always plays a crucial role in forcing the stakeholders to adopt BIM, due to the ability of BIM to present a high level of coordination among numerous stakeholders and various activities; it is usually a chosen method to handle complex projects. Hence, the project complexity was the main factor in the fourth case study in the absence of pressure from the client and the government.

Nevertheless, most of firms participating in the abovementioned projects had already adopted BIM much before it was mandated by the UAE government. They did this to improve their competitive advantage and to keep abreast of the technological development.

Table 09 demonstrates and compares the priorities of the driving forces that have been extracted from literature review on imposing BIM in the case studies.

Driving Forces	Case Study 1	Case Study 2	Case Study 3	Case Study 4
Government and client pressure	1	1	1	2
Projects complexity	2	2	2	1
Market pressure and competitive advantage	4	4	3	3
Reply to the technological development	3	3	4	4

Table 09: The priorities of driving forces.

It is an obvious observed from Table 06 that imposing BIM in the contract and requirement of the local authority are the effective forces to implement BIM in the construction projects in the UAE. In addition, the scale of a project in terms of number of stakeholders and activities involved plays a vital role in forcing the adoption of BIM in the project. Moreover, keeping pace with the technological development and obtaining a competitive advantage are internal motivations for the firms to adopt BIM.

Notwithstanding these facts, imposing BIM adoption does not necessarily mean appropriate implementation of BIM and utilisation of its benefits by the participants. As proved in the literature review and the case studies, the implementation of BIM requires changes in the framework of the procurement methods that are currently used in the UAE AEC industry.

The following radar Figure 25 illustrates the changes that have been occurred in the framework of the procurement methods which have been used in each case study, and demonstrates the commonalities and differences between the case studies.

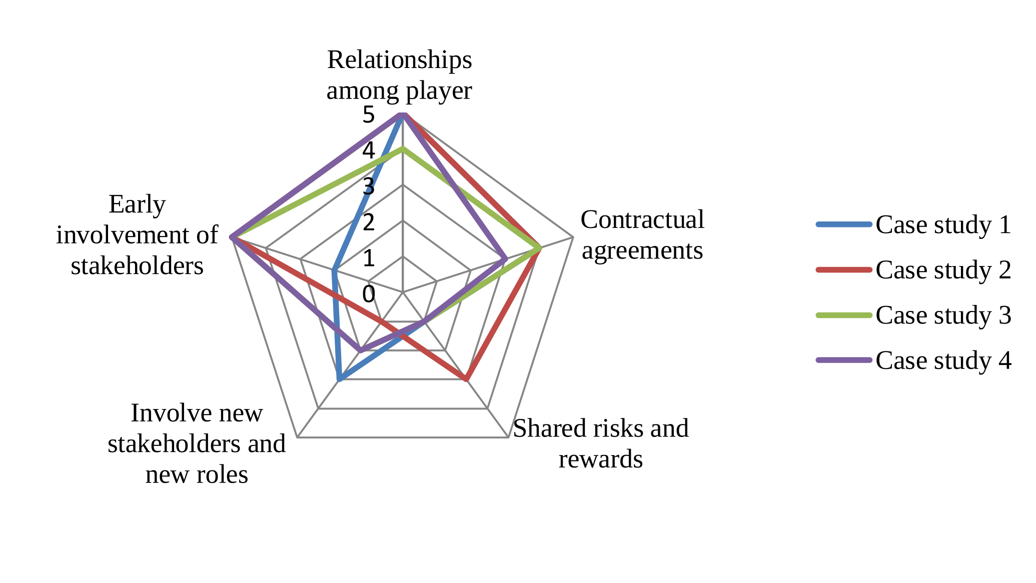

Figure 25: Comparison between the required changes in the framework of procurement methods in each case study.

The radar shape in Figure 25 demonstrates that the significant common change in case studies 2, 3 and 4 was the early involvement of main stakeholders. Meanwhile, the interviewees agreed that the fundamental change that should occur in the framework of procurement methods is allowing the participants to be engaged in the project from the design stage in order to create a proper BIM model at the onset that can be developed later in each stage instead of reconstructing it time and again in each stage, thereby reducing the cost and duration of the project considerably.

In addition, involving the participants from design stage assists in detecting the conflicts earlier and reduces the cost of the project; whereby solving the conflicts in the design stage is cheaper than solving it in the construction stage.

However, in case study 1, the main participants were not involved in the design stage, so the initial BIM model was not beneficial in the later stages, and the contractor spent more time creating a new BIM model in the tender stage to produce accurate pricing and to be developed later in the construction stage.

Another significantly common change among the four case studies was the change in the contractual agreements. As observed from the radar shape, there is a priority for reforming the agreement between the participants to ensure a successful BIM adoption. The agreements were changed in all the four projects to identify the responsibilities of each player and required LOD in each stage, thereby demonstrating the ownership of the BIM model. However, the priority of changing the contractual agreement in the fourth case study is less than the other project because this project was carried out in 2010, and at that time there was a lack of awareness about the implementation of BIM.

Nevertheless, the interviewees agreed that there are still drawbacks in the current contracts and they need a development to clearly underline the required input of each participant in each stage, determine the required specifications of the demanded model which will be delivered at the end of the project. Moreover, control the workflow of the information and determine the responsibilities and roles of each player. Furthermore, the implementation of BIM should be imposed in the agreement to oblige the participants to adopt BIM, especially sub-contractors owing to there are a lack of knowledge about BIM adoption, and are unable to submit shop-drawings through the BIM model.

In addition, the contractual agreement should allow the participants to share the risks and rewards in order to improve the relationship among the stakeholders. As known already, the relationship among participants plays an important role in ensuring the success of adopting BIM process that is clearly manifested in the radar shape in figure 25. This relationship was seen as a high priority in the four case studies but with slight variation.

Apparently, in the first case study, the relationship among participants was the highest priority due to the scale of the project and due to the fact that the contractor was a very experienced firm in BIM projects, in it the contractor created the BIM model from the scratch, thereby owning most of the information about the project. Therefore, it was mandatory to create a collaborative environment in this project in order to ensure proper sharing of information.

Similarly, in the second and fourth case studies, the priority of the relationship was at the highest level because the projects were procured through IPD and D&B, respectively, and the framework of these procurement methods depends largely on the collaborative relationship among the stakeholders. Whereas, in the third case study, the priority of relationship among participants was less than other case studies, but it is still at its highest level due to early involvement of main stakeholders anticipated on improving the relationship among players.

It has been confirmed by the interviewees that in order to achieve successful adoption of BIM, improvement in the collaborative relationship among participants and promotion of the free flow of information is required.

Evidently, sharing the risks and rewards is a recommended change in the procurement framework in order to promote the relationship among participants. It has not been applied in the first, third and fourth case study due to lack of awareness about BIM from the participants and the contractual agreement being not developed properly. However, in the second case study, sharing of risks and rewards has been applied, though not defined clearly in the contract.

Likewise, involvement of new participants and new roles is at low level in the all case studies due to the adoption of BIM in the UAE still being in its initial stages and a general lack of awareness about BIM from clients, so they did not hair third party to manage and control BIM process. However, a slight change has been happened lately in the roles of participants in order to manage the BIM process, thereby improving the

BIM model slightly and controlling the accessibility to the BIM model and flow of information.

4.2.6.1. Challenges and Obstacles

There were many common challenges that have been faced the four case studies in terms of improving the framework of the procurement method. The most significant challenge is the lack of awareness about BIM from main client, that is obviously observed in the contractual agreements, where the required specifications and LOD of the BIM model in each stage were unclear, and the responsibilities and roles of stakeholders were ambiguous.

Another challenge is the lack of awareness about BIM adoption in many stakeholders particularly sub-contractors which reflected on the quality of the final BIM model, thereby anticipating an increasing in the period of the project.

Furthermore, because they were not involved from the design stage, so a substantial piece of information was missing, causing various changes in the design in the construction stage and consequently reflecting on the cost and time of the project.

Chapter Five: Conclusions and Recommendations

5.1. Conclusions

It is obviously that the construction industry is playing a vital role in developing the economies of the nations, though suffering from low productivity phase. Therefore, there is a global trend towards mandating the implementation of BIM in order to improve the productivity of the AEC industry.

The UAE is one of the nations that has realised the benefits of the BIM process in evolving the AEC industry, such as promoting the communication and collaboration among the project stakeholders and improving the level of coordination among various disciplines, ultimately saving the duration and cost of the AEC projects. Accordingly, the UAE created strategies in order to mandate the implantation of the BIM process.

This study revealed that there are many forces that have enforced the AEC firms in the UAE to adopt BIM, and the most efficient force being the pressure from the government, by imposing the implementation of BIM as a compulsory requirement, provided that introducing clear requirements of the BIM model in each stage and identify how the firms will deal with local authorities through model.

Furthermore, the pressure from clients by imposing the implementation of BIM in the contracts is forcing the firms to adopt BIM. However, there is a crucial need to escalate the level of awareness about BIM, as the awareness about BIM among clients is at a moderate level which is not sufficient in the long run.

Apparently, many firms in the UAE adopted BIM much before it was made compulsory by the government. The main force driving them was the complexity of the projects which had increased due to tremendous disciplines and stakeholders are participating in one project. Moreover, most of these firms are international organisations and their headquarters in the countries that imposed BIM adoption since long, thus they adopted BIM in order to follow the standards of their headquarters and to have competitive advantage in the UAE market.

However, the implementation of the BIM process has been restrained due to the defects in the process of currently used project delivery methods that are hindering the utilisation of BIM benefits. There are critical defects in the current procurement methods used in the UAE AEC industry due to the hostile relationships among the participants which causes '***lack of cooperation, integration and confidence among project stakeholders***'. Furthermore, there is a deficiency in communication between the parties, resulting in a '***lack of information exchange, consequently low level of coordination***'.

In addition, the most popular procurement methods prevent the participants to be involved from the design stage, which generates numerous risks and uncertainness in the design, and causes changes in the design in later stages that reflects in the cost and duration of the projects.

This study attempted to assist the AEC firms in the UAE to utilise the benefits of the BIM process by examining the required changes and transformation for the framework of current procurement methods used in the UAE in order to implement BIM efficiently. It can be concluded that in order to adopt BIM process correctly there are few changes required in the framework of procurement methods, which are as follows:

- Relationship among project stakeholders
- Early involvement of participants
- Contractual agreements
- Sharing risks and rewards
- Involve new stakeholders and new roles

The awareness of BIM benefits plays a vital role in successful BIM implementation. When stakeholders realise that their earnings will increase upon implementing BIM, they will be forced to change their relationship from adversarial to more collaborative and integrated in order to deliver a project successfully. However, it requires change in the culture of the organisation to be more cooperative with other firms and be more open to share the information.

As noted previously early involvement of main stakeholders is beneficial for improving the level of coordination, detecting early conflicts and reducing the changes in the design; thus saving efforts, time and cost.

One of the main changes required is the contractual agreement to oblige all participants to adopt BIM, identifying the liabilities and responsibilities of each stakeholder upon inaccurate inputs, specifying the required inputs of each entrant in the model in each stage and identifying the intellectual property rights and the owner of the model. However, it has been confirmed that client is the final owner of the BIM model as he is paying for every nut and bolt of the project and he will be the one to use the BIM model in O&M. In addition, the contracts should determine how to involve main participants at the onset of a project. The firms can use the contract forms developed by several organisations, such as AIA, AGC and DBIA, and modify them according to the UAE market requirements.

Involving participants in the design stage will absolutely change the responsibility matrix and require sharing risks, wherein all stakeholders will participate collaboratively to create a single model that will be used in all the stages. In addition, the procurement method should also contain sharing of rewards in order to enhance the cooperation among the stakeholders, like the saving in the cost can be shared between stakeholders.

Simultaneously, with the implementation of BIM, new firms will appear on the image that will execute the BIM process and control the flow of data and the BIM model accessibility. Nowadays, new participants are being involved in the construction process, such as BIM consultancy, which is hired by the client to prepare employer information requirements and create the central data environment, and BIM manager, who is responsible for the coordination among inputs of each entrants. Therefore, the procurement method should identify their position in the procurement hierarchy and their relation with other stakeholders.

This study concluded that the most efficient procurement method to be used with BIM implementation is IPD, which allows the participants to be involved right from the design phase and sharing the risks and rewards. Moreover, the multi-parties' contract promotes the integration, collaboration and confidence among the stakeholders. However, the firms in the UAE are not yet familiar with IPD due to the market environment, there are few projects conducted through IPD though.

Although the most effective current procurement method used with BIM adoption is D&B because only one organisation is responsible for the design and construction and the integrated relationship among the participants enhances the cooperation and increases the level of coordination. However, it requires changes in the agreements to force sub-contractors to adopt BIM with predefined standards.

On the practical grounds, the DBB method is the most popular procurement methods used in the UAE. It assures best price for the client, but demands many changes in order to be convenient with BIM adoption. The most crucial change is involving participants earlier to create an accurate model from the onset of a project, else recreation of the model from scratch in every stage will reduce the chances of harnessing benefits of the BIM process in terms of saving time and cost.

Generally, the BIM process has a huge potential in improving the AEC industry in UAE, but for the participants to avail the BIM benefits, the process has to be modified in accordance with BIM adoption. As the clients carry the main responsibility of changing the process, because they are leading every process of the project, so in order to achieve the project objectives, they have to improve the efficiency of the project delivery method.

5.2. Recommendations

In the coming times, the BIM process will significantly participate in evolving the AEC industry in the UAE that demands cooperation among organisations to change the current process in order to achieve successful BIM implementation, whereby all stakeholders are expected gain profits from adopting BIM process.

The UAE government can play a significant role in the BIM implementation. It is recommended that it develops the required standards of the BIM model in each stage and improve the BIM department in the local authorities by providing training so as to make them capable in dealing with other firms. The UAE government can use the standards that have been issued by other countries, like British standards, in order to develop the local standards.

Meanwhile, the government also needs to increase the awareness about BIM in all firms, particularly clients, who are the owners and the decision makers in improving the construction process. It is recommended for clients to develop an in-house BIM department or hire a BIM management firm to manage the BIM processes like creating employer information requirements and central data environment, following the execution of BIM plan and managing the data workflow. Furthermore, the government needs to select an effective procurement method or do the required modifications in the current procurement methods so as to implement BIM process and achieve the project objectives. They also need to modify the contractual agreements to promote BIM adoption and maximise the utilisation of BIM.

While, the other stakeholders need to change their culture gradually to enhance the collaboration and coordination among other firms and improve the data exchange in order to utilise the benefits from the BIM process. It is recommended to these firms that in order to impose BIM, they hire sub-firms, such as sub-contractors or sub-consultant, to deliver the BIM model that can be used and developed in each stage.

5.3. Limitation of this Research

This study has the following limitations:

- The study conducted is based on the AEC market in the UAE, so the obtained results might not be applicable with other markets, unless conducting further verifications.
- Limited number of organisation accepted to conduct face-to-face interviews, so the case studies are created through interviewee with one or two stakeholders. The case studies could have been more elaborated had the interviews been conducted with all the stakeholders of the projects.
- As there were difficulties in conducting interviews, so not all the procurement methods have been tested and only the most popular ones were examined.

5.4. Recommendations for Further Studies

This study unveiled that in order to improve the implementation of BIM in the AEC industry, several areas require further study, such as:

i. To improve the integration among the participants, it is recommended to conduct a study to propose a detailed paradigm of the contractual agreements that can enhance the relationship among the project stakeholders and ensure proper BIM implementation, while taking into account how to resolve the disputes in BIM projects.

ii. Further studies should be conducted to find a method to record and register the BIM model in each stage especially when delivering from the design stage to the construction stage till the final delivery to the operator for O&M.

iii. Several studies should be managed to enhance sub-contractors and manufacturers to implement BIM that will have positive influence on the BIM model in terms of quality and time saving.

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Appendix 1

Qualitative semi-structured questionnaire:

<u>Section 1:</u> General View of BIM

- What are the driving forces to implement BIM?
- From extensive literature review, there are four forces to implement BIM, from your practices and experience, please rank the following forces :

Forces	Ranking
Client's needs and government requirements	
Market pressure and competitive advantage	
Projects complexity	
Reply to the technological development	

- Are the current procurement methods convenient with implementing BIM? Why?
- What are the required changes in procurement framework to ensure successful BIM adoption?
- Please rank the following changes

Required Changes	Ranking
Relationships among player	
Contractual agreements	

Shared risks and rewards	
Involve new stakeholders and new roles	
Early involvement of stakeholders	

<u>Section 2:</u> Case study

- What are the driving forces to adopt BIM in this project?
- What is the adopted procurement method in this project?
- What are the changes occurred in the framework of the procurement method to ensure successful BIM implementation?
- What were the challenges and obstacles that have been faced by participants to adopt BIM in this project?