Solutions for the UAE Architecture, Engineering, and Construction (AEC) industry to mandate Building Information Modeling (BIM)

حلول لصناعة التشيد والبناء بدولة الإمارات العربية المتحدة لتعميم نظام نمذجة البناء

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Abstract

For decades the construction industry has been challenged to improve its efficiency, therefore several attempts have been recorded proposing different initiatives. At the moment Building Information Modeling (BIM) is rapidly growing worldwide as a viable tool for this purpose. However, BIM is rarely used in the United Arab Emirates (UAE) Architecture, Engineering and Construction (AEC) industry despite the potential benefits of BIM to the industry.

The purpose of this study is to propose solutions to assist the UAE AEC industry to mandate BIM. Therefore, to identify the factors that influence the mandate of BIM, the research involved extensive literatures studies that lead to the conceptual model. The conceptual model involved four recognized factors that influence the implementation of BIM in the UAE AEC industry; these factors are the perceived benefits of BIM, the challenges and obstacles that hinder to implementation of BIM, the driving forces imposing the use of BIM and the readiness for organizations and the AEC industry to mandate BIM.

In order to collect the data, the research adopted combination of quantitative and qualitative approaches. Initially data was collected from BIM users and non-users via structured questionnaire survey that is distributed by mail to 362 organizations in UAE. These organizations were randomly selected from the Emirati Society of Engineers (ESE) and the Dubai Municipality directory. Then further qualitative approach via three case studies provided better understanding for the aforementioned four contributing factors for the mandate of BIM in UAE AEC industry. Interviews with carefully selected AEC industry professionals through face-to-face open-ended discussion have enabled proposing a set of practical solutions to swiftly mandate BIM in the UAE AEC industry.

The study findings indicate that, there is a moderate understanding for the essence of BIM in the UAE AEC industry, especially for the local developers, public authorities and small and medium size organizations. That means raising the awareness of BIM in the UAE AEC industry especially for the decision makers is the clue to motivate all the AEC players to mandate BIM. Moreover, the AEC players should recognize the challenges they may face during the switch to implement BIM. The study revealed that the most critical challenges that hinder the implementation of BIM are “lack of management commitment to implement BIM" and "the resistance to change, and clinging to the old ways of working".

Moreover, the UAE AEC industry nature to mandate BIM is promising, because majority of the big companies in building sector are international companies with excellent experience of BIM. Therefore, bringing their global experience of BIM into the UAE will assist in transferring and sharing BIM knowledge from these international organizations to the local organizations. That will significantly assist the smooth transition to implement BIM and will shorten the duration to mandate BIM in UAE.

Moreover, the UAE government can play a great and active role to introduce appropriate execution plans to implement BIM stipulating a timeframe to mandate BIM as a compulsory requirement in the AEC industry. In addition to including BIM in the AEC undergraduate and post graduates' syllabuses to introduce to the UAE AEC industry a new generation with full awareness of BIM.

***Keywords**: BIM, Benefits, Challenges, Driving forces, Readiness, Mandate*

ملخص البحث

منذ عقود وصناعة الإنشاءات تعانى من مشكلات كثيرة منها عدم قدرة هذه الصناعة على رفع كفائتها, وقد تم تسجيل محاولات عديدة لتحسين كفاءة قطاع الإنشاءات. فى الوقت الراهن ينمو نظام نمذجة البناء بشكل سريع, ومضطرد كحل عملى لرفع كفاءة صناعة التشيد والبناء حول العالم. ولكن ما زال إستخدام نظام نمذجة البناء فى دولة الامارات العربية المتحدة محدود على الرغم من انتشارة السريع حول العالم لفوائدة الكثيرة فى تحسين أداء قطاع الإنشاءات.

إن الهدف من هذه الدراسة هو طرح حلول عملية لمساعدة صانعى القرار لتعميم نظام نمذجة البناء فى قطاع التشيد والبناء بدولة الامارات العربية المتحدة. ولهذا السبب وللتعرف على العوامل التى تساعد على تعميم هذا النظام فى دولة الإمارات كان من الضرورى القيام بمراجعة الدراسات السابقة لنفس الموضوع ودراستها دراسة شاملة. وكان من نتائج هذه الدراسة هو إقتراح نموذج تم التعرف من خلاله على أربعة عوامل هى التى تؤثر على تنفيذ وفرص تعميم هذا النظام فى قطاع الإنشاءات بدولة الإمارات. هذه العوامل الأربعة هى:

- مدى الفهم لأهمية نظام نمذجة البناء وما هى الفوائد من تطبيقة
- التعرف على التحديات والعوائق لتطبيق وتعميم هذا النظام
- الضغوط والقوى التى تؤدى لتطبيق هذا النظام
- مدى إستعداد المؤسسات وقطاع التشيد للتحول الكامل والتخلى عن النظام المتبع لتطبيق هذا النظام الجديد.

ولتجميع المعلومات اللازمة لهذه الدراسة تبنت الدراسة منهجين من مناهج البحث العلمى معاً هما المنهج الكمى وذلك بطرح مجموعة من الأسئلة المحددة وتوزيعها بالبريد الالكترونى على 362 مؤسسة تم أختيارهم عشوائيا من سجلات جمعية المهندسنين- بالامارات العربية المتحدة وكذلك من دليل الشركات ببلدية دبى.

تلى ذلك المنهج الثانى وهو المنهج الاستقصائى وذلك بدراسة ثلاثة حالات قائمة من خلال مقابلات وطرح عدة أسئلة على خمسة من المتخصصين المحترفين فى قطاع التشيد بدولة الامارات العربية المتحدة. وقد ساهم ذلك فى فهم دقيق وعميق للأربعة عوامل سالفة الذكر وذلك للخروج بمجموعة حلول عملية لتسهيل وإسراع عملية تطبيق وتعميم نظام نمذجة البناء فى قطاع الانشاءات بالدولة.

وبعد تحليل نتائج البحث بالطرق العلمية وجد أن مدى فهم ماهية وحقيقة نظام نمذجة البناء وفوائدة ليس بالقدر الكافى الذى يؤهل إنتشار هذا النظام بدولة الإمارات وخصوصا من بعض الشركات المحلية وكذلك الشركات صغيرة ومتوسطة الحجم. وعليه فقدُوجد أن رفع مستوى الفهم لكينونة نظام نمذجة البناء وخصوصا لصانعى القرار بقطاع الإنشاءات هو مفتاح الحل لتحفيز تطبيق هذا النظام بالدولة.

بالإضافة الى ذلك فإن الدراسة خلصت إلى أنه يجب أن تتعرف المؤسسات على التحديات التى قد تواجهها أثناء تطبيق هذا النظام وقد كشفت الدراسة على أن أهم تحديين يواجهان التحول لهذا النظام فى الدولة هما "عدم إلتزام

صانعى القرار والأدارة العليا لتطبيق هذا النظام"و كذلك "مقاومة التغيير والتشبث بالعمل بالطرق القديمة فى قطاع الإنشاءات".

وعلى الجانب الاخر تعتبر بيئة قطاع الانشاءات بدولة الأمارات بيئة مبشرة بالنجاح لتبنى وتعميم نظام نمذجة البناء لما تمتلكه من مقومات. حيث أن معظم المؤسسات الكبرى التى تعمل بهذا القطاع مؤسسات عالمية لديها خبرة كبيرة فى نظام نمذجة البناء. وعليه فإن نقل خبرات هذه المؤسسات الى دولة الامارات عند فرض نظام تطبيق نمذجة البناء من الحكومة لن يتطلب وقت كبير وعليه فإن تعميم هذا النظام لن يتطلب وقت كبير أيضاً.

ولذلك أوصت الدراسة بإن حكومة دولة الإمارات العربية يمكنها أن تضطلع بدور فعال لتعميم هذا النظام وذلك من خلال تقديم خطط تنفيذ تتضمن وقت محدد يتم فيه تعميم هذا النظام كشرط إجبارى لكل المؤسسات العاملة بقطاع الإنشاءات بالدولة لدخول المناقصات للحصول على مشاريع جديدة. وكذلك يمكن للحكومة خلق جيل جديد لدية الدراية الكاملة بنظام نمذجة البناء ممن سيعملون بقطاع الانشاءات وذلك من خلال تضمين هذا النظام فى المناهج الدراسية للكليات والمعاهد الهندسية لطلاب الدراسات العليا وما دونها.

Dedication

-Even after 33 years of her death, she is the beacon of my life and the source of my inspiration.

“To my mother”

-To my dream that refused to die before I die.

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List of Abbreviations

2D CAD- Two Dimension Computer Aided Design

ADAC-Abu Dhabi Airport Company

AEC-Architect, Engineering and Construction

AIA- American Institute of Architects

BIM-Building Information Modeling

BREEAM- Building Research Establishment Environmental Assessment Method

CRC- The Cooperative Research Centre for Construction Innovation

DM-Dubai Municipality

FM-Facility Management

GDP-Gross Domestic Products

IFC- Industry Foundation Classes

IPD- Integrated Project Delivery

IPR- Intellectual Property Rights

JIT- Just In Time

LEED- Leadership in Energy and Environmental Design

MENA-Middle East and North Africa

MEP- Mechanical, Electrical and Plumbing

NBIMS- National Building Information Modeling Standards

O&M- Operation and Maintenance

RFID- Radio Frequency Identification

ROI- Return On Investment

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Chapter 1

1 Introduction

Construction industry is one of the significant economic pillars for nations worldwide, developed and developing countries alike.

According to the Office of National Statistics (2010), United Kingdom (UK) construction industry employs more than 1.9 million people which account 4.5% of employment in the UK with annual output more than 83.5 £ billion in 2007.

Similarly, According to the UAE annual Economic Report (2013) the UAE construction and building sectors contribute 12.5% of the Gross Domestic Product (GDP). In addition, regarding the UAE workforce distribution, the construction and building sector came ahead in terms of absorbing the employments which accounts for 22.1% of overall workforce in the UAE.

It is now twenty years since Sir Michael Latham published his report dubbed “Construction and the team” in 1994 which was followed by Sir John Egan’s report published on 1998 under the title “Rethinking construction” both reports reviewed and examined the weaknesses and challenges in the construction industry. They concluded that the client’s requirements are not always being achieved and that most projects were completed beyond the stipulated duration and far beyond the planned budget with poor quality and low productivity.

Latham (1994) found the construction industry to be fragmented with a poor ability to adopt innovative solutions, with lack of communication and mistrust amongst the Architecture, Engineering and Construction (AEC) players.

Latham (1994) recommended solutions to integrate the AEC industry players together to act as one team, working collaboratively for the same objective, and the client satisfaction should be the hub of the interest of the AEC players.

The weaknesses in the construction industry reported by Latham (1994) and Egan (1998) are persisting problems, therefore great attention to the construction problems were observed after Latham and Egan reports on 1994 and 1998 respectively, since then researchers and institutions are attempting to find practical solutions for the AEC recurring recognized problems.

One of the strong promising practical solutions which aptly proved its ability to overcome most of the AEC problems is Building Information modeling (BIM) which has emerged as the panacea for the AEC recognized problems.

This study attempted to engender an interaction between two groups i.e. BIM users and non-users in the UAE AEC industry to investigate each group’s perception of the benefits of BIM. It further explores the challenges for the implementation of BIM and the external forces driving the adoption of BIM and the UAE AEC industry internal readiness to implement BIM.

Moreover, to assist UAE AEC industry to swiftly mandate BIM, lessons learned from BIM early adopters such as New Zealand, Australia, UK and USA will be presented to pave the way for the UAE AEC industry to reap the utmost benefits of BIM.

1.1 Background of the problem

For decades, the AEC industry has been challenged by myriad problems. One of these significant problems that hinder the improvement of AEC industry is clinging to the old ways of working, inappropriate or poor response to the emerging technologies (National Research Council 1988). The construction industry has seen its projects over the years becoming more complex to manage not only due to increased technical complexity and poor responses from the AEC industry, but also due to the increased complexity of the supply chain and its contractual provisions. In addition to this, the pressure comes from increasing demand to build environmentally smart buildings.

It is also claimed that, construction productivity has been declining significantly over a number of decades. This decline in productivity is associated with what is seen to be the industry’s failure to deal with teamwork, fragmentation, lack of collaboration, poor communication, feeble profits and poor response to the new technology and the AEC industry’s slow changes (Latham 1994; Dulaimi et al. 2002).

Mitropoulos and Tatum (2000) argue that “advances in technology are widely regarded as major sources of improvement in competitive industries”. Hence adoption of new suitable technology is crucial to assist the AEC industry to overcome myriads of its recognized problems. This can be achieved by integrating the teamwork, promoting productivity, improving quality, improving profits, reducing costs and the project delivery duration to meet the client and user satisfaction, which accordingly enhances the company's competitive edge to sustain in the rival market.

Therefore, there is a need for significant changes in the AEC industry, especially after Latham and Egan's reports in 1994 and 1998 respectively. As already mentioned, these reports highlighted plenty of weaknesses in the construction industry that can easily be improved if the construction industry workforce rethinks its strategy for appropriate ways to enhance collaboration and to know that adherence to the old ways is no longer the best solution (Jernigan 2014).

Most AEC executives and professionals believe that BIM is the viable solution for a myriad of AEC problems. BIM is a revolutionary technology and process management tool that has positively changed the way buildings are conceived, designed, constructed and operated (Manning & Messner 2008; Hardin 2009; Linderoth 2010; Azhar 2011; Eastman et al. 2011; Abbasnegad & Moud 2013; Jernigan, 2014).

BIM roots can be traced back to the parametric modeling conducted in the USA and Europe in late 1970s and early 1980s; however the AEC industry practically started to use BIM in projects on 2000s. The worldwide use of BIM proved significant improvements and a paradigm shift in the AEC industry. Therefore in the last two decades, BIM became the main focus of AEC industry (Eastman et al. 2011).

AEC organizations that appropriately implemented BIM reaped the full benefits of BIM. They decreased project cost, increased productivity and quality, reduced project delivery duration, significantly reduced construction waste, responded appropriately to the clamor requirements for smart buildings, integrated AEC teamwork and supply chain, met the client and users' satisfaction and acquired significant competitive advantage in the AEC market (Azhar 2011; Eastman et al. 2011; Sebastian 2011; Elmualim & Gilder 2014).

Kunz and Gilligan (2007) studied 32 major projects in the USA, where BIM was appropriately implemented and integrated in the AEC industry, and reported the following improvements:

- Up to 40% elimination of unbudgeted change

- Cost estimation accuracy within 3% as compared to traditional estimate and up to 80% reduction in time taken to generate the cost estimate
- A saving up to 10% of contract value through clash detection
- Up to 7% reduction in project time
- Up to 13% saving of project overall cost
- Up to 70% cost saving for building maintenance
- Quality and accuracy improvement
- Document automation
- Full integration for the AEC teamwork and the supply chain players
- Enabled quick decisions and reduced risks

Notwithstanding the explicit perceived benefits of BIM, many organizations are reluctant to change to adopt BIM for many challenging reasons. These reasons are cited as client didn’t request or use BIM, the software is expensive as are pertinent hardware upgrading and relevant expenses, lack of experience for the *know-how* for the transition to implement BIM, required training of staff and additional hiring of BIM experts that incur additional costs. Other reasons include, BIM is not common for stakeholders, and some organizations believe that current ways are sufficient, change resistant, lack of commitment from top management, BIM involves restructuring the organization’s roles and responsibilities, and BIM requires long duration to accomplish the real benefits. (Migilinskas et al. 2013; Chan 2014; Eadie et al. 2014).

Liu et al. (2010) and Eadie et al. (2013) studied the driving forces for the implementation of BIM and classified these factors as government and client pressure, surrounding environment, pressure from competitors and the complexity of projects and profit declination.

Liu et al. (2010) studied the internal readiness of the AEC industry and the organizations that intending to implement BIM and found, the internal readiness is influenced by four factors, i.e. financial cost implications, early recognition of the benefits of BIM, top management attitudes and support for the adoption of BIM and the level of flexibility to implement the change.

According to Jernigan (2014) “hundreds of organizations around the world adopted BIM and reaped its benefits, met clients and users’ satisfactions and increased their profits by 5-12%”.

There are plenty of evidences from the reviewed literature demonstrates that, developed countries have recognized the benefits of BIM and they considered BIM as the AEC's future language that all the AEC organizations worldwide have to implement. This is evident from the rapid growth of BIM and mandates being issued in several countries such as the UK, where government planned on 2011 to mandate BIM in its AEC industry by 2016 (UK Cabinet office 2011; Eadie et al. 2013). Similar examples for countries mandated BIM are Singapore, USA, Norway, Germany, France, Finland, South Korea, Australia, Hong Kong, Canada and many other countries have adopted the mandate strategy to utilize BIM in their AEC industry (Mihindu & Arayici 2008; Takim et al. 2013).

1.2 Significance of the dissertation

The Middle East and North Africa (MENA) is still at the early embarking stage of the adoption of BIM. Additionally, some users in MENA are using BIM as a tool for specific purposes and not as an integrated process. BIM users as well as the AEC industry should understand that the most significant and real benefits of BIM are achieved when BIM is fully integrated (Building Smart Report 2011).

The remarkable lack of *know-how* to manage the hindrances for the implementation BIM is of the major reason for the modest use of BIM in the AEC industry in MENA area (Panuwatwanich et al. 2013).

Many executives as well as research institutions confirmed that the use of BIM is of particular importance in the countries experiencing construction boom to improve the construction performance (Eastman et al. 2011). UAE is one of the countries experiencing such construction boom. Some clients in the UAE started to recognize the benefits of BIM for its AEC industry and taken initial steps to utilize BIM (Building Smart Report 2011). (Baldwin 2012) reported that some government bodies and associated entities in the Middle East have also taken some significant steps to promote BIM as an integral part of the construction process. The UAE government-owned developers such as Masdar, Tourism Development and Investment Company (TDIC) and Mubadala, are increasingly requiring BIM as part of their prequalification process.

Dubai government decided to be part of the world's change that is reshaping the AEC industry by adopting BIM in its AEC industry. Dubai Municipality (DM) imposed BIM as a compulsory requirement for specific buildings in Dubai city as on 1st January 2014 via the Circular No. 196 issued on 18th November 2013 to all the developers, contractors and consultants (DM 2013). However Abu Dhabi, Sharjah, Ras al-Khaimah, Ajman, Umm al-Quwain and Fujairah governments did not impose BIM as a compulsory requirement in the AEC industry.

According to Jernigan (2014, p.32) “Changes to adopt BIM is happening like it or not”. In addition Eastman et al. (2011) affirmed that “BIM will mandate the worldwide AEC industry in the very near future. Therefore those who are not coping with the new change and expressing unwillingness for the implementation of BIM will be badly affected and they will soon be out of the competition game. Steward Brand (n.d.) stated that “Once a new technology rolls over you, if you are not part of the steamroller, you are part of the road”.

The implementation of BIM is a relatively long process that requires long duration to reap its real benefits. For example the UK and Australia planned to mandate BIM in more than four years 2011 to 2016 (UK Cabinet office 2011; SmartMarket Report 2014)

Much research affirmed that, the change to adopt BIM is not an easy task because some companies do not know-how to start the change. In addition switching to BIM involves three pivotal disciplines ***people, process and technology*** binding these three areas together is not an easy task (Eastman et al. 2011; Sharif 2011; Rezgui et al. 2013; Shafiq et al. 2013).

The significance of this study emerged from its practical field attempt to explore the perceptions of the UAE AEC industry about the benefits of BIM and the challenges for the implementation of BIM. The research classified the UAE AEC industry as BIM users and non-users. Further investigations were made to explore the driving forces imposing the adoption of BIM, in addition to examining the internal readiness for the organizations and the AEC industry for the implementation of BIM. In order to, propose solutions to pave the way for swift transition to mandate BIM in the UAE AEC.

1.3 Problem statement

The AEC industry is suffering many functional gaps among its parties. This starts at the client’s early perception passing thought the predesign and the design stages, construction, Operation and Maintenance (O&M) until the demolishing of the building.

Management professionals and researchers tried to bridge the recognized gaps of the AEC industry such as teamwork fragmentations, ineffective coordination, poor communications, buildings low performance, energy overconsumption, unsustainable buildings. In addition to design errors and clashes, project overrun , low productivity, low building quality, poor satisfaction of stakeholders/client/users and shortage or unauthenticated data for Facility Management (FM) during maintenance stage.

The boom that the UAE is experiencing creates tremendous pressures on its AEC industry. Therefore there is an urgent need to adopt the latest technologies and management tools to eradicate the recognized problems and to improve the performance of the AEC industry. In addition to respond to the increasing demands for smart buildings and to respond to the government's concerns of the continuous developments.

In fact, developed countries have pioneered the implementation of BIM for their AEC industries that enabled them to bridge the majority of the recognized construction performance gaps. However the AEC industry in many of developing countries still facing lack of commitments from the decision makers for the implementation of BIM.

There are ample of research that studied the perceived benefits of BIM and the challenges for the implementation of BIM. However the scarcity of research that has studied the driving forces that is imposing the implementation of BIM. In addition to the internal readiness of the organizations and the AEC industry to implement BIM, inspired the researcher to conduct this study. The purpose of the study is to recognize and prioritize the factors affecting the implementation of BIM for the AEC industry in the UAE, and then attempt to propose solutions to pave the way for the UAE AEC industry to swiftly switch to BIM to improve the construction industry performance.

1.4 Aim of the dissertation

The aim of this dissertation is to examine the readiness of the UAE AEC industry to mandate BIM, and hence propose solutions to enable the AEC industry to improve its performance.

1.5 Objectives

The objectives of this study are as follows:

1. To explore the perceived benefits of BIM, for BIM users and non-users in the UAE AEC industry.
2. To examine the driving forces and the external pressures imposing the implementation of BIM in the UAE AEC industry.
3. To identify what are the main challenges and obstacles that are hindering the organizations to utilize BIM.
4. To examine the internal readiness for the organizations and the AEC industry for the implementation of BIM.
5. To recommend solutions for the UAE AEC industry to mandate and expedite the implementation of BIM.

1.6 Dissertation Questions

The dissertation will attempt to answer the following questions.

Q1: What are the perceptions of the UAE AEC industry professionals for the benefits of BIM?

Q2: What are the challenges facing the BIM users during implementation of BIM and, what are the challenges and obstacles hindering BIM non-users to adopt BIM in UAE AEC industry?

Q3: What are the external pressures and forces imposing the implementation of BIM in the UAE AEC industry?

Q4: What is the required internal readiness for the organizations and the AEC industry to adopt BIM in UAE?

Q5: How to accelerate the implementation of BIM in the UAE AEC industry?

1.7 Scope of Work

The scope of the study will be limited to investigate the perceptions of the BIM users and non-users in the UAE AEC industry. In addition to introducing some lessons learned from overseas BIM pioneering countries.

To date there are few recognized mega projects in UAE using BIM, these projects are as follows:

- Midfield Terminal building- Abu Dhabi international airport

- Louver Abu Dhabi
- Guggenheim Abu Dhabi
- Al Mafraq hospital Abu Dhabi
- Investment Council Headquarter (ICHQ).

All projects that are using BIM have recently commenced the field works in less than two years, that means UAE is deemed to be in the embarking stage for the implementation of BIM. Therefore, some projects in UK and USA will be further studied to fully understand the lessons learned from a prudent BIM markets for the imposed external pressures to adopt BIM. Additionally, the AEC internal readiness and the best practices that assist the organizations to change to BIM will be also introduced.

1.8 Methodology

Data collected on three main stages:

First stage: extensive literature review for the relevant articles to build a deep understanding for the benefits of BIM, the challenges and barriers for the implementation of BIM, the driving forces and the external pressures that affecting the adoption of BIM, and the internal readiness for the organizations and the AEC industry to adopt BIM. In addition to recognize the actions required to pave the way for the UAE AEC industry to expedite and facilitate the mandate of BIM based on other countries experiences and lessons learned.

The data collected from the literature review used to steer the ***second stage*** and further adopted the quantitative approach to prepare a structured questionnaire survey to be distributed via mail to the medium and large scale AEC organizations in UAE. Medium and big organizations were identified according to the UAE classifications for the organizations' size, these organizations were recognized from the Emirati Society of Engineers (ESE) and from the directory of Dubai Municipality. Moreover, to identify the perceptions of BIM users and non-users for the barriers that hinder the mandate of BIM in the UAE AEC industry, the questionnaire survey distributed to 362 of randomly selected organizations represent BIM users and non-users.

The questionnaire was divided into five sections, first section dedicated for the demographic information, which investigated the respondents' personal information i.e.

BIM user or non-user, the company specialty, years of experience and working in UAE, academic qualification, position in the organization etc.

Section 2, 3, 4 and 5: In these sections the respondents were asked to rate their agreement or disagreement level to each question in a five Likert scale ranging from 1 to 5 for their perceptions about the four variables i.e. the perceived benefits of BIM, the challenges of the implementation of BIM, the driving forces and the internal readiness affecting adoption of BIM in UAE AEC industry.

Likert scale 1 represents “not at all significant” and 5 represents “extremely significant”.

Based on the questionnaire survey, the quantitative approach was used in two different statistical ways; first the standard method of ranking to compare and contrast the perceptions of the two groups (BIM users and non-users) for the four variables and to estimate the ranking agreement factor for each variable. The standard method of ranking for the four variables utilized the mean rank analysis and the Relative Importance Index (RII) to establish the respondents’ ranking for each factor of the four variables. And then the SPSS software further used to ranking the significance and the impact of the four variables on the implementation of BIM in the UAE AEC industry.

Third stage case studies via qualitative approach were adopted to collect the data from the field, this stage commenced after the data was analyzed in the previous stage of the quantitative approach. The Data collection involved face-to-face semi-structured interviews with carefully selected 5 professionals of three case studies in the UAE AEC industry. The first case study is an iconic running project in Abu Dhabi and the second case study represents the first public authority in UAE imposed BIM as a compulsory requirement, these two case studies represented the BIM users. BIM non users group represented in the third case study of a running project in Dubai. And further Skype interviews with BIM experts from UK and USA, these interviewees added in-depth understanding of the issues uncovered during the survey questionnaire and the case studies. In addition to adding other countries experiences and lessons learned.

1.9 The structure of the dissertation

The dissertation is divided into five chapters; the structure of each chapter is summarized as follows:

Chapter 1 entails the introduction that guides the reader to the research topic, background of the problem, the significance of the study and then provides the problem statement, aim and the study objectives. In addition to the dissertation questions and the scope of work and then outlines the methodology followed to collect and analyze the data.

Chapter 2 entails the literature review that is in general presented BIM, and further focused on the factors influencing the implementation of BIM in the UAE AEC industry. The literature studies offered a profound understanding of the influencing factors diminish the growth of BIM in the UAE AEC industry.

Chapter 3 represents the research conceptual framework that is emerged from the literature study, in addition to guidance from Chwelos et al. (2001) model. However the conceptual framework further developed to study the dynamics of the UAE AEC industry to assist the industry players to bridge the gaps hinder the implementation of BIM.

Chapter 4 represents the research methodology, data collection, data analyses and discussions. The research aim, objectives and the research questions leaded to the selection of the quantitative approach which further reinforced by case studies for better understanding of the factors influencing the implementation of BIM in UAE. This chapter explains also the technique used for the data collection and results analyses and discussions for the quantitative and the case studies.

Chapter 5 represents the research conclusion and recommendation that enables the UAE AEC industry to swiftly switch to mandate BIM. The research limitations and recommendations for further studies also included in this chapter.

Chapter 2

2 Literature Review

2.1 Advocated Change

For decades the AEC industry has been challenged to improve its efficiency and performance. McGraw Hill construction report (2007) has studied the construction productivity between 1964 till 2004 in the USA, and compared the results against the non-farm industries.

This report (see Figure 1 for summary) demonstrates the huge discrepancy in productivity between the AEC industry and the non-farm industry; the red line renders the tremendous declination for the construction productivity year by year, on the other side stands the productivity boom indicating the non-farm industries presented by the green line.

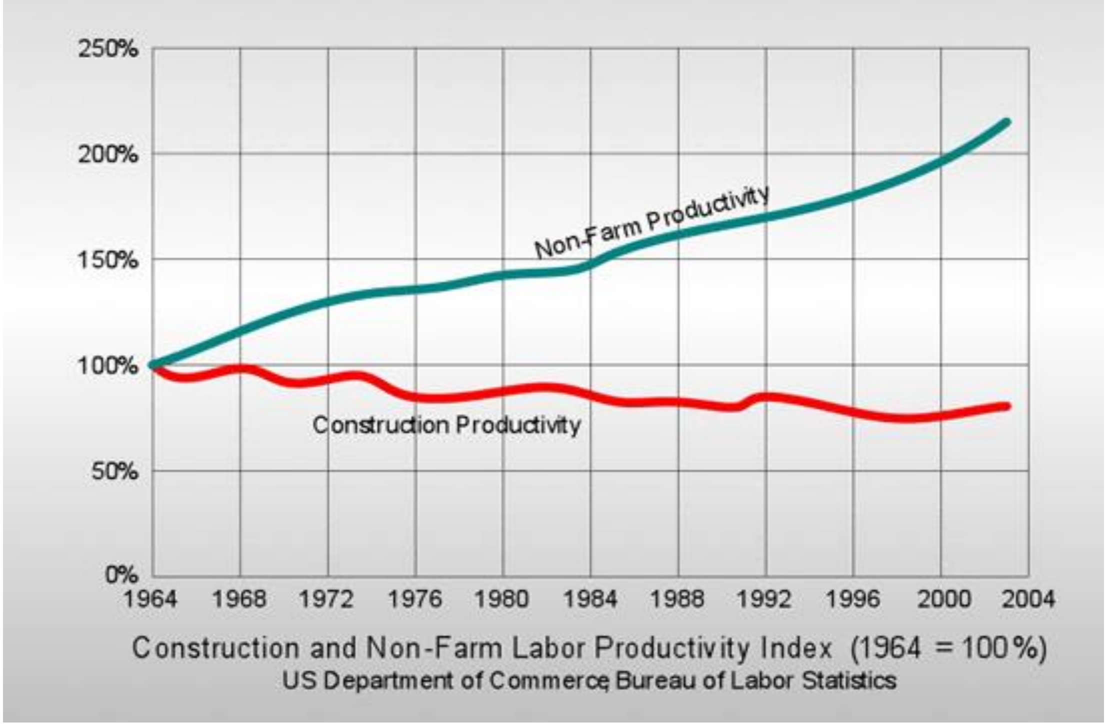


Figure 1: Construction productivity index compared to non-farm industries.

(Courtesy of McGraw Hill, MHC interoperability SmartMarket Report 2007).

Fig. 1 provides a clear picture for the inferior situation of the productivity for the construction industry compared with non-farm industries.

The construction industry has seen its projects becoming more complex to manage over the years not only due to the fragmented nature of the construction industry but also due to its resistance to change (Dulaimi et al. 2002; Williams 2002; Alshawi & Ingirige 2002; Ruikar et al. 2005).

It is now more than 20 years since Sir Michael Latham shared his thoughts on the construction industry when he published his report “Constructing the team” in July 1994. This report was followed by Sir John Egan’s report published in 1998 under the title “Rethinking construction”. Both reports extensively studied the construction industry in the UK and highlighted the weaknesses in the AEC industry. Once Latham (1994) and Egan (1998) disseminated their reports, the improvement of the AEC industry was the overriding concern for several governments and academics (Almualim & Gilder 2010).

Since then, the two reports and other research have recognized many weaknesses and challenges in the AEC industry. However, there is a consensus among several researchers and AEC professionals, that the most critical weaknesses that require prompt change are the fragmented and conservative nature of the AEC industry. This fragmented and conservative nature hinders swift responses to innovative technologies and diminishes the chances for improvements (Latham 1994; Egan 1998; Sun& Aouad 1999; More et al. 1999; Dulaimi & Kumarswamy 2001; Dulaimi et al. 2002; Carmona & Irwin 2007; Barret 2008; Hardin 2009; Elmualim 2010; Arayici et al. 2011; Baiden et al. 2011).

This being the case, there is a crucial need to steer the AEC industry into a real paradigm shift to increase productivity, efficiency, money value, improve quality, and enhance the sustainability (Latham 1994; Egan 1998; Baiden, Price& Dainty 2006). Dulaimi and Kumaraswamy (2000) recommended promoting the AEC industry performance through improving the communication, promoting sharing knowledge, integrating the fragmented nature of the construction industry. Moreover Elmuailim and Gilder (2014) recommended reducing lifecycle costs, reducing project duration and meet the client and user satisfactions.

Latham (1994) and Egan (1998) suggested improving the construction industry through continuous improvements and raising the capacity of the people (the team), the technology and the processes. However, McKenna (2006) affirmed that, people are the most critical pillar for any successful improvement for the industry, because people are the decision makers and highly influence the other two areas i.e. the processes and the technology.

Governments and clients are always concerned about quality improvement with reduced construction time and cost, likewise contractors and architects are interested in business improvements to increase their profits, promote their competitive advantages and meet client satisfaction to sustain in the rival markets (Azhar 2011). However, the complexity of the current construction processes is very difficult to manage (Williams 2002; Alshawi& Ingirige 2002). Therefore, the construction industry requires significant changes in its mindsets, processes and the technology (Latham 1994; Egan 1998; Hardin 2009; Love et al. 2013).

At the moment, BIM emerged to be the viable tool to improve the recognized dilemmas in the AEC industry. BIM is recognized as a revolutionary technology and process management, proposed as the potential solution for the AEC industry current problems (Azhar et al. 2008; Hardin 2009; Liu et al. 2010; Arayici et al. 2011; Azhar 2011; Azhar et al. 2012; Bryde et al. 2013; Love et al.2013; Love et al. 2014; Han 2014).

Many researchers studied the benefits to be gained from adopting BIM in AEC industry and found that. BIM offers an appropriate platform for sharing knowledge through its open environment, which can collaborate and integrate the project stakeholders (Grilo& Jardin-Goncalves 2010). BIM also has significant capacity to enhance building sustainability analyses (Azhar et al. 2011; Zanni et al. 2013).

Moreover, BIM offers error-free design by integrating the design teams through collecting all designs from different parties, i.e. Architects, structural and Mechanical, Electrical and Plumbing (MEP) designers, to be aligned in one model. Any design mistakes or clashes can be identified prior to starting the construction by applying the 3D visualization, simulation and clash detection. In addition to, the BIM's capacity to analyze different design alternatives to select the best option in a very short time (Manning & Messner 2008; Grilo& Jardim-Goncalves 2010; Eastman et al. 2011; Abbasnejad & Moud 2013).

It is believed that BIM effectively improves cost estimation and tendering proposals (Elbeltagi& Dawood 2011). Moreover, BIM fosters appropriate site logistics planning

(Sebastian 2011; Bhat & Gowda, 2013). Additionally BIM offers significant benefits for site management and safety planning (Nawari 2012). BIM significantly reduces project cost and time, and improves the delivered quality. Utilization of BIM increases the productivity (Kunz & Gilligan 2007; Hardin 2009; Eastman et al. 2011), in addition to the capacity of BIM to improve the performance of the FM teams during the O&M stage (Newoton 2004; Reddy 2011; Eadie et al. 2013).

2.2 What is BIM

The Associated General Contractors of America AGC (2005, p.3) defined BIM as:

> [T]he development and use of a computer software model to simulate the construction and operation of a facility. The resulting model is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriated and analyzed to generate information that can be used to make decision and improve the process of delivering the facility.

However, the American Institute of Architects (AIA) defined BIM from the designers' perspective as "a 3D visualization model that digitally represents of the physical and functional characteristics of project using BIM software and tools of clash detections and code specifications" (AIA 2002).

On the other hand, owners may define BIM as "a 3D model and real time dynamic building modeling software to identify and reduce risks and to increase productivity in design and construction, to finish the project on time within the budget and avail all the data required for the facility managers during the O&M stage" (Kymmell 2008; Liston 2008; Sinopol 2010; Eastman et al. 2011).

Different researchers have extensively studied BIM and proposed different definitions, which reveals that, the definition of BIM will vary based on several factors such as the perceived benefits of BIM, who is the party articulating the definition and what are the most benefits expected or reaped from BIM (Abbasnejad & Moud 2013).

However, the most common and consensus definition for BIM devised by the National Building Information Modeling Standards NBIMS (2010, p.21) they BIM defined as:

> [A] digital representation of physical and function characteristics of facility. BIM is a shared knowledge resource of information about a facility forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of

> the lifecycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of stakeholders.

The fundamental difference between BIM and the traditional 2D CAD methodology is that in 2D CAD the building is demonstrated in views i.e. elevations, sections and plans. Changing any part of these 2D drawings requires all the other relevant drawings to be updated and changed accordingly. This process is a highly error-prone process, which is one of the major causes of documents and design errors and poor documentation. 2D CAD drawing consists of lines, circles and arcs only. However, a BIM model is object-oriented which is defined in terms of building elements and systems such as spaces, walls, beams, foundations and columns. The BIM software contains all the details about any object, in addition to the ability of uploading the standards and specifications for compliance (Hardin 2009; Azhar 2011; Eastman et al. 2011; Elmualim& Gilder 2014)

BIM model carries all the information pertaining to the building including its physical and functional characteristics and the detailed information for the project lifecycle, in a series of smart objects. For example, a BIM model for a completed building has an installed Air Condition (AC) unit fixed in a certain place and has a unique number. A BIM model carries all the details about this AC unit such as data about the supplier, AC capacity, O&M procedures, energy consumption, etc. (CRC construction innovation 2007; Azhar & Richter 2009; Eastman et al. 2011).

BIM is not just software it is also a process that digitally manages the design, construction and O&M. BIM enhances the collaboration and communication for all project stakeholders, BIM significantly improves the workflow and project delivery processes within the entire project lifecycle (Hardin 2009; BuildingSmart 2010, Eastman et al. 2011).

The following Figure 2 demonstrates the project lifecycle and the benefits of BIM in each stage. Where the implementation of BIM integrates the stakeholders and collaborate the efforts of the entire project workforce to accomplish the project objectives to meet the client satisfactions.

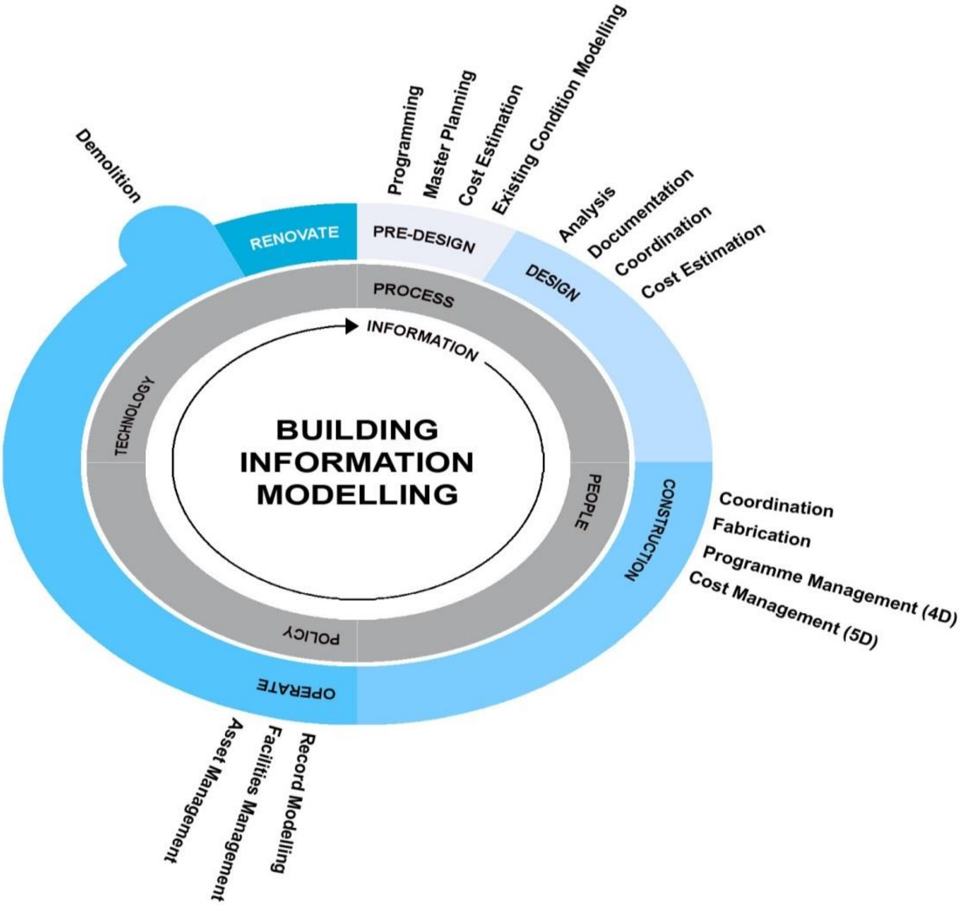


Figure 2: BIM benefits during the project lifecycle.

(Adapted from New Zealand BIM Handbook 2014, p.4)

Benefits of BIM are tangible to all the project teams throughout the entire project phases, starts at the project inception, briefing, design, construction, operation and maintenance till demolishing of the construction (Hardin 2009; Jung& Joo 2011; Eastman et al. 2011). Therefore, BIM is rapidly growing as the latest advanced technology in the AEC industry. A BIM hub is about improving the implementation strategies, processes and policies to integrate the people's efforts (team work) to collaboratively work towards the same objectives within a project's planned budget and schedule. Additionally, the use of BIM assists in delivering the satisfactory quality to meet the customer and client satisfaction (Azhar 2011; Kang et al. 2012; Bryde et al. 2013; Migilinskas 2013; Elmualim& Gilder 2014; Love et al. 2014; Chan 2014).

BIM as a software technology is very rich with different tools that can be used at different stages by the project teams.

Following are the main tools for BIM model and its major applications.

2.3 BIM tools

- **3D**: It is BIM model visualization and simulation tool enables the team to virtually visualize the building's details in physical environment, in addition to its ability to visualize the project with its construction sequencing (Hardin 2009; Grilo& Jardim-Goncalves 2010; Sebastian 2011; Azhar et al. 2012; Abbasnejad& Moud 2013).
- **4D**: It is a BIM model scheduling tool with the dimension of time sequencing which enables the team to visually check the progress of the project and identify the critical activities to appropriately deal with any risk (Dawood& Sikka 2008; kymmell 2008; Eastman et al. 2011; Abbasnejad& Moud 2013).
- **5D**: It is BIM model tool, where the dimension of time together with the project costs are built in, to enable appropriate evaluation of the duration of the construction and cost for each item in the project (Eastman et al. 2011; Bryde et al. 2012; Khosrowshiahi & Arayici 2012; Abbasnejad& Moud 2013).
- **6D**: It is BIM virtual model tool for the logistics of the construction site, to visualize the project sequential activities to prepare the safety analyses and safety plans. Additionally it enables selection of the locations for the material procurements and the selection of the location and types of machineries and equipment suitable for the site (Hardin 2009; Eastman et al. 2011; Abbasnejad& Moud 2013).

Each tool of the abovementioned used in one or more of BIM applications, following are the most common used application of BIM.

2.4 BIM applications

- **Material take-off:** It is an application that depends on a 5D tool to determine the precise material quantities (material take-off), and correlates placing orders for the materials with the delivery dates based on site needs. The accuracy of the 5D take-off estimates is highly reliable and can be conducted at any time of the project, this application contributes to avoid material waste and fosters lean construction principle (Azhar et al. 2012; Moreno et al. 2013)
- **Clash detection**: It is a 3D visualization application that can detect any clashes or undesirable interferences between the project elements, especially when there are several inputs of BIM models from different design teams i.e. Architect,

structural, sustainable and MEP designers to be unified in a single model (Kunz& Gilligan 2007; Sebastian 2011; Eadie et al. 2013).

- **Build-in code and specifications**: BIM software models are developed to include the required codes, standards and project specifications which can run automatic checking to verify the compliance with the uploaded codes, standards and project specifications to alert and notify any deviation in the drawings and submittals (Hardin 2009; Eastman et al. 2011; Osapuolet 2012).
- **Cost estimating**: It is an application depends on 5D BIM tool to estimate the cost in a very short time with great reliable accuracy at any time of the project, to enable decision makers to take the appropriate decisions on time (Sebastian 2011; Osapuolet 2012; Jernigan 2014; Love et al. 2014).
- **Project planning and construction monitoring**: It is an application based on a 4D tool that accurately visualizes and simulates the construction sequences. This also enables the client and contractor to monitor the construction activities and automatically compare the actual progress against the planned to find out where and why the delay occurs (Grilo & Calves 2010; Azhar 2011; Eastman et al. 2011).
- **Sustainability analysis**: BIM application tools such as 3D simulation and visualization are used to determine and evaluate the building future performance with a reliable accuracy. BIM simulation tool demonstrates the best orientation for the building to save the energy based on the sun direction, sound levels, wind speed and direction, light affection, spatial performance and the building envelope (Azhar et al. 2012).
  In addition to, the ability of BIM to compare and simulate the sustainability measures in terms of internal energy performance such as MEP details. Different options according to the specifications that are uploaded to BIM software, all these comparisons are implemented in no time to select the best option that is appropriate for the building throughout its life-cycle in terms of energy saving and sustainable principles (Kymel 2008; Azhar et al. 2012; Nawari 2012).

  Moreover the 5D tool enables estimating and selecting the best materials to be used, and 4D tool compares and contrast each option in terms of the time required for construction, and the cost and time saving (Eastman et al. 2011; Moreno et al. 2013).

- **Site logistics and safety management**: It is an application based 6D BIM tool that visualize the arrangements required for the site logistics i.e. the best locations for cranes, store yards and site offices and so forth. In addition to its ability to visualize the project activities to precisely evaluate the safety hazards to be ready for the appropriate responses. 6D tool enables health and safety specialists to train the staff and employees for the best practices based on the visualization and simulations of the project activities offered by BIM model (Hardin 2009; Zang & Hu 2011; Eastman et al. 2011; Sebastian 2011; Barlish & Sullivan 2012; Bhat & Gowda 2013)
- **Data transfer to facility management**: 3D model is a platform that is very rich with detailed information. This information includes the infinitesimal details for each and every item in the building with a unique barcode that carries a unique name, installation data, and the required maintenance date including manufacturer and suppliers contact details (Newoton 2004; Kymel 2008; Jordani 2010; Eastman et al. 2011; Moreno et al. 2013).

Sebastian et al. (2009) summarized that, “BIM is an integrated model in which process and product information is combined, stored elaborated and interactively distributed to all relevant building actors”. BIM takes the traditional paper-based tools of construction projects and put them in a virtual environment and allows a level of efficiency, communication and collaboration that exceeds these of traditional construction processes (Lee 2008).

In the last few years, several governments and clients worldwide recognized the benefits of BIM and started to use their power to impose pressures on the AEC industry to use BIM (Arayici et al. 2011; Barlish et al. 2012; Mihindu & Arayici 2008; Kang et al. 2012).

In order to determine the main factors influencing the implementation of BIM within the UAE AEC industry an extensive literature review was conducted. The following section will elaborate on the recognized factors influencing the implementation of BIM for any organization in UAE AEC industry that is intending to implement BIM. The literature studies unveiled four factors that influence the implementation of BIM as follows:

- The Perceived benefits of BIM,

- The challenges and obstacles hindering the implementation of BIM,
- The driving forces and the external pressures imposing the implementation of BIM,
- The internal readiness for the organizations and the AEC industry to implement BIM.

These four factors considered three main dimensions i.e. technological dimension (technology), organizational dimension (process and people) and the surrounding environment (local and global) influencing the implementation of BIM in the UAE AEC industry.

The technological dimension concerns the sophistication of software and its correlated costs; organizational dimension concerns the changes in processes and the change resistance from employees including top management attitudes to the change initiatives. And finally the surrounding environment concerns the local surrounding such as the external pressure from government, clients and competitors that is forcing the implementation of BIM, and the global pressure due to the rapid growing of BIM in the AEC industry worldwide.

2.5 Perceived benefits of BIM

Based on the extensive literature review the following table 1 summarizes the most recognized benefits of BIM and the beneficiary party.

Client: C, Architect/Engineer: A/E, Contractor/Subcontractor: C/SC, Supplier: S Other Stakeholders: ST, Facility Management: FM

Ser	Benefits of BIM	Beneficiary						References
		C	A/E	C/SC	S	ST	FM	
1	Teamwork Integration and collaboration.	√	√	√	√	√	√	(Anumba et al. 2008; McBride et al. 2011; Shen et al. 2012).
2	Quick and right decisions based on authenticated data.	√	√	√	√	√	√	(Kymel 2008; Jernigan 2014; Love et al. 2014)

3	Client early involvement	√	√	√	√	√	√	(Manning & Messner 2008; Eastman et al. 2011; Jernigan 2014).
4	Reduced project time and cost	√	√	√	×	√	×	(Howard et al. 2008; Hardin 2009; Eastman et al. 2011; Sebastian 2011; Osapuolet 2012).
5	Improved quality	√	√	√	√	√	√	(Nour 2007; Eastman et al. 2011).
6	Promotes the client and customer satisfactions	√	√	√	√	√	√	(Yang & Peng 2008; Karna et al. 2009).
7	Increase productivity	√	√	√	√	√	√	(Kaner et al 2007; Liu et al. 2010; Eastman et al. 2011; Olotunji 2011; Barlish & Sullivan 2012).
8	Reduce risks	√	√	√	√	√	√	(Khanzade et al. 2008; Hardin 2009; Sinopol 2010; Eastman et al. 2011; Barlish & Sullivan 2012; Porwal et al. 2013; Jernigan 2014).
9	Error-free design	√	√	√	√	√	√	(Banzjanac 2005; Samuelson & Bjork 2010).
10	Promote project understanding and eradicates any ambiguity	√	√	√	√	√	√	(Arayici et al. 2011; Azhar et al. 2011; Abbasnejad & Moud 2013).
11	Reduce the RFIs'	√	√	√	√	√	×	Kaner et al. 2008; Love et al. 2011; Jernigan 2014).
12	Reduce or eliminate change orders	√	√	√	√	√	×	(Khanzade et al. 2008; ; Sinopol 2010; Eastman et al. 2011; Porwal et al. 2013; Jernigan 2014).

13	Minimize or eliminate the reworks	√	√	√	×	√	×	(Hardin 2009; Eastman et al. 2011)
14	Reduce accidents by Promoting safety plans	√	×	√	×	√	×	(Zang & Hu 2011; Eastman et al. 2011; Barlish & Sullivan 2012; Moreno et al. 2013).
15	Enhance site logistics plans	√	×	√	√	√	√	(Sebastian 2011; Abbasnejan & Moud 2013).
16	Enhance the lean construction principle and value engineering	√	√	√	√	√	√	(Howard et al. 2008; Sebastian 2011; Osapuolet 2012)
17	Promotes the money value	√	√	√	√	√	√	(Barret 2008; Elmuailim & Gilder 2014).
18	Reduce construction waste	√	√	√	×	√	√	(AIA 2007; Azhar 2011; Eastman et al. 2011; Omar& Dulaimi 2014)
19	Improve the building sustainability analyses.	√	√	√	×	√	√	(Eastman et al. 2011; Porwal &Hewage 2013; Eadie et al. 2013).
20	Promotes the company's competitive advantages	√	√	√	√	√	√	(Sebastian et al. 2011; Azhar et al. 2012; Almualim & Glider 2014).
21	Promotes the prefabrications for better quality.	√	×	√	√	√	√	(Sebastian 2011; Bryde et al. 2012; Osapuolet 2012; Bryde 2013).
22	FM easy access to data for efficient O&M.	√	×	×	√	√	√	(Carmona & Irwin 2007; Kymmell 2008; Aouad & Arayici 2010; Azhar 2011).
23	All documents are automated and easily accessed.	√	√	√	√	√	√	(Eastman et al. 2011; Moreno et al. 2013).

24	Building information is integrated and stored in BIM model for easy reference.	√	√	√	√	√	√	(Liu et al. 2010; Eastman et al. 2011; Abbasnejad & Moud 2013).
25	BIM involves the client and keep the stakeholders informed and satisfied.	√	√	√	√	√	√	(Hardin 2009; Lui et al. 2010; Eastman et al. 2011; Azhar 2011; Elmualim & Glider 2014).
26	Comparing between different options in a very short time.	√	√	√	√	√	√	(Eastman et al. 2011; Azhar 2012).
27	Quickly and easily Integrate new team member	√	√	√	×	√	√	(Jernigan 2014).
28	Overcoming distance barriers.	√	√	√	√	√	√	(Hardin 2009; Eastman et al. 2011)
29	Promote the designers' capacity and increases the competition	√	√	√	√	√	√	(Banzjanac 2005; Samuelson & Bjork 2010; Eastman et al.2011)
30	Bridge the capacity gaps with the international AEC professionals	√	√	√	√	√	√	(Eastman et al. 2011)
31	Reduce the inventory duration and order materials Just In Time (JIT)	√	×	√	√	×	√	(Elbeltagi& Dawood 2011; Eastman et al.2011).
32	Reshaping the procurement strategies to share the risks and rewards by using IPD.	√	√	√	√	√	√	(AIA 2007; Glick & Guggemos 2009; Moreno et al. 2013; Love et al. 2014).
33	Laser scanning for **existing**	√	√	√	×	√	√	(Eastman et al. 2011; Volk

	properties/services and (RFID) to automatically produce as-built drawings							et al. 2014)
34	Quick and accurate production of as-built drawings for **new** constructions.	√	√	√	√	√	√	(Kymel 2008; Jernigan 2014; Love et al. 2014).
35	Quick and accurate identification of the construction with the GIS integrated with BIM	√	√	√	×	√	×	(Irizarry et al. 2013; Mignard& Nicolle 2014; Rafiee et al. 2014)
36	Conformity with specifications, standards and codes	√	√	√	√	√	√	(Howard et al. 2008; Hardin 2009; Eastman et al. 2011; Sebastian 2011)

Table 1: Benefits of BIM

It is clear that the AEC industry highly benefit from the implementation of BIM as well as all the project supply chain and project stakeholders (Hardin 2009; Liu et al. 2010; Azhar 2011; Eastman et al. 2011; Elmualim & Glider 2014).

The aforementioned table 1 explicitly demonstrates that the client is the most benefit from the implementation of BIM with the highest score of benefits i.e. 36 out of 36 which depicts that the client is the only party reaping the full benefits of BIM. Olofsson and Eastman (2008) confirmed that “the client is the greatest beneficiary of using BIM”. However each party acquires the benefits of BIM based on his/her business function.

The following part will elaborate the most recognized benefits due to the implementation of BIM.

2.5.1 Implementation of BIM improves collaboration and integration for the AEC industry.

Egan (1998, p. 15) concluded that “Inefficiency and waste account almost 30% of the capital costs of construction and much of this could be avoided through integrated team work; such fragmented team work inhibits performance improvement and prevents continuity of teams that are essential for efficiency”.

Eastman et al. (2011) highlighted that, due to teamwork fragmentation in the construction industry approximately 10.6$ billion additional costs were incurred to the building owners and operators in the USA in 2002. In addition, Dulaimi et al. (2002) and Briscoe and Dianty (2005) suggested that "Integration between all key construction players could be successful if there is a complementary of management and advanced information system that enhance effective communication to ensure superior, reliable and transparent information flow between project teams".

BIM has several recognized benefits; one of the fundamental benefits that BIM offers is integration of the teamwork during the different phases of the project, starts at the early concept stage till the deconstruction stage. BIM gives an ideal environment of collaboration and effective communication amongst the project teams i.e. client, architect, engineers, contractor, subcontractors, suppliers, stakeholders and FM, etc. (Eastman et al. 2011; Arayici et al. 2011; Azhar 2011; Azhar et al. 2012; Bryde et al. 2013; Jernigan 2014).

Based on several case studies, many researchers and AEC professional executives affirmed that, BIM has the potential capacity to promote greater efficiency and harmony to integrate the fragmented AEC players, by enhancing sharing knowledge through an advanced communication software system such as BIM model. The open nature and easy accessibility of BIM model fosters the trust and transparency among the project teams (Carmona & Irwin 2007; Azhar et al. 2008; Hardin 2009; Grilo& Jardim-Goncalves 2010; Eastman et al. 2011; Elmualim & Gilder 2011; Migilinskas et al. 2013; Chan 2014).

Dainty et al. (2001) claimed that "one of the significant barriers to the supply chain players in UK that deters the teamwork integration is lack of trust and negative attitudes. However, utilizing of BIM enhances high transparency of processes which enhances the trust of all the project teamwork and promotes the collaboration to form an integrated teamwork. BIM applications such as project scheduling and planning using 4D tool integrates the work activities in a visualized model with high accuracy and reliability (Leich & Messner 2008).

In the same context, NBIMS (2010) defined BIM as "a technology and management tool that integrates teamwork through swift sharing of information and knowledge in an open virtual environment to enhance the transparency and trust amongst the AEC players".

Owners considered BIM model as an effective and open transparent communication channel that integrates the project teams during the project lifecycle, where all project parties can easily access, extract and share the same information (Hardin 2009; Liu et al. 2010; Eastman et al. 2011; Abbasnejad & Moud 2013; Jernigan 2014).

The following figure 3 demonstrates the collaboration among the project stakeholders due to the open environment that BIM model offers.

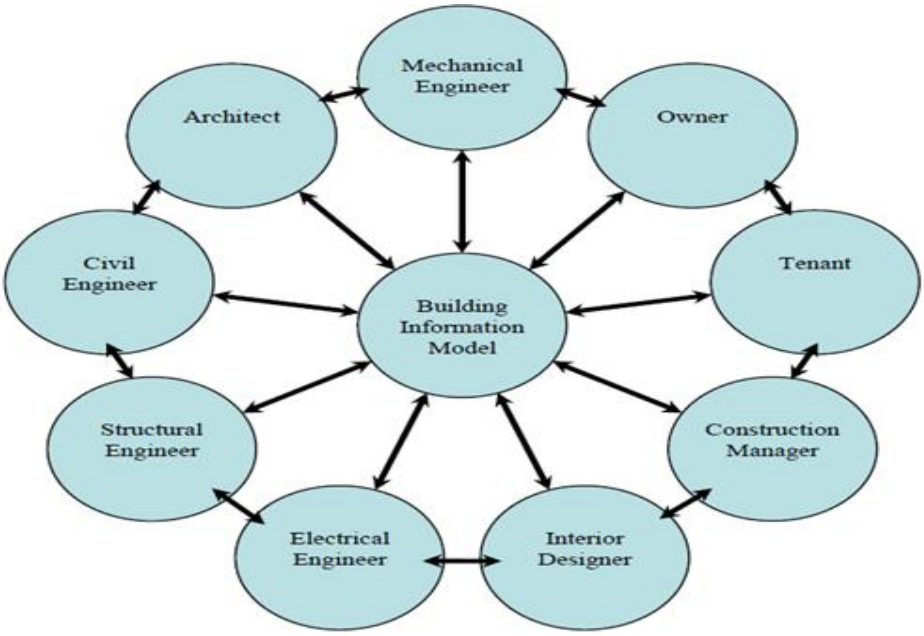


Figure 3: BIM is the premise of the collaboration and integration of the project team. (Courtesy of: holder construction, Atlanta, Georgia, USA).

In the last two decades, BIM is considered as the best technology and management tool in AEC industry that can integrate people, processes, systems and practices into a collaborative way. In addition to its capacity to reduce waste and promote the efficiency to overcome the AEC persisting problems (Glick & Guggemos 2009). Moreover, BIM model has the potentiality to improve communication, integration, interoperability, knowledge sharing, trust, certainty, client satisfaction and see the whole (Azhar 2011; Elmuailim& Glider 2013; Jernigan 2014). The aforementioned research proved with no doubts that, BIM has the capacity to integrate the fragmented nature of the AEC industry.

2.5.2 Client’s early involvement and decision

The AEC conventional methodology that is using 2D CAD design and construction is a linear process, where the preliminary design is done by the engineer, then developed as a final design after collecting the required approvals from different stakeholders. Finally, this final design is given to the main constructor who starts the construction and once the construction is completed, and the constructor has handed over the as-built to the client who in turn should deliver the same to FM team.

In this liner process the next phase cannot commence unless the previous is completed, which require close following up to deliver the task from one party to another. These linear processes hinder the collaboration among different project teams and needs the client to act as the project champion to follow up the successful delivery of each process (Love et al. 2014).

The current practices and the fragmented nature of the AEC industry is hindering the early involvement of the client in the design stage, where the client can only see the final design on 2D drawings after its full completion, which may be difficult for some clients to envisage the project details in 2D drawings (Jernigan 2014). The conventional methodology embraces tremendous lack of information, which deters the decision makers from responding appropriately to the arisen problems (Hoof& Ridder, 2004).

However, BIM model with its object-oriented capacity and 3D visualization and simulation tools is advanced software that promotes the client’s involvement and provides clear understanding for the design and construction for all parties. It also reduces drastically the ambiguities of the design and construction during the entire project lifecycle (Azhar et al. 2008; Yan et al. 2011; Barlish & Sullivan 2012; Moreno et al. 2013). The integrated environment offered by BIM ensures client early involvement, which commences at the early conceptualization stage till the demolition stage. The BIM model pledges rapid, correct and accurate updating for changes. BIM also fosters quick and accurate decisions based on reliable data to support the upstream project development processes to increase the confidence in completeness of scope to accomplish the project satisfactory outcomes (Manning & Messner 2008; Eastman et al. 2011; Jernigan 2014).

Moreover, clients can exploit the capacity of BIM of crossing the geographical distance barriers. By using a BIM model to consult a specialist or designers overseas with geographical restraints to suggest changes or advice to the client virtually, on the monitors for the same BIM model, in no time to assist clients for quick and right decisions (Azhar et al. 2011).

2.5.3 Acquired competitive advantage

The AEC by nature is highly a complex and competitive industry, therefore it is critical for business to know how to satisfy the clients and customers, so as to ensure sustainability to survive in such rival markets (Nzekwe-Excel et al. 2009; Eadie et al. 2013). Karna et al. (2009, p. 119) claimed that, "the organizations that succeeded to meet client satisfactions can form long term connections with the client to sustain in the market. That means client satisfaction is the main motive for organizations to add competitive advantage than its rivals".

Mitropoulos and Tatum (2000) suggested that, adoption of new suitable technology or processes is crucial to promote the organization's competitive advantage. The implementation of BIM with its recognized benefits offers enhanced ability for companies to compete in a wider spectrum of service areas and with different clients in the sophisticated markets, hence adoption of BIM ensures competitive advantage and continuity in the AEC markets (Liu et al. 2010; Moreno et al. 2013; Jernigan 2014).

Liu et al. (2010) concluded that, adoption of BIM is a very important aspect for architects, engineers, contractors, subcontractors and suppliers who can reap myriads of benefits of BIM to remain competitive in AEC market (Liu et al 2010).

Eastman et al. (2011) argue that, the wide implementation of BIM improves the designers' potential capacities. Whereas BIM models can be prepared in India for a client in the UK, that will apply massive pressures to all designers all over the world to improve their capacities, because with the use of BIM the competition is borderless.

In the AEC industry it is obvious that, few companies are having visionary leaderships, those visionaries regardless of their company size are eager to continuously improve, to adopt new suitable innovations such as BIM. That will enable them to maintain their company's competitive advantage to sustain in the markets; these companies are always ahead of the competition game. Companies with visionary leadership are not exposed to any type of pressure from their competitors. However, they are always ahead of their competitors to add competitive advantages and respond swiftly to market changes to win new projects (Moore et al. 2003; Ruikar et al. 2005; Liu et al 2010; Eadie et al. 2013).

The UK government adapted the compulsory policy to force the AEC industry players to invest in and implement BIM in order to win public sector contracts. The UK government exerts its influence on the AEC organizations to wholly integrate BIM into their work practices to survive prior to the deadline stipulated by UK government, where by 2016 BIM non-users will be excluded from any bid (Brewer et al. 2012; Eadie et al. 2013).

Mihindu and Arayici (2008) claimed that, over the past decade, many countries worldwide mandated BIM in their AEC industry such as USA, UK, South Korea, Netherland, Finland, Sweden, Norway, Germany, France, Singapore, Hong Kong, Australia and Canada. Failure to adopt the change to BIM would result in loss of competitive advantage and accordingly fewer chances to win new projects (Mitropoulos &Tatum 2000). Many researchers and executives identified the implementation of BIM as a great tool to add competitive advantage to the AEC organizations (Liu et al. 2010; Eadie et al. 2013; Eastman et al. 2011; Elmualim& Gilder 2014).

2.5.4 Reliable sustainability analyses

Wright and Broose (2011) defined the sustainability as “a system or process that can be continued indefinitely without depleting any of material or energy resources required to keep it running”. However, the most agreed definition for sustainability among sustainability specialists has been articulated by the World Commission on Environment and Development through the united nation report published in 1987, WCED (1987, p.37) defined sustainability as “a form of development or progress that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

The current practices for AEC industry deemed to be against the sustainability principles, where buildings operations consume 40% of the global energy, which significantly contributes to the global warming to threaten the future of the forthcoming generations (Schueter & Thessling 2008). This alarming fact reveals the crucial need to build smart building by considering the building sustainability analyses during the building lifecycle. Therefore for the last three decades smart building with low energy consumption are the governments and environmental institutions overriding concern to reduce building energy consumption and to reduce the subsequent environmental impacts to the naught during the building life-cycle i.e. pre-design to demolishing (Azhar & Brown 2008; Schueter et al. 2009; Park et al. 2012).

In the conventional non-BIM design practices, the early involvement of sustainable assessment design analyses is not possible because many data are not available due to the linear sequencing nature of the conventional design. Using this conventional design means that sustainable assessment can be performed only after the production of the final design and construction documents (Soebarto & Williamson 2001; Schessling 2009; Nguyen et al. 2010). Thus, the traditional 2D design and construction method i.e. non-BIM gives little thought to the operational phase from sustainable point of view (Sassi 2006; Vakili & Boussabaine 2007). That is because the sustainable design performed at the late stage is always controlled by confined options, which lead to the adoption of bolt-on solutions rather than proposing effective solutions to fix the unsustainable design. This is due to the extreme difficulty of proposing big design changes at the late stage of the building design already developed, because of the client and stakeholders concern about the time for redesign and changing the project delivery date and the additional costs. That means, efficient sustainable design should be at the design's early stage and starts with the conceptual design to achieve the design of smart sustainable buildings (Ding 2008; Schluter & Thessling 2009; Azhar 2012).

In the last two decades, BIM has emerged as a promising software technology and management tool. That is proven its significant ability to overcome most of AEC traditional problems in terms of building sustainability analyses. It compares and evaluates the building's energy consumption during the building's different phases to precisely predict the building performance starting from the building's conceptualization, design, construction and O&M till the building's demolition phase (Kymel 2008; Eastman et al. 2011; Moreno et al. 2013).

BIM tools such as simulation and visualization are used to determine and evaluate the building's future performance with reliable accuracy. A BIM simulation tool linked to design rating analyses measures such as LEED and BREEAM. BIM enables demonstration of the best orientation for the building to save energy consumption based on the sun's direction, sound levels, wind speed and direction, light affection, spatial performance and building envelope (Arayici et al. 2011; Azhar et al. 2011, Hardin 2009; Abbasnejad & Moud 2013).

In addition to the ability of BIM to compare and simulate the indoor energy performance details such as different MEP options according to the specifications that have been uploaded to the BIM software, these comparisons are implemented in no time to select the best option. This means that appropriate selections are made for the building throughout its life-cycle in terms of energy saving, best materials used, cost and time saving etc. That means the final design implemented by BIM carries sufficient flexibility to accommodate possible changes for long term sustainability during the building lifecycle (Prins 1992; Osapuolet 2012; Eastman et al. 2011).

2.5.5 Control of the site construction

Major causes of project failure occur at the construction phase; however, the supply chain can benefit enormously from BIM to improve the construction performance (Vesely et al. 2002; Kazaz et al. 2012). The current non-BIM construction practices are lacking in appropriate site control (Egan 1998). BIM is an appropriate process and management tool, which should be considered by the Project Managers (PM) as a way to manage construction projects (Bryde et al. 2013).

A 3D model provides a great visualization tool enabling designers, contractors and clients to work together to identify and resolve problems with the help of the model before walking on-site. In the traditional way of construction, most clashes are identified when the contractor receives the design drawings and everyone is on-site and construction work started, so clashes are detected late during the construction. Therefore delays are caused and decisions need to be made very quickly in order to provide solutions. However, BIM has the potential capacity to identify problems such as clashes between different designs, early in the preliminary design phase, and hence the detected problems are resolved before construction begins which save time and money and to promote the money value and efficiency (Abbasnejad & Moud 2013).

Supply chain teams can also benefit from BIM 4D detailed scheduling and visualization, to demonstrate the entire building’s lifecycle. This accurately determines the duration of each construction task, the upcoming tasks and the associated equipment, logistics, materials and resources requirement for JIT and site delivery to promote the quality and save time and cost (Grilo & Calves 2010; Azhar 2011; Eastman et al. 2011). If further design changes are made for any reason, the BIM model will be able to automatically identify those changes, which may affect the critical path and indicate the corresponding impacts on the overall delivery of the project (Abbasnejan & Moud 2013). BIM virtual model enables checking and evaluation for all changes prior to physical implementation to avoid abortive works, time and money loss too (Carmona & Irwin 2007).

BIM enables the contractor to develop the construction documents such as drawings, procurement details, and material submittals easily and swiftly because quantities and materials can be precisely and quickly taken-off from the BIM model using 5D and 3D tools (Khemlani 2006). The BIM model defines precisely what needs to be purchased; it is possible to place purchase orders directly using BIM model. Purchasing orders are well correlated to the 4D project plan to ensure no waste of material or time to conform to Lean Construction (LC) principle (Eastman et al. 2011). Moreover, BIM model enables checking the procurement status for services and materials, by tracking the status of these activities. Project planners can perform queries to easily identify gaps in the procurement process as they relate to design and construction. By linking the schedule to the BIM model, it is also possible to visualize where procurement delays are likely to impact the construction (Eastman et al. 2011).

BIM model used to track the construction progress by visual tracking and contrasting the variances between planned budget and actual cost, to recognize where these variances are occurred, to identify the key problems to propose the appropriate course of actions (Hajian & Gerber 2009; Eastman et al. 2011).

The traditional 2D CAD drawings carries design inaccuracy and uncertainty, which makes it difficult to fabricate materials offsite, as a result most activities and construction must take place onsite and only after exact conditions are established. Onsite construction work is always costly, more time-consuming and prone to produce errors and poor quality. That would not occur if the work done in the factory, where the cost is lower and the quality is better, onsite activities produce tremendous amount of construction waste (Ortizet et al. 2010; Eastman et al 2011).

Azhar (2011) and Nawari (2012) reported that, BIM models have innumerable advantages in the offsite construction domain including, speed, economy, sustainability and safety as it is saving huge number of labors at the construction site to reduce the chances of accidents, in addition to less construction waste.

A study of BIM on large healthcare projects in the USA revealed that it is possible to achieve 100% prefabrication for mechanical system installation with zero clashes in MEP installation activities. This in turns yielded 20-30% labor saving for MEP sub-contractors and saving further up value chain (Olofsson & Eastman 2008).

BIM and lean construction principles work hand in hand to significantly reduce the construction waste (AIA 2007; Azhar 2011; Eastman et al 2011). A case study for the Greater Cairo conducted by Omar and Dulaimi (2014) concluded that, BIM ensures JIT arrival of people, equipment and materials to significantly reduce the construction waste by 54-84%.

In addition, BIM model used to evaluate and appropriately plan the site logistics preparation, by visually watching the space for tower cranes, store yards and site offices to save the cost and time for unplanned location of any construction logistics may require to be moved due to clashing with later site activities (Abbasnejan & Moud 2013).

2.5.6 Error-free design

Egan (1998, p.7) concluded that, one of the greatest barriers for improvement in the AEC industry is that too many clients still selecting designers and constructors based on the lowest price only. Lopez et al. (2010) has extensively studied the causes of the design errors and preventions in construction and concluded that, main causes of design errors in the AEC sector are as follows:

- **People**: People with poor skills, poor integration and collaboration amongst different design teams and inadequate consideration for the constructability.
- **Technology**: Ineffective utilization of technology and automation.
- **Process**: Inadequate quality assurance to check project specification, code compliance and clashes among different design teams.
- **Time constraints**: Estimated time for design is not adequate to complete error-free design.
- **Client**: Uninformed client hinders early decisions and collaboration between client and the design teams.

Changing any part of 2D CAD drawings requires all the other relevant drawings must be changed accordingly and need to be updated one by one; this process is an error-prone process which is of the major cause of document errors and poor documentation. Thus traditional 2D CAD drawings carry inconsistency, inaccuracy and uncertainty in design (Azhar & Richter 2009; CRC construction innovation 2007; Eastman et al. 2011). Therefore, there is a crucial need to change to adopt a technology that can overcome all the aforementioned weaknesses during the design stages. That is directly steering to the implementation of BIM, to produce an error-free design.

The use of BIM eradicates the chances for design errors, where BIM models consist of objects which are defined in terms of building elements and systems such as spaces, walls, beams, foundations, columns, windows, doors and ducts, etc. these objects are in 3D formats. These objects are defined as parameters and not isolated creatures so changes in one object will automatically change all other related objects. Hence, making changes in the design phase is accurate, fast and easy and an error-free process (Hardin 2009; Eastman et al. 2011; Azhar et al. 2012; Abbasnejad & Moud 2013; Jernigan 2014).

Moreover, one of the main reasons for the design-errors in AEC industry is the fragmentation of the design teams, where design teams usually acts independently of each other or may be against each other (Sebastian 2011; Elmualim & Gilder 2014). Implementation of BIM integrates the different design teams through a healthy environment of trust with a robust and reliable open communication channel, to share the same information. In addition to the ability to extract and add to BIM model in order to develop BIM final model after detection and correction of any clashes (Migilinskas et al. 2006; Howard et al. 2008; Arayici et al. 2011; Love et al. 2011; Farr et al. 2014).

Using BIM tools enhances the control of the design inputs, through early detections of clashes and errors from different designers, in addition to specifications and project codes compliance checking (Howard et al. 2008; Hardin 2009; Eastman et al. 2011; Sebastian 2011; Osapuolet 2012). BIM model improves the design quality including error-free drawings that significantly reduce the risk interconnected with the change orders and RFIs' (Kaner et al. 2008; Love et al. 2011; Jernigan 2014).

Eadie et al. (2013) claimed that, utilization of BIM tools such as clash detection can accomplish saving up to 10% of contract value and reduce project duration up to 7%.

These saving can achieve 15% of the project overall saving due to implementation of BIM. Kymel (2008) concluded that, designers can benefit from BIM by developing better design and rigorous analyses of digital models and visual simulation, receiving more valuable and early inputs from the project owner and stakeholders. Better code compliance via visual and analytical checks in addition to early forensic analyses to graphically assess potential failure, leaks, and evacuation plans and so forth.

The developed error-free design due to using BIM leads to an improved buildings and significant reduction in complications during the construction and post construction phases (Banzjanac 2005; Samuelson & Bjork 2010). It is evident that, BIM is currently the most common denomination for a new way of approaching the design, construction and maintenance (Succar 2009).

2.5.7 Meet client satisfaction

Latham (1994) in his report concluded, client satisfaction is one of the weaknesses found in the AEC industry. Moreover Egan (1998, p 7) claimed that, client dissatisfaction was found in public and private construction organizations alike, where the causes of client dissatisfaction are the late project delivery, poor quality and cost overrun.

Much research after Latham's and Egan's reports studied the client satisfaction and attempted to propose models to be followed to achieve the client satisfaction. It is obvious the today's construction market is more complex than before, because it is imposing tremendous competitive pressures on the AEC organizations. It is critical for business to recognize how to satisfy the client, so as to meet the customer and client satisfaction to ensure sustainability in the market (Dulaimi 2005; Nzekwe-Excel et al. 2009). Client satisfaction is the pivotal factor of business success, which adds competitive advantages, where the organization better able to meet the client satisfaction is needed than others and able to form long term customer connections (Karna et al. 2009). According to Chan and Tang (2001) client satisfaction is a function of the perceptions and expectations against the outputs. However Karna et al. (2009) argued that, there is no consensus assessment model or framework exists to evaluate the client satisfaction.

Many researchers have proposed measures to assess the client satisfactions; Holt et al. (2000) found the project cost is the most important measure to satisfy the client.

However Ling and Chong (2005) and Al-Momani (2000) found the delivered quality of the project is the most important parameter to meet the client satisfaction. Yang and Peng (2008) and Karna et al (2009) studied 22 factors for client satisfaction and concluded that; less cost, high quality, shorter time, and effective communication are the most important factors to meet the client satisfaction. Adamson and Pollington (2006) concluded that, the goal of the construction business is to deliver the best quality product to meet client's satisfaction on-time and within budget. Moreover, Nzekwe-Excel et al. (2009, p 173) identified cost, quality, safety and time are the most important four factors to meet the client satisfaction.

Many researchers found that, the factors to accomplish client satisfaction varies according to the client type, project complexity and location, stakeholders attitudes and some other factors (Karna et al. 2009). Much research proposed that; cost, time, quality and safety are the factors require great attention to meet any client satisfaction.

BIM offers significant benefits for construction projects and project owners through faster delivery, better quality, reduced project cost, time and risks (Building SMART 2011, Jernigan 2014). Implementation of BIM improves the productivity with high quality, shorter project time and reduced cost, which are the factors to meet the client satisfaction (Mihindu & Arayici 2008; Arayici et al. 2011; Barlish et al. 2012; Kang et al. 2012).

2.5.8 Reduce time and cost and increase quality

Egan (1998, p. 26) concluded that, the quality of AEC industry will never improve and time and costs will not reduce until the workforce adapt teamwork culture.

Several researchers and AEC professionals believe that, implementation of BIM saves the project time and cost through integrating the fragmented project players, where BIM is the central model for all involved actors through the project lifecycle. A BIM model can be accessed easily by all project members (Sebastian 2011; Bryde et al. 2012; Osapuolet 2012; Bryde 2013). It is obvious, BIM model can bridge the gap to avail a healthy teamwork culture among the AEC industry players to reduce the projects time and costs.

Implementation of BIM reduces the risks in all the project stages, by developing an error-free design starts at the pre-construction stage to devise an appropriate concept about the project and establish a reliable feasibility study. Then detecting the clashes in advance prior the construction started to significantly reduce RFIs, rework, and change orders. Accordingly contractual disputes will be reduced or even eradicated, which by turn promotes the trust among the project teams (Khanzade et al. 2008; Hardin 2009; Sinopol 2010; Eastman et al. 2011; Barlish & Sullivan 2012; Porwal et al. 2013; Jernigan 2014).

Moreover, early implementation of value engineering using 4D scheduling and 5D cost and materials estimation to compare the best option in 3D visualization and simulation, would significantly reduce the project time and cost. This process takes few hours where the same process in 2D CAD traditional methodology takes several weeks with less reliability (Howard et al. 2008; Hardin 2009; Eastman et al. 2011; Sebastian 2011; Osapuolet 2012)

Kunz and Gilligan (2007) and Liu et al. (2010) studied the benefits reaped by utilizing BIM and the clash detection and found that, clash detection saves up to 10% of contract value and up to 7% reduction in project time. However Liu et al. (2010) argued that, this saving go some-ways towards 15% of the project saving through use of BIM. This argument is recently fostered by Jernigan (2014) who studies several case studies in the USA to conclude that, new projects using BIM can save 8-15% of the project cost.

BIM promotes the client's early involvement to give a clear picture about the project through visualization and simulation of the project activities in different stages. BIM offers reliable and authenticated cost estimation and schedule for the project which enables fast consensus decisions which significantly save the project time and accordingly the project cost (Liker 2003; Koskela 2003; Arayici et al. 2011; Schade et al. 2011; Abbasnejad &Moud 2013).

The accurate error-free drawings developed by BIM increase the offsite prefabrication which promotes the quality and ordering of the materials to be delivered JIT according to the project schedule to reduce the inventory costs, damage chances and reduce the construction waste. Additionally, error-free drawings promote off-site prefabrication which will reduce the quantum of onsite activities to reduce the accidents and promote the delivered quality because of better quality control in specialized factories compared with site works (Salem et al. 2006; Liu et al. 2010). In addition, BIM and lean construction enhance each other to minimize the waste, which significantly saves the cost of the wasted materials and the time to clear these materials (Kaner et al. 2007; Liu et al. 2010; Eastman et al. 2011; Olotunji 2011; Barlish & Sullivan 2012)

BIM offers great opportunity for sustainability analyses and value engineering principle through simulation to compare and contrast different options to select the best; these options are rendered in 3D mode to give a reliable cost and time estimate for each option. In the same context, BIM can reduce up to 80% for the time required to generate cost estimate for a given design change to compare several options and to notify the client about the cost and time implications due to the design change (Azhar 2008; Osapuolet 2012; Jernigan 2014; Love et al. 2014).

Everett and Frank (1996) found that, the accident costs accounts 7.9-15% of the project costs. However, implementation of BIM significantly reduces or eradicates theses accident costs, where BIM fosters the safety plans through the utilization of project simulation and 6D tool to recognize the safety hazards, to readily prepare appropriate responses (Bhat & Gowda, 2013; Sebastian 2011).

Barret (2008) compared the cost for design and construction of a building to the required costs for O&M for the same building and found that, if the cost of design and the construction is 10 million for a building, then the required cost for O&M in 20 years will be 20 million. This means that the O&M costs required for a building in 20 years is double the AEC costs of the building. It is obvious the tremendous wastage in the O&M costs created from the unavailability of the correct information for the FM teams (Eastman et al. 2011). However, BIM produces authenticated as-built drawings for the building with all the required details for the FM teams to reduce the time and cost in the O&M stage by 8-35% of the O&M total cost (Kymel 2008; Jernigan 2014; Love et al. 2014).

Because of the reliable accuracy for BIM model and the variety of BIM tools such as material take-off (5D), production of error-free design (3D), sustainability analyses and construction monitoring (3,4D), BIM reduces contingencies and accordingly increase the Return On Investment (ROI) by three to four times (Hardin 2009). In addition, BIM improves productivity and increases quality through the automatic compliance checking to ensure the correctness of the drawings and the materials with the project specifications and standards (Hardin 2009; Eastman et al. 2011; Osapuolet 2012).

2.5.9 Improve Safety management

Egan (1998, p.25) claimed that, the decline of productivity in the construction industry is interrelated to the health and safety poor conditions.

It is not surprising to know that, the construction industry considered the second dangerous workplace compared with other industries, that is because of the high rate of accidents resulted in fatality, disability and injuries (Waethrer et al. 2007; Bhat & Gowda, 2013; Schofield et al. 2013). According to Bhat and Gowda (2013, p.105) "each year the accidents occurred in the construction industry resulted in 1.2 million death and 50 million injuries worldwide". Moreover, Hallowell (2011, p.592) claimed that "Poor health and safety conditions in the construction sites causes accidents which have a substantial impact on the construction projects and raised the overall project costs up to 15%".

Therefore, finding a solution to improve the health and safety performance was a great concern from health and safety specialists and the AEC players.

The practical experiences proved that, BIM offers a great opportunity to the contractors to analyze the safety performance and identify the safety hazards prior to starting the construction activities. That is through the utilization of 6D visualization tool to prepare an appropriate safety assessment plan (Hardin 2009; Zang & Hu 2011; Eastman et al. 2011; Barlish & Sullivan 2012; Moreno et al 2013). The 3D and 6D visualization tools are great education and training tools for the labors as well as the staff to visualize the hazards and to learn how to avoid or deal with them (Eastman et al. 2011).

Improvements in the safety performance avoid or reduce the site accidents accordingly avoid the idle man-hours (the injured) to foster the productivity rates. That is to avoid the financial implications due to the accidents i.e. mortal compensations or hospitalization and recovery costs (Waethrer et al. 2007; Bhat & Gowda, 2013). Moreover, implementation of BIM can convert the financial losses due to the site accidents to profits, as many construction sites were completed with zero accidents because of the implementation of BIM which promoted the organization's profits (Moreno et al. 2013).

2.5.10 **Benefits of BIM for suppliers and manufacturers**

Suppliers and manufacturers play a great role for the success of any construction project, however the suppliers and manufacturers facing myriads of challenges in the conventional (non-BIM) methodology.

Rickert et al. (2000) summarized these challenges as follows;

- Poor communication between the suppliers and the contractor or subcontractor.
- Poor information sharing between the supply chain players.
- Pressures and disputes due to the short duration between placing order and the required delivery date.
- Poor quality of the materials due to short duration for the delivery.
- Supplier(s) inflexibility and cost issues.
- Lack of early involvement of the suppliers or manufacturer.
- Continuous change orders which require materials changes
- Inaccurate delivery schedule due to change orders.
- Mistakes in the placed orders due to the mistakes in the drawings.

BIM utilization improves all the above weaknesses to avoid the traditional problems between the supplier and the contractor or subcontractor. Eastman et al. (2011) concluded that, BIM offers detailed information rich models of the building components, which can be integrated for manufacturing details to reduce information requests from the manufacturers and improves materials' quality. Moreover, BIM offers precise estimate for the material, using take-off 5D tool, to early place material orders which gives enough time for the supplier or manufacturer to deliver the materials. 4D BIM tool produce reliable delivery schedule for the materials to the site, BIM models also enable the suppliers(s) to be early involved in the design to add their experience and share their knowledge, for which the supplier considers himself/herself as a partner of the project success (Linderoth 2010).

BIM models with error-free design increases the offsite prefabrication, which by turns improves the suppliers' business to make more profits (Banzjanac 2005; Samuelson & Bjork 2010).

As a matter of fact, most of construction projects in the UAE are procuring overseas materials with distance barriers, especially MEP materials. However, Eastman et al.

(2011) claimed that, due to the implementation of BIM, the overseas communication is no longer a barrier, because overseas suppliers and manufacturers can easily access to BIM model to share, amend and extract the data via BIM model.

Implementation of BIM significantly reduces the contractual and financial implications between the supplier/manufacturer and the contractor or subcontractor; to save the supplier/manufacturer time and promote their business. Utilization of BIM guarantees delivery of the required materials in time with satisfactory quality and reduced costs. This is due to the supplier/manufacturer's early involvement and inputs in the design stage. BIM also offers for the suppliers and manufacturers appropriate communication channels, promote the knowledge sharing, and develop reliable design and schedule (Porwal & Hewage 2013; New Zealand BIM handbook 2014).

2.5.11 Benefits of BIM for facility management

The conventional construction method is linear sequential processes, where the generated drawings by the designers delivered to the constructors who will produce the as-built drawings after the completion of the construction. Due to these linear processes lots of important details are always lost; therefore the facility management suffers of the missed and lost data (Love et al. 2014). Newoton (2004) claimed that, 85% of the lifecycle cost of a facility occurs after construction is completed and approximately 10$ Billion are annually lost in the USA alone due to inadequate information access i.e. incomplete as-built and interoperability issues during O&M phase.

However using BIM reduces 8-35% of the O&M overall costs (Jernigan 2014; Love et al. 2014; Kymel 2008). Moreover, Philips and Azhar (2011) argued that,

> [T]he fundamental benefit of BIM model is that, it provides comprehensive information details about a building and its spaces, systems and components. The overall goal is to transfer these details to FM teams. The information about building system and equipment can be easily accessed for any equipment such as Variable Air Volume (VAV) box location, name, model number, product type, operation and maintenance manuals, commissioning information and performance data; this makes it very simple for maintenance worker to access the required information vital to different systems in the building.

One of the significant benefits offered by BIM is that, FM teams are early involved in the design stage to share their experience and requirements to be considered at the very early stage. BIM model contains complete information about a facility as it is evolves through planning, design and construction. This information can leverage for downstream use by facility managers, thereby the O&M of a facility is more efficient with BIM database, because any information about equipment is just one click away (Newoton 2004; Reddy 2011). That means, FM can use BIM model to click on any equipment and fixture to obtain full details about the product, warranties, lifecycle of the product, maintenance checks, replacement cost, installation and repair procedures and even place order for replacement and spare parts online (Jardani 2010; Sebastian 2011; Osapuolet 2012).

2.6 Summary of the benefits of BIM

Implementation of BIM can reshape the AEC industry to overcome the majority of its recognized persisting problems, by delivering better quality with low cost in a shorter time to meet the client and customer satisfactions.

Client and the supply chain benefit highly from BIM, where BIM improves productivity, integrates the project teams, improves communication. In addition to the ability of BIM that is promoting the sustainability of buildings to minimize the energy consumption. Moreover utilization of BIM produces error-free design, boosts offsite prefabrication, promotes safety management, and enables early involvement for the client and suppliers/manufacturers. In the construction stage BIM enables close control for the construction activities via reliable and accurate program of works. The utilization of BIM tools enables delivering of authenticated as-built drawings with full details for FM that is significantly reduces the O&M costs. The rapidly growing of the utilization of BIM in many countries worldwide, makes the AEC players and academic researchers strongly believe that, utilization of BIM transfers the AEC industry to a new promising era.

2.7 Challenges and obstacles hindering the implementation of BIM

The merits of BIM is well recognized by all AEC industry players, therefore BIM has been utilized in high profile and large projects, such as London 2012 Olympics, Veldodrome cycle track and the 48 floor Leaden hall building “The Cheese grater” which is one of the London’s tallest buildings (Bryde et al. 2013). BIM also utilized for complex projects such as EMP museum at Seattle center, Walt Disney Concert Hall, Shanghai World Expo cultural center, Washington national park, Shanghai tower; all these projects completed successfully in shorter time and less cost with better quality by using BIM (Chien et al. 2014). Therefore BIM is widely implemented worldwide especially in developed countries, however still some AEC organizations are facing challenges for the implementation of BIM (Elmualim& Gilder 2014; Eadie et al. 2014).

The following section will elaborate the major challenges and obstacles for the AEC organizations are intending or on the way to implement BIM. Based on conducting extensive literature review, the following section recognized the challenges and obstacles that diminish the chances of the implementation of BIM and classified them into five categories as follows:

1. Management challenges
2. Technical challenges
3. Surrounding environment challenges
4. Financial challenges
5. Legal/contractual challenges

2.7.1 Management challenges

2.7.1.1 Inadequate BIM experience (know-how) to change

The future of BIM is exciting and promising (Azhar et al. 2012). Some construction owners in the last few years started to identify BIM and insist on utilization of BIM from all AEC players in their projects (Mihindu & Arayici 2008). Traditionally adoption of BIM starts with the recognition of the benefits of BIM and how these benefits can promote the organization’s competitive advantage, increase ROI and eradicate the majority of the traditional AEC problems (Elmualim & Gilder 2014; Love et al. 2014).

Hardin (2009) claimed that, the implementation of BIM drastically changes the organizational culture, processes, the used technology, roles and responsibilities to restructure the organization chart. Therefore, BIM is not a ready-made solution; it has to be customized to suit each organization in accordance to its condition, characteristics and business function (Sebastian 2011).

The changing journey to adopt BIM commences at the organization’s recognition of its financial stands, technological improvement needs, and the organization’s level of flexibility to adopt changes (Eastman et al. 2011). However one of the barriers deters adoption of BIM is the organization lacking *know-how* to plan and proceed for the change to implement BIM. The adoption of BIM significantly changes the organization's culture and impacts most of the organization's reoccurring daily processes (Gu & London 2010; Arayici et al. 2011).

Gu and London (2010) confirmed that, there is a crucial need for an appropriate guidance to know where and how to start and to evaluate many issues to select the best route to implement BIM. A proper evaluation and assessment should be conducted to the organization's readiness to adopt the change, the required funding and the organization financial stand, what are the available tools and what are the required additional tools. In addition to know-how to work through the legal procedures and to identify the impacts on the organization's culture. Therefore it is very important for the top managements to know-how to change to BIM, otherwise the transition to utilize BIM would stop prior to starting.

(Gareis 2010) argued that, there is no or little experience and competence to manage implementation of BIM, hence learning from previous experience from others is important. However later study by Migilinskas (2013) concluded that, due to the uniqueness of each organization the virtual backgrounds and pre-prepared models for the implementation of BIM from the market best practices are superficial and not trustable. Furthermore, the Associated General Contractors of America (2005) claimed that, unlike many other AEC practices, implementation of BIM embedding management challenges, where there is no clear consensus on how to implement BIM.

Chien et al. (2014) and Osapuolet (2012) confirmed that, because of inadequate experience of the processes to change to implement BIM, the unknown risks and uncertainties could be barrier to implement BIM, which results in unwillingness for the implementation of BIM.

2.7.1.2 Inadequate support from the top managements to adopt BIM

Successful change in any organization regardless of its size should be adapted and supported by the top management (McKenna 2006).

In order to successfully implement BIM in the AEC organizations, top management should be convinced to support this change. They should be clear about the benefits of BIM and its influences to the organization and how it will improve the organization's performance to add competitive advantages, and how that will increase the profits

(Ruikar et al. 2005; Azhar 2012). Once the benefits of BIM recognized by the top managements, hence they are responsible to take a decision to make BIM as obligatory and lead the change to implement BIM (Linderoth 2010). Therefore top managements are playing a pivotal role of leading the organizational change (Burke 2010, Herold et al. 2008).

Implementation of BIM requires changing people, processes and technology, thus top management should be open-minded, ready and flexible for the change consequences (Arayci et al. 2011). Therefore, top managements who support the adoption of BIM are the change catalysts and leaders. They should have a clear vision and flexible plan to implement BIM, their vision including the benefits and impacts should be well communicated with all the employees to be ready to support the change (Hardin 2009). Therefore in the journey to the change to BIM, The change leader(s) should appropriately communicate, motivate, intellectually stimulate and inspire the employees to support and adopt the change (Bass et al. 2003). Bass et al. (2003) considered the high quality leaderships are the key factor to face any resistance to the change. Therefore it is obvious that, top management support is the hub of the success for any change within the organization.

However, top management may be not supportive to the implementation of BIM because they are not fully convinced of the benefits of BIM (Sharif 2011). They may see changing to BIM and its impacts on people, processes and the technology as risky or embedding uncertainties (Jimmieson & Griffiths 2005). Those top managements may adopt a watch and see policy to measure and evaluate the pros and cons of the implementation of BIM on other competitors (Ruikar et al. 2005; Linderoth 2010; Jernigan 2014). They may also see it is not required at this time and may be useful in future (Azhar et al. 2011). Top managements may think BIM is working only for complex projects (Chien et al. 2014). Or they probably see it is difficult for their small organization to adopt BIM due to the unaffordable costs required to invest in BIM (Kouider et al. 2007; Liu et al. 2010; Eastman et al. 2011; Migilinskas et al. 2013) Unsupportive top managements may also consider the costs required for the implementation of BIM is enormous to be spent in a short duration with considerable uncertainty for ROI (Azhar et al. 2011; Azhar et al. 2012; Moreno et al. 2013; Yan & Damian 2008; Won et al. 2013).

Dulaimi (2005, p. 7) argued that, “the change processes will be a source of frustration if the top management was not committed to this change and not willing to commit the necessary change requirements and resources”. Hence it is obvious that, top managements who are not committed to the implementation of BIM will use their power to hinder any attempts for the changes towards BIM. Therefore, it is clear that the biggest barrier to adopt BIM in the AEC industry is the lack of support and commitments from senior management (Migilinskas et al. 2013; Chien et al 2014). Moreover, several researchers affirmed that, top management support is the most important factor for the success of any change in the AEC organizations and also to avoid any critical barriers (Niazi 2009; Nielsen & Nielsen 2011; Eisenhardt, 2013; Hutzschenreuter & Horstkotte 2013).

2.7.1.3 **Resistance to change**

The AEC industry by its nature is a conservative industry and does not welcome change easily; therefore, adopting new technology such as BIM is a big challenge (Ruikar et al. 2005). This means that the reasons for the failure of many change initiatives can be found in the resistance to change (Padro & Fuentes 2003).

Implementation of BIM is about changing the processes, technology and people. People always dislike change because of the uncertainties that are attached to the change initiatives, and the comparison between current status quo (the comfort zone) and what might be after the change (Arayici et al. 2011; Simona 2012).

Most construction organizations are reluctant or conservative with regards to the use of new technology, because it has not been previously adopted or less organization tried and the benefits are yet tangible. Thus many organizations deem the change involves high degree of risks, so most construction organizations are not willing to take that risk but would rather wait and watch (Ruikar et al. 2005; Linderoth 2010; Jernigan 2014).

Adoption of BIM necessitates dramatic changes in the staff’s daily routine work, which is greatly resisted especially from the old and senior staff, because of the fear of lack of success or the impact of change on them (Ruikar et al. 2005; Jordani 2008; Migilinskas et al. 2013).

For successful implementation of BIM, the change should not be forced (Ruikar et al. 2005). However the employees’ fears and reservations should be fully understood. For example where employees’ resistance starts with the wrong perception about the need for the change or in some cases the new change may threaten their employment (Griffiths et al. 2000; Holt 2002; Pardo & Fuentes 2003; Ruikar et al. 2005).

Some employees or top management will suffer from the implementation of BIM because of forfeiting their authority; hence they will try to survive by using their power to resist the change towards BIM rather than accepting it (Beer & Eisentat 1996; Eastman et al. 2011).

Therefore, for successful implementation of BIM, all staff should be motivated to be supportive to switching to BIM, by understanding the potential and the value of BIM compared to the 2D conventional drafting method. In addition, employees need to know why that change is important not just to the company but to them too (Ruikar et al. 2005; Gareis 2010; Arayici et al. 2011). Moreover employees should understand that; organizations can survive in a dynamic competitive market only by responding to the market changes and by adopting important changes such as BIM, to move from the present state towards future state to increase its benefits and competitive advantages to be sustainable in the market (Ruikar et al. 2005; Gareis 2010).

Jung and Joo (2011) suggested that the changing strategy should be segregated to specific levels of adoption and for easy control to ensure the speedy and successful implementation of BIM.

One of the most successful models for change which could be followed to accomplish the implementation of BIM, was devised by Kotter (1996) who segregated several steps starting with “establishing a sense of urgency for the change which need to be conveyed to the employees, creating a guiding coalition for the change, develop an appropriate vision and strategy suitable for the employees and the organization according to its status quo. Change should be communicated to all employees, to empower others to act on the vision. Other measures could be used such as creating short win plans, consolidating improvements and sharing the success with employees. Producing more change and anchoring the new approaches to prevent employees from “slipping to the old ways”.

Therefore the top management who succeeded in communicating and convincing the employees with their vision of change, the change will be swiftly and easily implemented, because the change will be bottom-up (Waddell & Sohal 1998).

Arayici et al. (2011) concluded that effective change starts at the employees' level and is supported by top managements. In this way bottom-up approach is easier than the top-down approach, which is likely to be resented by employees with several levels of resistance and little succeeded. Hence it is clear that, resistance to change is one of the major challenges and obstacles that impede implementation of BIM (Yan& Damian 2008; Sebastian 2011; Elmualim& Gilder 2014; Eadie et al. 2014).

2.7.1.4 Difficulties correlated to workflow transition due to changes in roles and responsibilities

Replacing the 2D CAD environment with BIM involves more than acquiring software, it is about changing the processes, people and the technology. Implementation of BIM requires changing almost every aspect of the business within the firm, such as changing the existing strategic management's methods and practices (Arayici et al. 2011; Eastman et al. 2011; Love et al. 2014).

For effective implementation of BIM, managers and employees are required to fundamentally change their behavior, not just doing the same things in a new way but entirely change the way of their thinking and behaving, which require familiarizing themselves with the new processes, roles and responsibilities (Elmualim& Gilder 2014; Love et al. 2014). Therefore, Turner and Crawford (1998) claimed that, any change on the organizational level requires reshaping capabilities to fit the new changes. Thus adoption of BIM involves rearranging roles and responsibilities within the organization (Linderoth 2010).

Accordingly, Heitgar and Doujak (2008) claimed that, the major challenge of rearranging roles and responsibilities lies in the hard cuts and new growth. Consequently, some traditional roles such as draftsman may become obsolete and replaced by BIM modeler; new roles may be created such as BIM manager who should be responsible for coordination, control, development and updating BIM model (Gu & London 2010; Sebastian 2011).

According to Oyediran and Odusami (2005) and Oladapo (2006) the utilization of technology such as BIM will create unemployment to quantity surveyors and other professions, which explicitly indicates an active resistance to implementation of BIM from the affected professions.

At the outset of successful implementation of BIM, the workflow transition faces difficulties where employees are overwhelmed in a short-time with lots of tasks (Chien et al. 2014). Therefore, the disruption in the workflow caused by the implementation of BIM requires time for the learning curve for employees to familiarize themselves with the new processes of the new roles and responsibilities (Moreno et al. 2013).

Hence, implementation of BIM significantly changes the old ways and practices, which require time for training and education to be familiar with the new methodology and technology (Eastman et al. 2011). Accordingly, leaders should help people to quickly absorb the workflow transition by anticipating sub-par performance and attitudinal problems and be ready to support, educate, train, retrain, encourage, rewarding and sharing the success with the employees to adapt the change (Craig & Julta 2001; Simona 2012).

Generally, the organization with a flexible culture is supportive to innovations and more conducive to the successful implementation of changes than organizations with inflexible organizational culture (Dulaimi et al. 2002; Jones et al. 2009). Many studies explicitly manifested that, the difficulties compounded with the workflow transition of roles and responsibilities are one of the long-term challenges facing the leaders who lead the change to implement BIM, which requires prudent and flexible plans.

2.7.2 Technical challenges

2.7.2.1 Inefficient Interoperability

To complete a construction project it requires a collection of experiences and potentials from different parties such as architects, structural designers, MEP designers, contractors, subcontractors, client, suppliers and FM teams at the different stages during the project lifecycle. These parties may use different software programs (Hardin 2009). Each party will select the software suitable for their specialty and business function to effectively finish their task, i.e. architects may use software not used by the structural or MEP designers and the contractor is using different software not compatible with the engineer or suppliers and so forth, these variances and incompatibility of software create a big barrier to exchanging and abstracting the data from or to the BIM model (Weygant 2011; Bryde et al. 2013; Migilinskas et al. 2013; Chien et al. 2014).

However, the BIM hub is about collaboration and integrating different teams by sharing and exchanging the data of the BIM model, whereas different software used by different parties creates interoperability barriers. That hinders the data exchange and abstract from or to the BIM model (Wikforss et al. 2007; Linderoth 2010; Eastman et al. 2011).

Therefore the term “interoperability of BIM” was proposed, as the ability of different BIM users to exchange the details of BIM models in different software with the ability of extraction, amendments or changing the details of any counterparty model. Therefore, interoperability is vital feature for team collaboration and integration of the BIM final model (Eastman et al. 2011, Azhar et al. 2012).

Smith and Tardif (2009) confirmed that interoperability was a big challenge to BIM users. However, since 2007 the interoperability pertinent problems have been significantly reduced because of the introduction of Industry Foundation Classes (IFC) scheme which significantly helped to solve the interoperability issues.

IFC is defined as an international public standard schema collectively developed by BIM software vendors. IFC enables the opening or importing BIM files to reuse the created data in other applications using different software; IFC schemes can overcome the problems of using different software for BIM models (Smith& Tardif 2009; Liu et al. 2010; Eastman et al. 2011; Ku &Taiebat 2011; Thein 2011).

However, Azhar et al. (2012) argued that, even with Industry Foundation Classes (IFC) and similar schema such as Extensible Markup Language (XML), the interoperability issues still posing considerable risks for data exchange and interoperability for the use of BIM models among different teams, because both of these approaches have their inherent limitations.

2.7.2.2 **Difficulties of managing BIM Model**

The BIM model is accessible to all project teams i.e. architect, structural designers, MEP designers, sustainable analysis, contractors, subcontractors, suppliers, clients and FM. These different teams can abstract data and modify the BIM model anytime to continuously create a new version of BIM model (Eastman et al. 2011, Azhar et al. 2012; Chien et al. 2014). The flow of data and the changes of BIM model trigger a great risk if the BIM model is not well managed and controlled. That means BIM model could be exposed to drastic errors, losses of liabilities which result in contractual implications and the failure of the project (Gu & London 2010; Azhar et al. 2012).

Hence, there is crucial need to assign a person to manage and control the BIM model, the position of model manger or, alternatively called BIM manager is important to eliminate the uncontrolled BIM model correlated risks. By controlling the flow of data from or to the BIM model, the BIM manager will be the sole person authorized to enter the data for the master BIM model to develop the BIM final model (Thompson & Miner 2007). The master BIM model is a collection of several BIM models from different teams. Accordingly, the final BIM model is then developed, which is free of any errors or clashes and ready for the use by the constructor (Hardin 2009; Eastman et al. 2011).

It is claimed that, the model manager should possess Information and Communication Technology (ICT) experience, construction experience, excellent experience of BIM software and communication management skills, because he/she is dealing with the BIM system and project actors (Inpro 2009). The main task of the model manager revolves around the responsibility of managing the information flow and updating the data and ensuring its accuracy in the final BIM model. He/she receives BIM models in various software format from different teams and converts it to a single master BIM model, running the clash detection for these models, delivering the electronic drawings and specifications to the contractor for implementation, preparing the as-built BIM files to be used by FM (Hardin 2009, Eastman et al. 2011; Brewer et al. 2012; Sebastian 2011; New Zealand Handbook 2014).

Therefore, the model manger is deemed the regulator and facilitator of the BIM model. He/she should not take any decision on design and engineering solution nor the organizational processes. His/her responsibility should be focused on development of the BIM model and leave the engineering solutions to designers and similarly management issues to PM (Hardin 2009; Sebastian 2011).

The Model Manager may be assigned by the client directly to act impartially or may be hired as an extension to another consultant’s role to be included in the consultant payment pattern (Azhar et al. 2012; New Zealand Handbook 2014). This means that, prior to starting the project the model manager and his/her payment schema should be well defined (Osapuolet 2012).

Sebastaian (2011) and (Jernigan 2014) believe that, architects with excellent experience of BIM are the best to act as model managers because they synthesize information and management capabilities of a complex processes at a very high level and have accomplished success in previous projects implemented by BIM.

However, due to the scarcity of BIM professionals, finding a qualified BIM/model manager with the required experience pattern is not an easy task. This is considered by professionals as one of the major barriers for the implementation of BIM (Moreno et al. 2013). This is more difficult for those industries that recently started to utilize BIM such as the UAE AEC industry to find the adequate number of BIM professionals and qualified BIM manager.

2.7.2.3 Lack of **skilled resources and complexity of BIM software**

Although, BIM is rapidly growing in the last two decades, however still there is tangible lack of qualified and skilled BIM software operators (Aouad et al. 2006; Chan 2014). Arayici et al. (2009) commented that the skill gap has arisen due to the fast implementation of BIM worldwide and the available skilled resources are fewer than the tremendous demand. It is claimed by several researchers and executive professionals that BIM software is more complex and requires a long time to train the in-house staff compared with the conventional 2D CAD software (Liu et al. 2010; Arayici et al. 2011).

Consequently, the AEC executives and researchers maintain that the tremendous market demand, and the length of time required for training due to the complexity of BIM software are the main reasons behind the lack of availability of BIM capabilities in the AEC market (Liu et al. 2010; Linderoth 2010; Ku & Taiebat 2011; Eadie et al. 2013; Migilinskas 2013).

In light with the belief of BIM is the future for the AEC industry and to overcome the market unavailability of BIM skilled resources several researchers suggested that, governments should establish clear guidelines for BIM training programs to be included in the AEC students’ curriculum at university. Moreover, BIM software vendors should support the AEC industry by developing training programs to enable the trainees to cope with the latest BIM skills in the shortest time (Gu & London 2010; Azhar 2011; Hore et al. 2011; Chan 2014). By implementing these two approaches within few years skilled BIM operators will be available to adequately respond to the huge demand of BIM skilled operators.

Hence it is clear that lack of available BIM capabilities in the AEC market is considered as one of the biggest hindrances to the implementation of BIM (Moreno et al. 2013; Chien et al. 2014; Elmualim & Gilder 2014).

2.7.3 Surrounding environment

2.7.3.1 Lack of demand from the governments/clients to use BIM

Implementation of BIM entails several financial, legal, contractual, managerial and cultural challenges, because switching to BIM is changing the processes, people and technology (Hardin 2009; Lu & Li 2011). Eadie et al. (2013) and Chan (2014) indicated that, it is difficult to change the mindset of private clients within a short time to pay more for implementation of BIM. Consequently, some AEC organizations and clients are not willing to immediately implement BIM and they rather prefer the “wait and watch” strategy to evaluate the impact on the business, the benefits and challenges of the implementation of BIM to their competitors who have already adopted BIM (Eastman et al. 2011).

Chan (2014) confirmed that, in order to mandate BIM in AEC industry, governments and clients should take the lead to increase the demand for the implementation of BIM. A live example of BIM leading country is the UK who adopted a strategy to impose BIM as an industry practice for the AEC projects, and decided that by 2014 not to consider any contractor in forthcoming government contracts without BIM. This means that, the AEC organizations are striving to implement BIM before the deadline stipulated by the UK government (Porwal & Hewage 2013). Similarly the goal of South Korea is to make BIM compulsory by 2016 for all public projects and for non-public projects with a value over 50$ million (Brewer et al. 2012).

The governments or private clients’ lack of commitments to impose BIM in the construction projects explains why the level of implementation of BIM in MENA and some parts of South America is still modest compared with other leading countries such as the UK, USA, Finland, Australia, New Zealand and Norway (Issa 2011; Porwal & Hewage 2013).

Due to the recognized benefits of BIM Dubai Municipality has adopted the forcing strategy and imposed BIM as a compulsory requirement to specific building projects since the 1st of January 2014(Circular 196, 2013), which explains the boom in the implementation of BIM in Dubai compared to other emirates such as Sharjah, Ajman, Umm Alquwain, Fujairah and Ras Alkhaimah.

Several researchers and veteran professionals claimed that, the largest impediment to use BIM in AEC projects is the lack of demand from the governments/clients to use BIM as a compulsory requirement (Kunz & Gilligan 2007; Brewer & Gajendran 2010; Eadie et al. 2013; Won et al. 2013; Chan 2014). It is obvious from the recognized benefits of BIM that, the client is the most beneficiary from the implementation of BIM (Olofsson & Eastman 2008; Eadie et al. 2013). That means governments and clients can play an active role to rapidly mandate BIM in the AEC industry.

2.7.3.2 **Not all stakeholders are using BIM**

The basic premise of BIM is integrating different stakeholders at different phases of the construction project life cycle, which enables different stakeholders to share the BIM model data (Grilo & Jardin-Goncalves 2010; NBIMS 2010; Sebastian 2010, Farr et al. 2014).

It is obvious; the AEC players can only reap the full Benefits of BIM once it has been broadly adopted throughout the AEC industry. It is difficult for an organization to fully reap the full benefits of BIM while other stakeholders in the same project are not using it (Liu et al. 2010; Linderoth 2010; Elmualim & Gilder 2014). That means, if one party is using BIM and the other parties in the same project are not using BIM, the data exchange will be a big problem and collaboration among the project teams will never be achieved. Therefore, stakeholders' lack of commitment to utilize BIM is deemed a great drawback to those who are willing to use BIM or already using BIM (Eastman et al. 2011; Ku & Taiebat 2011).

One of the recognized gaps within the supply chain for the implementation of BIM is that, it is difficult for small organizations to adopt BIM due to the high cost required to invest in BIM within a short time. Thus, it is difficult for small subcontractors or architects involved in a project to use BIM (Kouider et al. 2007; Liu et al 2010; Eastman et al. 2011; Migilinskas et al. 2013). In addition to the high expenditures required to invest in utilization of BIM, some companies are not adopting BIM due to lack of need or no request by clients to use BIM and lack of qualified BIM resources (Gilligan 2007). Hence it is claimed that, utilization of BIM for AEC organizations should be compulsory and at the same time with a deadline date to bridge any gap could be created by one of the supply chain players who is not willing to implement BIM (Linderoth 2010; Eadie et al. 2013).

It is obvious; the lack of commitment from some parties within the AEC industry to implement BIM is recognized as huge barrier that demotivate others to implement BIM. In addition, that lack of commitment is negatively affecting the BIM users to fully reap the benefits of BIM (Eadie et al. 2014).

2.7.4 Financial challenges

2.7.4.1 Costs associated with the implementation of BIM.

Implementation of BIM requires huge funds within a short time, as the AEC organization must purchase the software and hardware licenses which are expensive, and then train the staff how to use the software in accordance with long term training programs because of software complexity, purchasing licenses and staff training require high initial investment costs (Thompson & Miner 2010; Bryde et al. 2013; Chien et al. 2014; Eadie et al 2014).

Other types of initial costs required for the implementation of BIM is hiring BIM experts i.e. BIM consultancy services to seek advice for a BIM execution plan and to assist the organization to select the most appropriate software adequate for their business function and to advice the training plan and the required BIM resources (Azhar et al. 2012; Moreno et al. 2013). Moreover the additional remunerations for the trained employees to keep them in the company, especially there are irresistible financial incentives for BIM operators to move to other companies due to the considerable lack of BIM resources. In addition, there are other types of costs created due to the management time spent in planning, implementing, evaluating and organizing the integration of new systems into the work practices (Ku & Taiebat 2011; Love et al. 2013; Migilinskas et al. 2013).

Ruikar et al. (2005) concluded that, implementation costs of a new technology is a great barrier for SMEs, especially if SMEs’ are always forced to adopt the change by spending a huge amount of money within a short duration.

However, several researchers claimed that, the impact of the huge investment required to implement BIM varies from one organization to another, according to several factors such as the financial stands, organization size and internal readiness to adopt new technology (Ruikar et al. 2005; Kouider et al. 2007; Liu et al. 2010). Hence based on much research, case studies and AEC professionals feedback, the costs associated with implementation of BIM is deemed one among the most significant barriers for organizations to implement BIM, because a huge cost is spent in a short duration with considerable uncertainty for ROI (Yan & Damian 2008; Azhar et al. 2011; Azhar et al. 2012; Moreno et al. 2013; Won et al. 2013).

However, Chain (2014) proposed a solution that:

> [g]overnments can play a significant role to facilitate the implementation of BIM in the AEC industry, by providing training programs to educate organizations' staff on how to implement and use BIM, governments should offer awareness sessions through professional institutes and academia to promote the organizations' awareness of the significance and benefits of BIM, to encourage them for investing in BIM.

Similarly, Hore et al. (2011) suggested that, in order to facilitate and encourage implementation of BIM in the AEC industry, governments should subsidize the training programs with a close collaboration from software vendors.

There are records and evidences that some governments who enforced implementation of BIM supported the AEC organizations for swift transitions. Morrell (2010) stated that, the UK government is mandating BIM for all AEC activities; hence the government pledged its support to promote the use of BIM through the UK government's supporting program to organizations. Moreover, Singapore Building and Construction Authority (SBCA) fully subsidized training programs to assist organizations to educate their employees for BIM; the goal of SBCA is to mandate BIM by 2015 for all its public projects (Brewer et al. 2012).

2.7.5 Legal and contractual challenges

2.7.5.1 Unclear Intellectual Property Rights (IPR).

Compared to the 2D traditional CAD drawings, the BIM model is replete with electronic information that is ready to be transferred between the project players in an open platform. Project teams such as architects, designers (structural and MEP), sustainable analysts, contractors, and suppliers can extract and reuse the data and modify it to form the BIM model (Porwal & Hewage 2013; New Zealand BIM handbook 2014). After the completion of the project the client will hand-over the BIM final model to FM team for their use during the O&M stage (Lewis et al 2010; Porwal & Hewage 2013).

It is claimed by several researches and AEC professionals that, if the client is paying for the designers/engineers to produce BIM final model, then the client sees himself/herself as entitled to ownership of the BIM model; however, the designers, suppliers and contractors who fully or partially participate in the design see themselves as insecure for their IPR regarding their inputs for the BIM model (Eadie et al. 2010; Eastman et al. 2011; Azhar et al. 2012; Oluwole 2012). Liu et al. (2010) claimed that, still there is a great fear of sharing BIM model because of unclear responsibility and unprotected IPR associated with its use. Many researchers considered the IPR of BIM model is one of the vague sovereign and deemed as a barrier for implementation of BIM in AEC industry. That is because the lack of contractual conditions and standards determining the ownership of the data within the BIM final model (Ku & Taiebat 2011; Sebastian 2011; Azhar et al. 2012; Elmualim & Gilder 2014; Migilinskas et al. 2013; Chien et al. 2014; Eadie et al. 2014).

However, Chao-Duivis (2009) claimed that, the liability and the IPR for the inputs of the BIM model can be easily traced, as the ownership of the building outlines created by architect who will be held liable and the owner for his/her input to the BIM final model. Similarly the electricity designed part will be the liability and ownership of the electrical designer and so forth. On the other hand, Thompson (2001) stated that it is very important to stop disincentives or inhibitions that discourage implementation of BIM, or project participants from collaboration to establish the BIM final model.

Therefore, there is a consensus agreement from several researchers and professional executives who proposed settling the IPR issue, by setting forth the issue in the contract documents, detailing the rights and responsibilities for each party and the Level of Data (LOD) transfer.

Moreover, other researchers and AEC professionals suggested that, these issues pertaining to IPR should be stipulated by the government in standard documents or by the client in the absence of the government standards; hence every party within the project will be clear prior to starting the project about the IPR and his/her liabilities (Rosenberg 2007; Gu & London 2010; Osapuolet 2012).

Bryde et al. (2013) and New Zealand handbook (2014) proposed practical solutions for the IPR issues, whether there is a government standard or not; each party should grant the other an unrestricted royalty free license to use the model i.e. designers grants the client unrestricted permission to use the final model and its details to the extent required to enable the client to benefit from the BIM model during the project entire lifecycle i.e. From perception and predesign till demolishing. And on the counter party, the client grants the designers permission to reasonably reuse merely their inputs to the BIM final model in other projects to maintain the designers intellectual advantages.

2.7.5.2 AEC Traditional procurement methodology

The AEC industry, widely challenged by its fragmented nature, resulted in many owners sharing the frustration associated with traditional procurement strategies and the repetitive problems from these traditional procurement models, especially problems correlated with fragmentation, sharing risks and rewards. In addition to the need for solutions to reduce waste, improve productivity and respond appropriately to owners' demands (Latham 1994; Egan 1998; Dulaimi et al. 2002; AIA 2010).

However, the current traditional procurement strategies, such as Design-Bid-Build (DBB), Design and Build (DB), Construction management at risk (CM@R), management contracting (MC) involving linear process. That means one task being followed by another with a large number of isolated files that need to be continually updated and constantly managed with risks not always appropriately allocated (Hardin 2009). Traditionally, in the conventional procurement methodologies the architects, designers, contractors, suppliers are in the supply side and the client is in the demand side. Therefore always there is conflict among the demand players who considered themselves adversarial because of the fragmented nature resulted in the blurred tasks (Sebastian 2011). In addition to the conflicts created among the supply chain players and the client because of improper risk allocation and unfair sharing of risks and rewards (Dulaimi 2010; Ling et al. 2014).

Jannadia et al. (2000) argued that "unbalanced risk allocation in contract provision, adversarial relationships between projects' participants together with the traditional client-contractor mentality have long been identified as the major source of construction problems". Therefore BIM was proposed to resolve most of the AEC radical problems, where the BIM fundamental premise and value is at integrating the fragmented players of the project by involving them at the very early stage of the project outset and sharing the risks and rewards (Azhar et al. 2011; Eastman et al. 2011).

Hence it is obvious, the traditional procurement models are not in line with BIM fundamental values, also BIM benefits are not fully reaped with the traditional procurement methodologies which considered as a barrier to reap the full benefits of BIM (Linderoth 2010; Sebastain 2011; Powrwal & Hewage 2013; Eadie et al. 2014)

This means that there is a crucial need to change from the traditional to an integrated procurement strategy, which requires a paradigm shift of mindset to accept the changes and the reshaping of roles and responsibilities, sharing the risks and rewards among the construction players (Hardin 2009; Sebastian 2011; Porwal & Hewage 2013; Love et al. 2014).

Porwal and Hewage (2013) concluded that, there is no one significant project delivery method appropriate for BIM. However, Migilinskas et al. (2013) and Moreno et al. (2013) suggested that, to use BIM effectively the project must be delivered with most collaborative approaches such as CM@R or DB. Therefore, it is evident there are less benefits of utilizing BIM using DBB. Likewise, Hardin (2009) concluded that, BIM is not useful in DBB with the exception of trying to use it to quickly extract quantities for estimation purpose.

Integrated Project Delivery (IPD) was proposed to be the appropriate construction procurement strategy suitable for BIM, where IPD is defined as a “project delivery approach that integrates people, system, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value of owner, reduce waste, and maximize efficiency through phases of design, fabrication and construction” (AIA 2007).

Based on BIM core values and IPD definition it is clear that, there is mutual synergy between BIM and IPD, where BIM supports the concept of IPD to integrate people and processes, IPD and BIM are built on collaboration principle to optimize the efficiency (AIA 2007; Glick & Guggemos 2009; Moreno et al. 2013; Love et al. 2014).

Several researchers and professional executives concluded that, the most suitable project delivery method for BIM is the integrated project delivery approach, where all BIM benefits can be reaped such as reducing waste, optimizing productivity, sharing risks and rewards, integrating the fragmented teams and responding to client needs (Hardin 2009; Azhar et al. 2011; Eastman et al 2011; Moreno et al. 2013; Jernigan

2014; New Zealand BIM Handbook 2014). However, still the traditional procurement strategies are dominating the AEC industry which creates obstacles to reap the full benefits of BIM (Hardin 2009).

2.7.6 Summary of the challenges and obstacles hinder the implementation of BIM

It is obvious, the implementation of BIM is not free of challenges; it is perilous process since there are several challenges that hinder the change to BIM. However organizations and the AEC industry can avoid or be prepared for these challenges by promoting the real awareness of BIM. These challenges can be classified into five categories: the management challenges that entail the organization's lack of know-how to proceed with the change to BIM. One of the most important challenges that deters the implementation of BIM is the lack of top management support to BIM.

In addition, most of changes to adopt new technology or processes are facing sever resistance; hence resistance to change towards BIM is one of the most significant challenges too.

Implementation of BIM significantly changes the normal processes and accordingly changes the workflow, roles and responsibilities where some employees will lose their power and some new careers will be created with high authorities. Therefore this challenge deemed critical due to the sever resistance from the impacted employees especially the top management or old employees.

Second category is technical challenges which entail BIM model interoperability where the project teams are always using different and incompatible software, which hinders the free flow of the information and data among the project teams especially the design teams.

On the other hand, BIM model requires rigorous control for inputs, otherwise the BIM final model will encompass several mistakes and the liabilities of these mistakes could be lost.

One of the obstacles to implement BIM is lack of skilled resources to operate the BIM software models, where the demand for the BIM operators is extremely more than the available resources.

Third category of challenges is the surrounding environment within the AEC industry and the influence of the AEC players on the organizations that are implementing or on the way to implement BIM. Which means lack of government or client demand to implement BIM is recognized as one of the most paramount drawbacks that hinder the organizations to utilize BIM.

In addition, the lack of utilization of BIM by some stakeholders prevents BIM users of reaping the full benefits of BIM. Consequently, if the majority of the project stakeholders are not using BIM the BIM user will be forced to stop using BIM in the project otherwise BIM user could lose the communication and streamlining of information with the project stakeholders. This challenge is deemed to be one of the common recognized challenges in the embarking markets to implement BIM.

The fourth category of challenges is the financial challenges, where costs associated with the implementation of BIM are considered as a great challenge for small and some medium size organizations. Because implementation of BIM requires big funds within a short duration which SMEs' cannot afford.

Fifth recognized category of the challenges pertaining to the implementation of BIM is the legal and contractual challenges, where IPR is one of the challenges faces the supply chain players from one side and the client on the other side. Client considers himself/herself the owner of the BIM final model, because he/she paid to produce the BIM final model; however the supply chain players felt unprotected to their IPR.

The paramount premise of BIM is about collaboration; however most of the used procurement strategies are not fully supporting the collaboration principles. That means there is crucial need to change the current procurement strategies to follow the procurement strategy that is integrated with BIM such as IPD. However the domination of the traditional procurement strategies is one of the recognized challenges to reap the full benefits of BIM.

It is very important for the organizations intending to implement BIM to well understand the recognized challenges and obstacles to be ready with the appropriate plans for swift and successful implementation of BIM.

The literature review presented several challenges and mitigations to some of these recognized challenges and obstacles, which highly benefits the organizations and the AEC industry to avoid some challenges to facilitate the transition to BIM.

2.8 Driving forces and pressures that imposing the implementation of BIM

Based on the extensive literature survey, it was found that there are few researches investigated the driving forces for the implementation of BIM. In order to fill this knowledge gap and to profoundly understand the forces behind the wide and quick implementation of BIM in the AEC industry worldwide, the following section will explore these driving forces.

Goulding and Lou (2012) claimed that, in the last 10 years the AEC industry witnessed unprecedented technological changes. Moreover, Moreno et al. (2013) cited that, McGraw Hill construction survey in the USA and Europe confirmed that, the adoption of BIM increased widely from 28% in 2007 to 71% in 2012 and still booming nowadays. That is explaining the positive unprecedented change in the AEC industry in the last decade.

The decision for implementation of BIM is not only motivated by recognizing the benefits of BIM, but also influenced by driving forces. Those are the external pressures/forces imposed from externals and/or the surrounding environment such as competitors to adopt the new change to BIM (Liu et al. 2010; Eadie et al. 2013).

Organization may adopt new changes due to the forces/pressures imposed on them from powerful authority. That means the organization does not have the choice but to adopt the imposed changes (Liu et al. 2010).

AEC organizations are likely forced by powerful external motives, such as governments or clients. Failure to adopt the imposed changes would result in loss of competitive advantage accordingly, less chances to win new projects (Mitropoulos &Tatum 2000).

The literature study revealed that, the driving forces and external pressures/forces to implement BIM are influenced by three main factors as follows:

- The imposed pressures from the government /client to implement BIM,

- The imposed pressures from the surrounding environment such as the competitors
- The imposed pressures from the project's complexity and the declination of profits are deemed external forces to adopt new changes to improve the performance and increase the profits to respond to the project complexity or to the sophisticated clients.

2.8.1 Government or clients' pressures to implement BIM

Much research cited that, the implementation of BIM improves the construction productivity and quality to satisfy the client needs, shorten the project duration and reduce the costs. Furthermore BIM responds effectively to the sustainability requirements and furnish the FM with full details for the building to reduce the O&M costs (Eastman et al. 2011; Eadie et al. 2013; Porwal & Hewage 2013).

Therefore, in the last few years, BIM is gaining significant support from governments and clients, where several governments and clients worldwide, imposed pressures on the AEC organizations to use BIM (Mihindu & Arayici 2008; Arayici et al. 2011; Barlish et al. 2012; Kang et al. 2012). Some governments such as the UK, Finland, Denmark, Norway, France, Australia, New Zealand, South Korea, Singapore and USA have imposed the use of BIM as a compulsory requirement in the AEC industry (Khosrowshahi &Arayici 2012; Brewer et al. 2012).

In 2007 the General Service Administration (GSA) which is a USA governmental agency imposed BIM as a compulsory requirement for all new GSA projects (Ozbek 2012). Similarly, Chinese and Hong Kong governments are strongly supporting implementation of BIM for their AEC industry (Fung 2011). Norway mandated BIM since 2010 to all the AEC industry public and private projects. Finland is one of the world's early adopters for the implementation of BIM, which started the transition to BIM since 2001and then mandated BIM as a compulsory requirements in its AEC industry since 2007 (Brewer et al. 2012).

Dubai Municipality made BIM as a compulsory requirement since January 2014 in specific buildings such as the buildings that are more than 40 stories or more than 300,000 sq. feet or hospitals, universities or the like, or any building designed by international consultant (DM 2013).

Many researchers suggested that, the best way to mandate BIM especially for the organizations that are expressing unwillingness to implement BIM. The governments or clients should impose the use of BIM in the contracts as a compulsory requirement (Nitithamyong & Skibniewski 2006; Eadie et al. 2013; Porwal & Hewage 2013).

According to Brewer et al. (2012) and Porwal & Hewage (2013) and Eadie et al. (2013) the UK government imposed BIM in 2011 as an industrial practice for the AEC projects, and planned for the smooth transition to cascade the implementation of BIM on four levels as follows:

Level 0: Unmanaged 2D CAD with paper (the traditional 2D practice without any mention for BIM),

Level 1: Managed CAD in 2D or 3D with a collaboration tool providing common data environment,

Level 2: Managed 3D via implementation of BIM and deployment of BIM tools such as 3D, 4D and 5D. This level completed in 2014 and any organization not complying with the level 2 requirements, the UK government decided not to include them in forthcoming government contracts.

Level 3: Full open process and data integration using all BIM tools and exploiting all BIM benefits, the deadline date for this level is 2016.

Arayici et al. (2011) concluded that, governments such as UK are trying to promote the value for money, by investing in forcing the AEC organizations to implement BIM to be able to win the public contracts. Accordingly organisations will strive to respond and obey the imposed forces to implement BIM before the deadline stipulated by UK government. Therefore, governments try to optimize their investments in the implementation of BIM and as a result they award the projects to organizations are using BIM (Porwal et al. 2013).

Many researchers and executives affirmed that, the main driver behind the rapid implementation of BIM in the AEC industry is the strict demands from the governments and clients to use BIM (Ruikar et al. 2005; Grilo & Jardim-Goncalves 2010; Linderoth 2010; Liu et al. 2010; Eadie et al. 2013; Moreno et al. 2013; Won et al. 2013; Chain 2014; Elmualim & Gilder 2014)

Hence, due to the governments and clients imposing actions that made the implementation of BIM is a compulsory requirement, BIM is booming and its benefits are well reaped by remarkable improvements in the AEC industry (Chan 2014).

2.8.2 Surrounding environment and competitive pressure

The construction industry by its nature is a highly competitive industry and only organizations with competitive advantage will survive in such rival market (Eadie et al. 2013). Adoption of new suitable technology is crucial to enhance the organization's competitive advantage to sustain itself in the market (Mitropoulos & Tatum 2000).

Some AEC organizations are adopting the new technology earlier than their competitors to acquire competitive advantages that enable them to win projects and improve their performance (Ruikar et al. 2005)

Moore (2003a) classified technology adopters during the technology lifecycle according to a bell shape shown in figure 4, Where innovators are the very early first adaptors to the technology, then comes the early adaptors with certain chasm, early majority then the late majority and laggards come last.

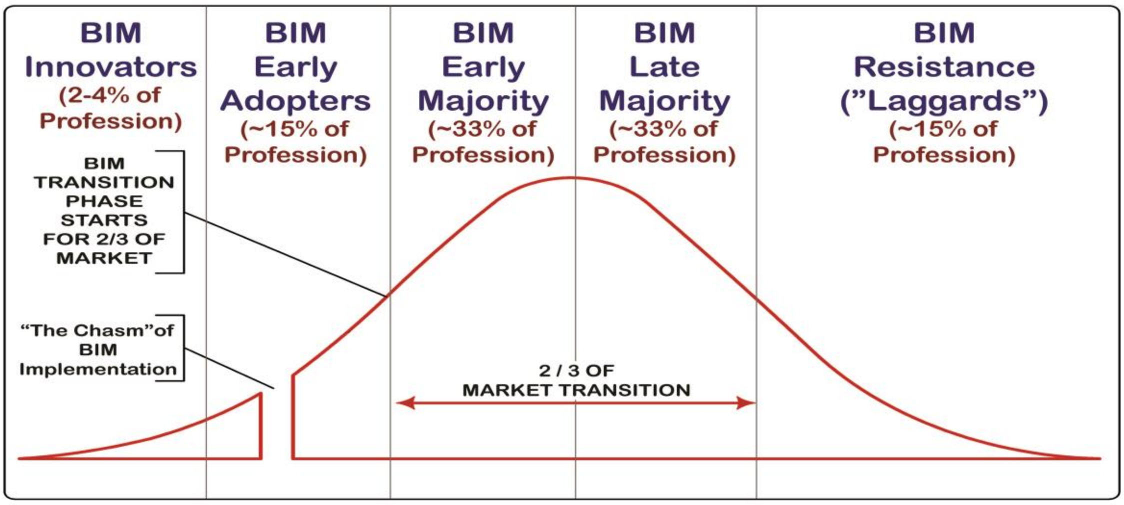


Figure 4: BIM adoption lifecycle developed based on (Moore 2003a) model to suit BIM.

A later study conducted by Ruikar et al. (2005) classified the technology adaptors following to technology adoption lifecycle as shown in fig.4 which developed from Moore (2003a) model as follows:

Innovators: they are the technology enthusiasts who are following up the latest technology and they are always aware and implement it before others.

Early adaptors: the visionaries who have the insight to match the emerged technology after a profound analyses and testing of the pros and cons of the emerged technology and correlate it to their strategic opportunities to gain competitive advantage over their competitors.

Early majority: pragmatists who deeply evaluate the technology influences on others before adopting this technology in their business, and they are interested in responding to the market changes rather than their concern about the technology itself.

Late majority: this group has a conservative nature to any emerged technology and they are always pessimistic about the technological ability of adding value to their business and they always see the technology outcomes as not being worth the investments; they use the technology only under duress.

Laggards: this group simply does not believe in technology and are satisfied and happy with their old ways and not ready to make any technological changes.

As BIM is rapidly booming, TRADA (2012) claimed that BIM adopters in 2012 are considered in the later stage of the early majority and heading towards late majority. Where, Ruikar et al. (2005) concluded that, the late majorities are those organizations who implement new technology only when they are forced or they want to avoid being left behind their competitors. Therefore adoption of BIM is influenced by the organization’s willingness to acquire competitive advantage that can merit the organization by pushing step ahead of their competitors (Ruikar et al. 2005).

The innovators and majority of early adaptors are not waiting for any external pressure to force them to adopt any technological implementation such as BIM; however they well grasp the benefits of BIM as the vehicle to sustain their competitive advantage with better position in the AEC market and they adopt it as an internal change initiative (Arayici et al. 2011).

Therefore, in the AEC industry BIM innovators and early adaptors acquired great competitive advantages compared to their competitors. Therefore, the added competitive advantages considered as a great pressure and external driving forces for BIM non-users to adopt BIM; otherwise they will be out of the competition game (Liu et al. 2010; Eadie et al. 2013; Moreno et al. 2013; Chan 2014).

2.8.3 Projects complexity and profit declination

Figure 1 indicates that, the AEC industry is suffering from tremendous declination of the productivity and profits. The AEC productivity decline continuously across the construction industry as 30% of time spent in design and construction process is wasted. That means the need to integrate the design and construction process to save time wasted is crucially required (Jerningan 2014). Moreover, Nour (2007) claimed that, the AEC industry is facing many problems. Therefore, it is essential to increase the AEC's productivity, improve efficiency, improve infrastructure value, improve quality and sustainability, promote effective collaboration and communication of stakeholders in construction and reduce the life cost.

Many researchers claimed that, the implementation of BIM could be the viable solution to save the time waste and its relevant problems. In addition, implementation of BIM offers a significant advantage to overcome the productivity declination problems (McGraw Hill construction 2007; Azhar et al. 2012; Elmualim& Gilder 2014; Eadie et al. 2013; Jernigan 2014).

Hardin (2009) confirmed that, the complex nature of buildings is one of the main drivers for the implementation of BIM in the AEC industry, because the 2D CAD traditional processes are helpless if the sustainability requirement is added, because of the inaccuracy and unreliability of the conventional methodology. Especially with sophisticated owners and contractors who are willing to change the inefficient processes to achieve full collaboration among project teams and deliver better outcomes.

Moreover, unsatisfied clients and end-users are one of the main driving forces towards the adoption of BIM, where clients and end-users argue a building takes too long, costs too much or is of the poor quality standards. Thus one among the most important drivers for the implementation of BIM could be the intrinsic value that building high quality, shorter time and saved costs of the building and the reliable information will be provided to clients and building users to satisfy them (Elmualim & Gilder 2014).

Grilo and Jardim-Goncalves (2010) and Kang et al. (2012) claimed that, the most important driver for implementation of BIM is delivering substantiality gains in terms of productivity in the AEC industry, closely followed by enhanced cost reduction and enhanced predictability.

2.8.4 Summary of driving forces and pressures imposing the implementation of BIM

Organizations may implement BIM as a response to an external pressure; the external pressures may be imposed from government or client to utilize BIM as a compulsory requirement. In this case the organization has no choice but to implement BIM, otherwise the chances of winning new projects will be very limited and the organization may be out of the competition game.

The surrounding environment and the competitors is deemed as a huge external pressures for the AEC organizations to implement BIM, where organization implemented BIM has a better chance to win new projects because of its added competitive advantage. This added advantage creates a huge competition gap with those who did not implement BIM, therefore, in order to bridge this gap the organization has to implement BIM to sustain its ability to compete and continue in the AEC market.

Moreover, implementation of BIM can be a response to the project complexity or sophisticated client to promote the organization’s profits due to the AEC industry common declination of profits as demonstrated in figure 1.

2.9 AEC industry and organizational internal readiness for the implementation of BIM

An extensive literature study has been conducted; however, due to the scarcity of research that has investigated organizational internal readiness to implement BIM, literature survey conducted to similar disciplines of BIM such as the Electronic Data Interchange (EDI) and organization internal readiness for technology and software. The literature review recognized that, the organizational internal readiness to implement BIM is influenced by four main factors such as the organizational decision due to the recognized benefits of BIM, top management attitude towards implementation of BIM, the organizational level of flexibility towards the change, and the organization financial readiness to fund the costs associated with the implementation of BIM (Orlikowski 1996; Mitropoulos et al. 2000; Chwelos et al. 2001; Ruiker et al. 2005; Liu et al. 2010; Eadie et al. 2013).

2.9.1 Organizational decision due to the recognized benefits of BIM

Whether the organization is forced to implement BIM or the implementation of BIM is an internal initiative. Organization should well-understand the benefits of BIM, the added value and the gained competitive advantage to the organization, and the business improvement that could be accomplished due to the implementation of BIM (Sebastian 2011; Azhar et al. 2011; Eastman et al. 2011; Elmualim& Glider 2014).

Table 1 presents the most recognized 36 benefits of BIM, and section 2.5 elaborated the full details of the benefits of BIM.

The perceived benefits of BIM determine the execution plan, the involved personnel and which areas will be tackled based on the organizational priorities, status quo and business function. Many AEC organizations such as innovators and early adopters implemented BIM due to the recognized benefits of BIM. It is obvious implementation of BIM improves most of the AEC recognized problems such as improves the AEC performance to satisfy the client and customer needs, promotes the competitive advantage, integrate the fragmented teams and increases profits and so forth (Eastman et al. 2011; Elmualim & Gilder 2014).

2.9.2 Top managements' attitudes towards the implementation of BIM

Top managements can be the motivators to guide and lead the change initiatives such as the implementation of BIM, by exploiting their power to overcome any problem to accomplish the successful change. Additionally, top managements can be against the change which means unsupportive top managements can use their power to deter the change by creating irresistible drawbacks and barriers (Rainer& Hall 2002; O'Connor& Basri 2012; Herranz et al. 2013). Therefore the top managements' attitudes towards the implementation of BIM are very important.

This topic almost covered in the challenging section 2.7.1.2; however the following section adds different dimensions.

Traditionally, the top management's main task in any organization is to meet the organization's business goals (Herranz 2013). And to take decisions to respond to the continuous market changes (Liang et al. 2007). Therefore, to gain the top managements support to the change, they should be motivated.

Herranz et al. (2013) claimed that, there is nothing can motivate the top managements than visible benefits and meeting the business targets by having greater competitive advantages compared to their competitors. From the recognized benefits of BIM it is obvious that the factual benefits of BIM can be a great motivator for top management to meet their business targets.

It is clear that, change initiatives involving organizational change is a very challenging and complex process, which requires appropriate plans to the affected areas and people to avoid any undesired consequences or any negative impacts on the organization (Tunks1992; Robbins & Finley 1997). Therefore, Mathiassen et al. (2005) argue that, one of the most common causes of change failure occurs when top managers allowed the roles and responsibilities to be ambiguous. This ambiguity creates conflicts among the employees who may be demotivated towards the new change and be less committed to the implementation of BIM. Therefore, Iversen and Ngwenyama (2006) and Herranz et al. (2013) concluded that, for successful change to implement BIM, top managements should determine the change initiative and execution plans with its infinitesimal details such as feasibility study, business objectives, identified motivations, change agents. In addition to, the involved employees, roles and responsibilities, plans to resolve the conflicts, the required resources such as human, financial, technical resources and the alike. Moreover, they should determine the milestone dates and the success measures for each phase and sharing the success and rewarding the employees who contribute to the success; all these details must be ready before the plan is announced.

Therefore, it is very simple to recognize the supportive and unsupportive top managements from their attitudes and actions towards the change initiatives, where the top managements support can be seen in devoting time to the change execution program. In addition to, reviewing the plans, risk assessment plans, long term funding plans, change steering committees, availing the required resources, following up the results, and facilitating any rising challenges to overcome any problem (Young & Jordan 2008).

2.9.3 Organization level of flexibility towards the change

Waziri et al. (2014) argue that, the successful organizational change requires systematic and proactive management due to the resistance from people involved in the change. The first step of successful change is recognizing the benefits and understanding the needs for the change. And the second and the most important step is readiness for the change which involves the people, processes and technology (Jimmieson & Griffiths 2005).

Therefore, Kotter (1996) concluded that, failure to develop organizational readiness to adopt the change deemed the main reason for the failure of any change. Hence, organization should reach the flexibility and maturity levels to successfully change the processes and strategy to adopt BIM (Liu et al 2010).

There is no consensus agreement for a single model for the readiness for the change to be followed by the construction organization (Waziri et al. 2014). However, one of the most promising paradigms found for the organizations’ readiness proposed by Holt et al. (2007) that is dubbed the “change message” which consists of five messages as follows;

1. **First message :Discrepancy**

It is an assessment process where the benefits of change are recognized, then assessment of the change whether needed or not and what will be the discrepancy between the current status quo and the future after implementing the change.

2. **Second message :Appropriateness**

It is the stage where comprehensive evaluation of the organization status quo from all perspectives such as technological, humans, cultural and financial etc. The aim of this process is to select the right change approach that is suitable for the organization. It is explicit the change approach may vary according to the organizations’ status and surrounding conditions.

3. **Third message :Change efficacy**

The ability of the involved people to carry out the change in a collaborative way, the involved people are classified into two groups: the first group is the change agent (top management and others) and the recipients (employees). In this stage availability of expertise and resources i.e. human, financial, technological and consultation are assessed.

4. **Fourth message :Principal support**

In this stage the support to the organizational change is measured from all parties including the top managements and the employees as well as the stakeholders.

5. **Fifth message :Personal valence**

The perceived benefits of the initiated change to individuals in the organization are shared. Failure to embrace the change and an insistence on maintain the current status unchanged, is a sign that the construction organization is not ready yet for the change

It is obvious, organizations with flexible culture are the most successful organizations to adopt the change initiatives and swiftly implement BIM with the optimum reaped benefits and within the minimum negative impacts (Chwelos et al. 2001; Hardin 2009; Liu et al. 2010)

2.9.4 Organization financial readiness to fund the costs associated with implementation of BIM

The organizational financial readiness to fund the costs associated with the implementation of BIM is well covered under the challenges section "***Financial challenges section 2.7.4.1***".

It is claimed by several researchers and professional executives that, organization financial readiness to fund the costs associated with implementation of BIM is a major factor influencing the decision for the implementation of BIM (Liu et al. 2010).

2.9.5 Summary of the AEC industry and organization internal readiness to implement BIM:

The implementation of BIM can be an internal initiative when the organization reaches a level of maturity enables the top management to take the decision to adopt the change to BIM. However, several factors can support or hinder the change, such as the flexible culture mandating the organization, which supports the change. Moreover, the support from top managements and the organization's financial stand and readiness to bear the change implications. There are several factors that should be properly assessed prior to starting the implementation of BIM.

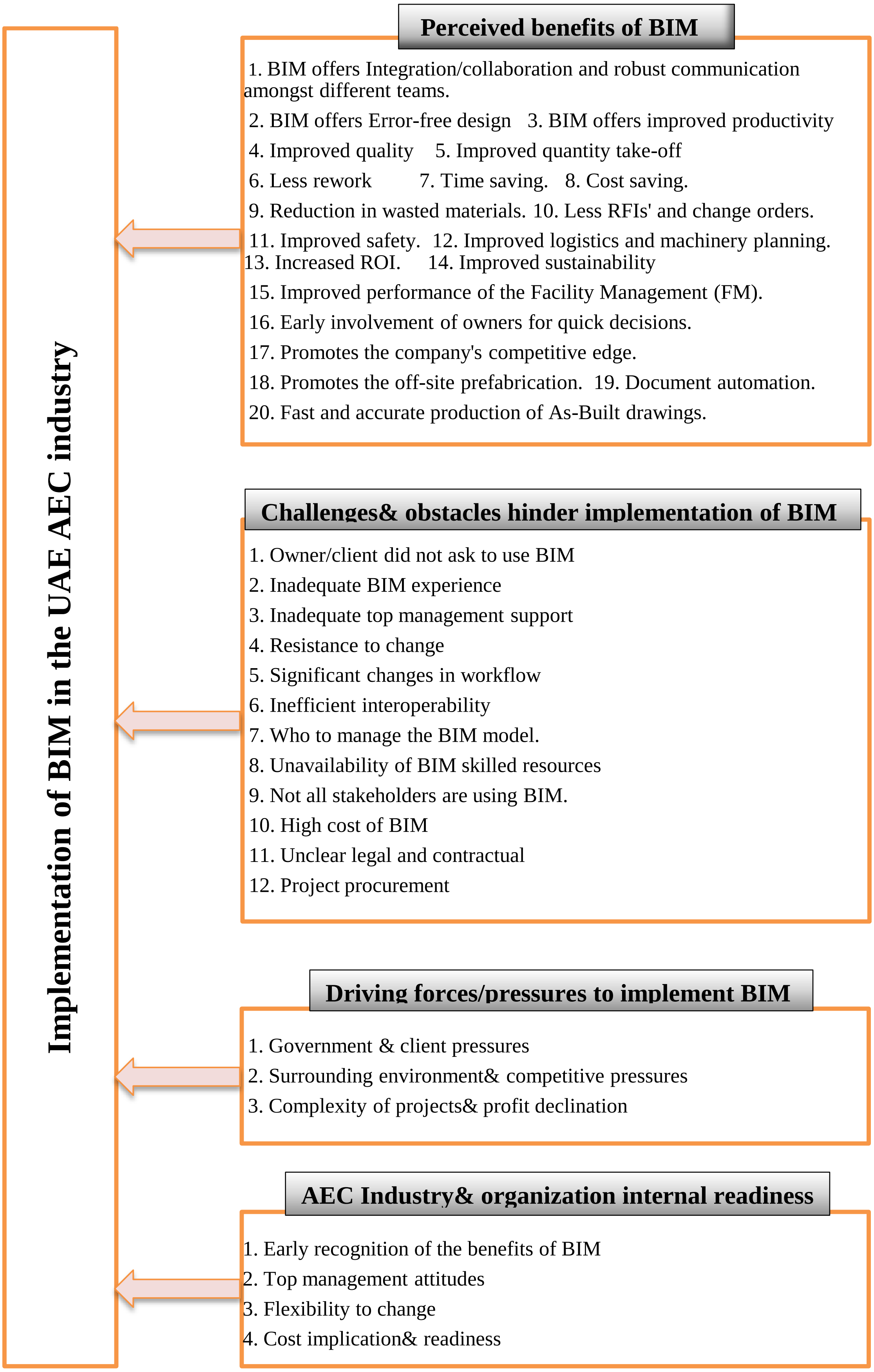
These factors are the perceived benefits of BIM, the top management's attitude towards implementation of BIM, organization level of the flexibility towards the change and the organization's financial readiness to fund the costs associated with the implementation of BIM. In the absence of one of these four factors the organization deemed not ready to implement BIM, where the change towards BIM could be an impossible task and the implementation of BIM is doomed failure from the start.

Hence, the organizations and the entire AEC industry should be well aware about the required preparations and readiness to implement BIM successfully.

Chapter 3

3 Conceptual framework and hypotheses

The research model in figure 5 developed from the extensive literature survey and the model proposed by Chwelos et al. (2001); however, this model has been further developed to conform with the recognized four factors influencing the implementation of BIM in the UAE AEC industry.



Implementation of BIM in the UAE AEC industry

Perceived benefits of BIM

1. BIM offers Integration/collaboration and robust communication amongst different teams.
2. BIM offers Error-free design 3. BIM offers improved productivity
4. Improved quality 5. Improved quantity take-off
6. Less rework 7. Time saving. 8. Cost saving.
9. Reduction in wasted materials. 10. Less RFIs' and change orders.
11. Improved safety. 12. Improved logistics and machinery planning.
13. Increased ROI. 14. Improved sustainability
15. Improved performance of the Facility Management (FM).
16. Early involvement of owners for quick decisions.
17. Promotes the company's competitive edge.
18. Promotes the off-site prefabrication. 19. Document automation.
20. Fast and accurate production of As-Built drawings.

Challenges& obstacles hinder implementation of BIM

1. Owner/client did not ask to use BIM
2. Inadequate BIM experience
3. Inadequate top management support
4. Resistance to change
5. Significant changes in workflow
6. Inefficient interoperability
7. Who to manage the BIM model.
8. Unavailability of BIM skilled resources
9. Not all stakeholders are using BIM.
10. High cost of BIM
11. Unclear legal and contractual
12. Project procurement

Driving forces/pressures to implement BIM

1. Government & client pressures
2. Surrounding environment& competitive pressures
3. Complexity of projects& profit declination

AEC Industry& organization internal readiness

1. Early recognition of the benefits of BIM
2. Top management attitudes
3. Flexibility to change
4. Cost implication& readiness

Figure 5: Conceptual framework

The study will identify the impact of the four recognized factors on the implementation of BIM in the UAE AEC industry. The four factors identified from the literature study are the perceived benefits of BIM, the challenges and obstacles hinder the implementation of BIM, the driving forces and pressures imposing the utilization of BIM and the organizational and AEC industry readiness to utilize BIM. And then will investigate the level of maturity and readiness of the UAE AEC industry to effectively implement and mandate BIM considering the aforementioned four factors.

This study considers the model in figure 5 will be able to assist the UAE AEC industry players to recognize the gaps that diminish the chances for the successful implementation of BIM. The model will assist the UAE AEC players to bridge the recognized gaps and to exploit the AEC industry chances and opportunities to foster the implementation of BIM. The model introduced four factors that have direct impact on the implementation of BIM in the UAE AEC industry as follows:

The perceived benefits of BIM (independent variable): this refers to the anticipated benefits and advantages that the use of BIM can offer to the organization and the entire AEC industry. The perceived benefits of BIM are highly influencing the decision for the implementation of BIM.

The study will check the validity of first hypothesis, *H1: The higher the appropriate recognition of the benefits of BIM the greater chances of the successful implementation of BIM.*

That means the more recognition and appropriate awareness of the benefits of BIM will highly assist and encourage the organizations and the UAE AEC industry decision makers to implement BIM.

Challenges and obstacles of BIM (independent variable): this refers to the drawbacks that diminish the chances of the implementation of BIM.

The study will check the correctness of the second hypothesis *H2: The higher the challenges and obstacles the lesser chances to the implementation of BIM.*

That means the pre-recognition of the challenges and obstacles will greatly assist the organizations and the industry to deal with these impediments and promote the chances of the implementation of BIM. However, the less awareness or readiness of these challenges and obstacles will negatively impact the chances of implementation of BIM, on the organizations and the UAE AEC industry levels.

Driving forces and pressures to implement BIM (independent variable): this refers to the external pressures from powerful authority such as the government or the client to impose the utilization and mandate of BIM as a compulsory requirement.

The study will check the correctness of the third hypothesis *H3: Higher external driving forces and pressure to adopt BIM leads to greater chances of the implementation of BIM.*

That means the driving forces could be a great chance to mandate BIM in the UAE AEC industry, in this case the driving forces are deemed to have a positive impact if the organizations and the UAE AEC industry are ready to adopt the changes to implement BIM.

However, the driving forces could have a tremendous negative impact on the organizations and the industry if the government or clients impose pressure to implement BIM in the absence of the organization or the UAE AEC industry's readiness to adopt the changes.

The UAE AEC industry and organizations' internal readiness (independent variable): this refers to the organization and industry level of preparation and readiness to adopt the change initiatives.

The study will check the correctness of the fourth hypothesis *H4: The appropriate internal readiness to adopt the change to BIM leads to greater chances for the successful implementation of BIM.*

That means the internal readiness of the organization and the UAE AEC industry is very crucial to drive the success towards the implementation of BIM. Therefore, if the organization and the entire UAE AEC industry are ready to adopt BIM, that will drive a great success and swift transition to implement and mandate BIM.

However, if there is no or little internal readiness from the organizations and the UAE AEC industry, this will leads to unwanted negative implications.

Implementation of BIM in the UAE AEC industry (The dependent variable): this refers to the readiness and the maturity level of the UAE AEC industry to implement and mandate BIM. This level of maturity varies from not at all adopting BIM and even not willing to adopt BIM to full committed and supportive to implement BIM. This dependent variable is directly influenced by the four independent variables as suggested in the conceptual framework model and the proposed hypotheses. Therefore, considering the aforementioned variables are imperative to the study the successful transition to the implementation of BIM on the organizations and the UAE AEC industry levels to propose the solutions to mandate BIM in the UAE.

Chapter 4

4 Methodology

The literature study developed a profound understanding for the four independent variables i.e. the perceived benefits of BIM, challenges and obstacles that hinder the implementation of BIM, the driving forces and the irresistible pressures imposed on the organizations to implement BIM and the UAE AEC industry and organizations' internal readiness for the adoption of BIM.

This understanding of the four independent variables used to check their impact on the dependent variable that is represented in the implementation of BIM in the UAE AEC industry.

The literature study and the developed conceptual framework were the prime source to develop the aforementioned four hypotheses. Hence, to check these hypotheses an initial questionnaire survey adopting the quantitative approach was developed to collect and analyze the data. The analyzed data used to recommend a solution package to the decision makers in the UAE AEC industry to facilitate the soft and swift transition to mandate BIM. From the previous experiences in many countries, it is obvious the implementation of BIM will highly improve the performance of the AEC industry in the UAE.

The quantitative approach selected to collect the maximum number of responses to understand the impact of the four independent variables on the implementation of BIM in the UAE AEC industry (the dependent variable). Therefore the quantitative approach was found a reliable methodology to test the hypotheses composed of variables derived from the literature study (Naoum 2013).

Prior to finalizing the questionnaire, in November 2014 a pilot sample of a carefully selected 10 veteran professionals with average experience of 10 years in the UAE AEC industry. And on average they have handled 6 projects in UAE, where five of them represent BIM users and the others five represent BIM non-users. These veteran professionals were selected from local and multinational AEC organizations in the UAE market. The initial questionnaire was refined based on the feedback received from the pilot sample of the 10 professionals.

The refined questionnaire survey sent to the pilot sample of the veteran professionals via email and then they were contacted to solicit their opinions about the emailed questionnaire to identify any confusion or ambiguous questions. Afterwards the final questionnaire was developed to collect the data, and hence the final questionnaire was accessible via online survey platform dubbed “Survey Monkey”. This platform enables easy and swift filling of the survey via the internet and then gathers the responses automatically to save and store them via an online database. The questionnaire link was distributed by email to the randomly selected organizations in the UAE AEC industry such as contractors, subcontractors, architects, clients, suppliers…etc. The questionnaire was available from 28th November 2014 till 2nd March 2015 (more than 3 months). The questionnaire link sent to the organizations that are registered as members of the directory of Emirati Society of Engineers which includes the entire UAE AEC industry players. In addition to organizations that are registered in Dubai municipality, avoiding duplications was considered.

The questionnaire survey consists of five sections. Section 1 consists of respondents' personal information and demographics such as profession, years of experience in UAE, academic qualifications, awareness of BIM, location, the organizations nationality, BIM user or non-user….etc.

In section 2, 3, 4 and 5 each respondent was asked to rate the to what extent he/she agree/disagree with each of the perceived benefits of BIM, challenges for the implementation of BIM, the driving forces for the implementation of BIM and the organization and UAE AEC industry internal readiness to implement BIM, on a five point Likert scale ranging from 1 to 5, where 5 represents ‘extremely significant’, and 1 represents ‘not at all significant’.

The questionnaire developed to collect the data from two groups (BIM users and BIM non-users) that is working the UAE AEC industry, both groups responded to the same questionnaire.

The questionnaire survey sent to 362 AEC medium to big organizations in the UAE, however the returned responses were 71 responses (19.6%), the uncompleted responses were 14 (19.7%) of the returned responses. Therefore the considered as true responses were 57 (80%) of the returned responses, which represents 15.75% of the overall tested sample.

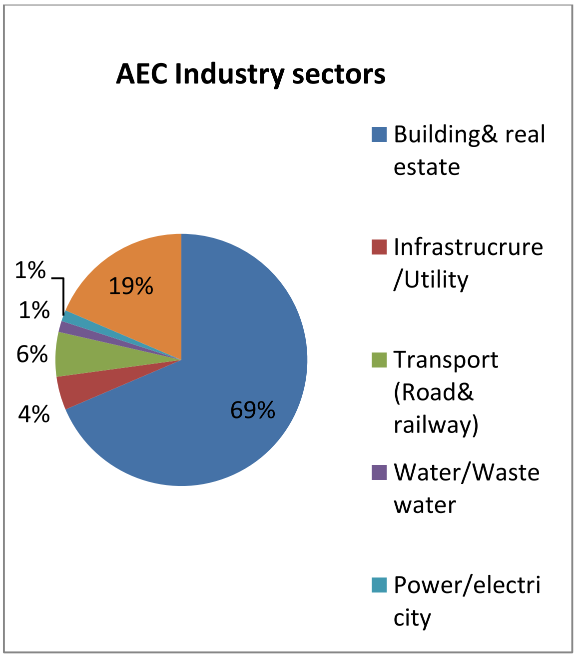
The returned responses reflected high awareness about the term BIM, where 98% heard or adopting BIM and 2% only are not aware what the meaning of BIM is.

The randomly tested sample covered all the UAE, however the received responses represented four emirates only i.e. Abu Dhabi 20 responses, Dubai 32 responses, Sharjah 4 responses and Ras Elkhemah only 1 response. Moreover the completed responses represent 12 public organizations and 45 private organizations.

The collected responses represent 65% as BIM users and 35% as BIM non-users, where 20% of BIM non-users are on the way to adopt BIM in the near future, and 7% planning to use BIM but not in the near future. However 8% of the BIM non-users are not planning to adopt BIM. These figures are reflecting high level of awareness for the importance of BIM in the UAE AEC industry or imposed pressures to implement BIM.

80% of BIM users within the UAE AEC industry were found in Dubai and almost 20% are in Abu Dhabi; however the other five emirates are BIM non-users.

The following figures 6 and 7 represent the organizations involved in the data collection.



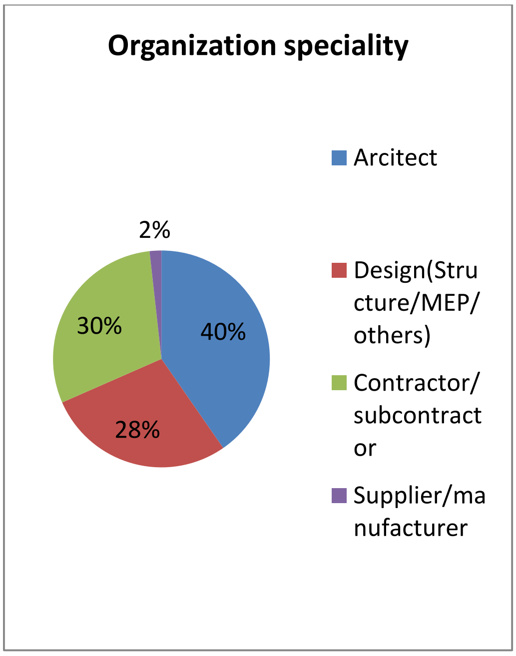


Figure 6: AEC industry sectors

Figure 7: Organization specialty

The following table 2 represents the organizations' level of experience and maturity in using BIM for the tested sample.

Sr.	**The years of experience for the company in using BIM.**	**UAE Local company** (working in UAE AEC market)	**International company** (working in UAE AEC market)
1	0	**65% (non-users)**	0%
2	1-2	35%	0%
3	3-5	0%	7%
4	6-10	0%	80%
5	More than 10	0%	13%

Table 2: The organizational level of experience and maturity in using BIM for the local and international organizations that is working in the UAE AEC market

Table 2 indicates that the UAE AEC industry still in the embarking stage, where 65% of its local organizations are BIM non-users and those who are BIM users i.e. 35% of the local organizations used BIM in less than two years ago. However the international organizations working in the UAE AEC industry seems to be holding a great experience of BIM which is in average 10 years. It is obvious those international organizations gained their experience of BIM from the early implementation of BIM in their home-countries. According to Dubai Statistics Center (2013) Majority of the international AEC organizations in Dubai belong to the developed countries such UK, France, Norway, Italy, USA, Canada, Japan, China, Australia and New Zealand.

In order to analyze the collected data, the quantitative methodology was used in two different statistical ways. The first way is the standard method of ranking to compare and contrast numerically the perceptions of the two groups (BIM users and non-users) for the four independent variables. In addition, to measure the level of agreement for each independent variable for the two groups by utilizing the Ranking Agreement Factor (RAF).

The second statistical data analysis involved SPSS software to rank the impact of the four independent variables on the implementation of BIM in UAE AEC industry which represents the dependent variable.

The standard method of ranking for the four variables utilized the mean rank analysis and the Relative Importance Index (RII) to establish the respondents' ranking on each of the four independent variables. The following mathematical equation represents the RII:

$\mathrm{RII} = \frac{\Sigma \mathrm{W}}{\mathrm{A} \times \mathrm{N}}$ ………..where (0≤ RII ≤1)

W: refers to the weighting given to each question by the respondents, according to Likert scale (5 is extremely significant and 1 is not at all significant).

A: refers to the highest weight for each question.

N: refers to the total number of respondents.

For each variable of the four independent variables the RII was determined for the two groups of the BIM users and BIM non-users and the comparison between the two groups illustrated in Radar shape to demonstrate the difference in weights which represent the level of agreement/disagreement between the two groups.

Then the RAF was developed between the two groups of BIM users and non-users to unify the ranking of the factors for each variable.

Where $\mathrm{RAF} = \frac{1}{N} \sum_{i=I}^{N} (\mathrm{Ri}, 1 - \mathrm{Ri}, 2)$………………………1

Maximum RAF calculated from the following formula:

$\mathrm{RAFmax} = \frac{1}{N} \sum_{i=I}^{N} (\mathrm{Ri}, 1 - \mathrm{Rj}, 2)$…………………………2

Where

$\mathrm{Ri}, 1$: The ith rank of an item for BIM users

$\mathrm{Ri}, 2$: The ith rank of an item for BIM non-users

N: the total number of items (is same for both groups).

$\mathrm{Rj}, 2$: The jth rank of an item for BIM non-users

Where j=N-i+1

Percentage Agreement (PA) will measure in percent the level of agreement between the two groups for the factors of each variable that is rendered in radar shape.

PA=100-PD

Where PD (percent disagreement) = $\frac{RAF \longleftarrow \boxed{\text{From Formula 1}}}{RAF\ max \longleftarrow \boxed{\text{From Formula 2}}}$

Hence, as much as the RAF is close to zero that means a closer agreement between the two groups and similar opinions about the variables. However, as much as the PD increases the agreement between the two groups is less and different opinions are envisaged about the factors for each variable (Chan& Kumaraswamy 1996).

Afterwards, SPSS software used to analyze the collected data to test the following four hypotheses,

H1: The higher the appropriate recognition of the benefits of BIM the greater chances of the successful implementation of BIM.

H2: The higher the challenges and obstacles the lesser chances to the implementation of BIM.

H3: Higher external driving forces and pressure to adopt BIM leads to greater chances of the implementation of BIM.

H4: The appropriate internal readiness to adopt the change to BIM leads to greater chances for the successful implementation of BIM.

Reliability test conducted to measure the internal consistency of the questions and the reliability for the construct of each variable. Then, Pearson correlation test conducted to test the strength of the relationship between the four independent variables and the dependent variable to enable ranking of the significance of the four independent variables based on their impact and effect on the dependent variable (Field 2013).

Based on the analyzed data from the quantitative approach, and as a second stage for data collection and analyses, it was seen that the field data collection from case studies will enrich the overall data analyses. Therefore further semi-structured questionnaire was prepared and face-to-face interviews were conducted with five experts for three case studies in Abu Dhabi and Dubai. The data analyses of the three case studies added great elaborations that enabled deeper and better understanding for several issues cannot be elaborated in the quantitative approach. The data analyses from the case studies enabled the researcher to compare and contrast the responses from both approaches i.e.

the qualitative and the quantitative. This comparison added significant values because it supported some results and contradicted other results from the quantitative approach with realistic elaborations in both cases.

The quantitative followed by qualitative approach enabled better understanding of the prioritized factors. The indicated hierarchy of the critical factors draws the attention to the most critical factor that is influencing the mandate of BIM in the UAE AEC industry.

In order to determine the sample size, the following formula was applied.

$N=\left(\frac{Z_{\propto/2}\times\delta}{E}\right)^2$ ………… (Cohen 1988)

Where N is the minimum sample size

$Z_{\propto/2}$=1.96 from Z table where *p*=0.05 with accuracy of 95%.

δ Is the allowable standard deviation and E is the allowed error.

$\therefore N=\left(\frac{1.96\times0.6}{0.2}\right)^2 = 34.574$

Hence, the minimum sample size should not be less than **35** responses; however the collected sample size is **57** responses, therefore the sample size and responses deemed reliable (Bartlett et al. 2001).

4.1 Data analyses, findings and discussion

The following table 3 depicts the mean rank analyses and RII for each question.

Ranking of each question will follow the values of RII, which means the higher the RII the higher the ranking.

However, RII for different elements may have the same value, hence the value for the Likert scale rating of “more than 4 i.e. 4 and 5 together” will be used to judge the higher ranking. For example in case, the number of more than 4 rating is same, hence the value for the Likert scale rating of 3 will be used to further judge the ranking of the elements (Eadie et al. 2013).

4.1.1 **Perceived benefits of BIM.**

Sr.	Perceived benefits of BIM	BIM **users (responses)**					BIM **non-users (responses)**				
		Mean	**No.=3**	**No.≥4**	**RII**	**Rank**	**Mean**	**No.=3**	**No.≥4**	**RII**	**Rank**
1	BIM offers Integration/collaboration and robust communication amongst different teams.	4.648			**0.929**	1	4.5			**0.90**	2
2	BIM offers Error-free design	3.784	3	35	**0.757**	16	3.9	7	13	**0.78**	20
3	BIM offers improved productivity	3.919			**0.784**	14	4.4	0	20	**0.88**	4
4	Improved quality	4.243	4	30	**0.849**	3	4.35	0	20	**0.87**	8
5	Improved quantity take-off	4.189			**0.838**	6	4.4	2	18	**0.88**	6
6	Less rework	4.135	5	29	**0.827**	10	4.4	0	19	**0.88**	5
7	Time saving.	3.946			**0.789**	13	4.7			**0.94**	1
8	Cost saving.	4.081			**0.816**	12	4.35	1	19	**0.87**	9
9	Reduction in wasted materials.	4.216			**0.843**	5	4.25			**0.85**	14
10	Less RFIs and change orders.	4.162	5	28	**0.832**	8	4.45	2	18	**0.89**	3
11	Improved safety.	3.351			**0.670**	20	3.9	3	15	**0.78**	19
12	Improved logistics and machinery planning.	3.729			**0.746**	18	3.95	4	15	**0.79**	17

13	Increased ROI.	3.703			**0.741**	19	3.95	2	15	**0.79**	18
14	Improved sustainability	3.784	12	22	**0.757**	17	4.3	2	16	**0.86**	13
15	Improved performance of the Facility Management (FM).	3.892			**0.778**	15	4.35	1	19	**0.87**	10
16	Early involvement of owners for quick decisions.	4.162	6	28	**0.832**	7	4.35	0	18	**0.87**	12
17	Promotes the company's competitive edge.	4.378			**0.875**	2	4.2	2	18	**0.84**	15
18	Promotes the off-site prefabrication.	4.108			**0.821**	11	4.2	3	17	**0.84**	16
19	Document automation.	4.135	4	30	**0.827**	9	4.35	1	19	**0.87**	11
20	Fast and accurate production of As-Built drawings.	4.243	5	28	**0.848**	4	4.4	1	18	**0.88**	7
	Total	**80.808**					**85.65**				
	Total Mean score	**4.040**					**4.282**				

Table 3: Mean and RII for the perceived benefits of BIM for BIM users and non-users

Table 3 demonstrates that BIM non-users consider the perceived benefits of BIM are more important than BIM users with an overall weight of **85.65** against **80.81**for BIM users.

The first five ranked perceived benefits for BIM non-users based on their weight respectively are “time saving”, “BIM offers Integration/collaboration and robust communication amongst different teams”, “Less RFIs and change orders”, “BIM offers improved productivity” and “Less rework”.

It is obvious that BIM non–users “expectations” for the benefits of BIM revolves around two main spectrums; the first represented in their expectations that utilizing BIM will assist them in resolving the reoccurring day-to-day operational work problems. And the second is represented in using BIM will assist them in meeting the client satisfactions.

BIM non–users consider the use of BIM as a significant solution for their current operational problems; they considered BIM as the vehicle to integrate the AEC fragmented teams. In addition they considered BIM is able to clarify the ambiguities to minimize the change orders and the abortive works, which leads to increasing the productivity and promoting the organizations’ profits.

It is obvious continuity in a rival market such as UAE market is compounded with the client satisfaction, which is the overriding concern for all the AEC organizations. Hence table 3 shows a close understanding between BIM users and non-users for the benefits that BIM offers, which leads to the client satisfactions such as “integration of project the team work”, “saving the project cost”, “improving the quality” and “less RFI and change orders”.

Table 3 and the higher mean value reflects higher level of awareness for the benefits of BIM from BIM non-users group. BIM non-users considered the utilization of BIM will save the project time (ranked as the 1st). In addition they expected BIM will eliminate the waste of time resulted from the fragmentation among the project teams, where BIM can offer an easy and transparent communication channel to integrate all the project teams (ranked as the 2nd). Moreover they expect more clarity of the project through using BIM tools, which by turns will reduce the change orders and RFI (ranked 3rd). Moreover, they expressed optimistic expectations for the improvements of the projects’ quality (ranked 4th) which is one of the most important requirements to meet the client and customer satisfactions to sustain in the market. It is obvious that the source of the expectations for BIM non-users about the benefits of BIM are acquired basically from the presentations offered to them by BIM software vendors. Because sometimes their ranking entails contradictions between some rigorously correlated factors such as “time saving” and “cost saving” which are ranked as 1st and 9th respectively with weighting 0.94 and 0.87 respectively, with big gap of 0.07 in weighting. However the same factors are ranked 12th and 13th from BIM users with close weighting 0.789 and 0.816 respectively with very slight difference i.e. 0.027.

BIM users reported their top five ranking for the perceived benefits of BIM as “BIM offers Integration/collaboration and robust communication amongst different teams”, “promotes company’s competitive edge”, “improved quality”, “fast and accurate as-built drawings” and “reduction in wasted materials”.

Therefore, it is obvious, the BIM users’ perception for the benefits of BIM derived from the practical experience, therefore the perceived benefits for BIM users were escalated to a higher level of practicality compared to the BIM non-users, which is based on expectations and perception with no practical experience.

The perceived benefits for BIM users revolves around three main areas, first is meeting the client satisfaction, second is promoting the company’s competitive advantage and the third is enhancing the sustainability.

The literature review revealed that, the client satisfactions can be achieved through, integration of the project team (ranked 1st) by BIM users which significantly will improve the quality (ranked 3rd) and eliminate the time waste to improve the accuracy to produce accurate as-built drawings (ranked 4th) for further use by FM teams.

Improving the organization competitive edge and promoting the organization capacity to sustain in the market is one of the tangible benefits for BIM users because of early implementation of BIM, BIM users are step ahead compared to BIM non-users. Therefore BIM users are always preferred by the clients, and their chance to win new projects is much higher than BIM non-users, especially for the clients who made BIM as a mandatory condition to win new projects such as Dubai Municipality, Masdar city and Abu Dhabi Airport Company (ADAC).

BIM users considered BIM as an ideal tool to reduce the materials’ waste which promotes the sustainability. BIM is promoting the offsite prefabrications and significantly reduce the reworks.

The least three perceived benefits for BIM non-users are “BIM offers Error-free design”, “Improved safety” and “Increased ROI”.

However, for BIM users the least three perceived benefits respectively are "Improved safety", "Increased ROI" and "Improved logistics and machinery planning".

The least three perceived benefits for BIM non-users and BIM users are close to each other, where they are sharing the same opinion about less benefits for increased ROI and improved safety. That sounds realistic because adoption of new technologies and changing the entire work processes always carries uncertainties until the end of the project. As it is well known that, the implementation of BIM still in the embarking stage in UAE and all the projects using BIM are yet to be completed. Therefore no appropriate evaluation can be conducted for the ROI unless the project is completed; however and on the counter side the huge expenditures made to implement BIM are well estimated.

BIM users and non-users ranked the ability of BIM to improve safety as the lowest ranks (20th and 19th respectively). That can be understood from the fact safety is a culture that requires adequate time to change the employees and staff behaviors. That behavior cannot be immediately changed even in the existence of the most advanced work methodology and technology such as BIM.

BIM non users considered "error-free design" as the least benefit of BIM (ranked 20th), that can be understood from the heavy amount of mistakes that BIM non-users are facing for the design in every project. Therefore it is not easy for them to believe there is a new technology can produce an error-free design without a factual practice, hence they consider this benefit as a myth.

Similarly, BIM users considered "error-free design" as one of the least benefits of BIM, which is ranked as the 16th out of 20 this reflects the BIM users' frustration. This frustration is explained by BIM users (case study 1) who elaborated that in many cases they are forced to produce drawings in the conventional 2D CAD methodology, because most of the stakeholders and the client are not BIM users and not familiar with BIM software. That means BIM is not fully integrated in the project, therefore many drawings are still produced in the conventional 2D CAD methodology with errors.

The literature review revealed that in AEC markets that is more experience and mature for the use of BIM, they considered one of the most significant benefits of the use of BIM is its ability to develop error-free design. In fact BIM has been implemented recently in the UAE AEC industry i.e. less than 2 year. Therefore reaping and recognizing all the benefits of BIM requires more time at least till the completion of the project. Hence it is expected that, the same respondents (BIM users) may reshuffle their responses once they are becoming BIM experts.

In order to compare the perceived benefits for BIM non-users and BIM users the following radar in figure 8 demonstrates the degree of agreement and disagreement between the two groups based on the weighting for each factor.

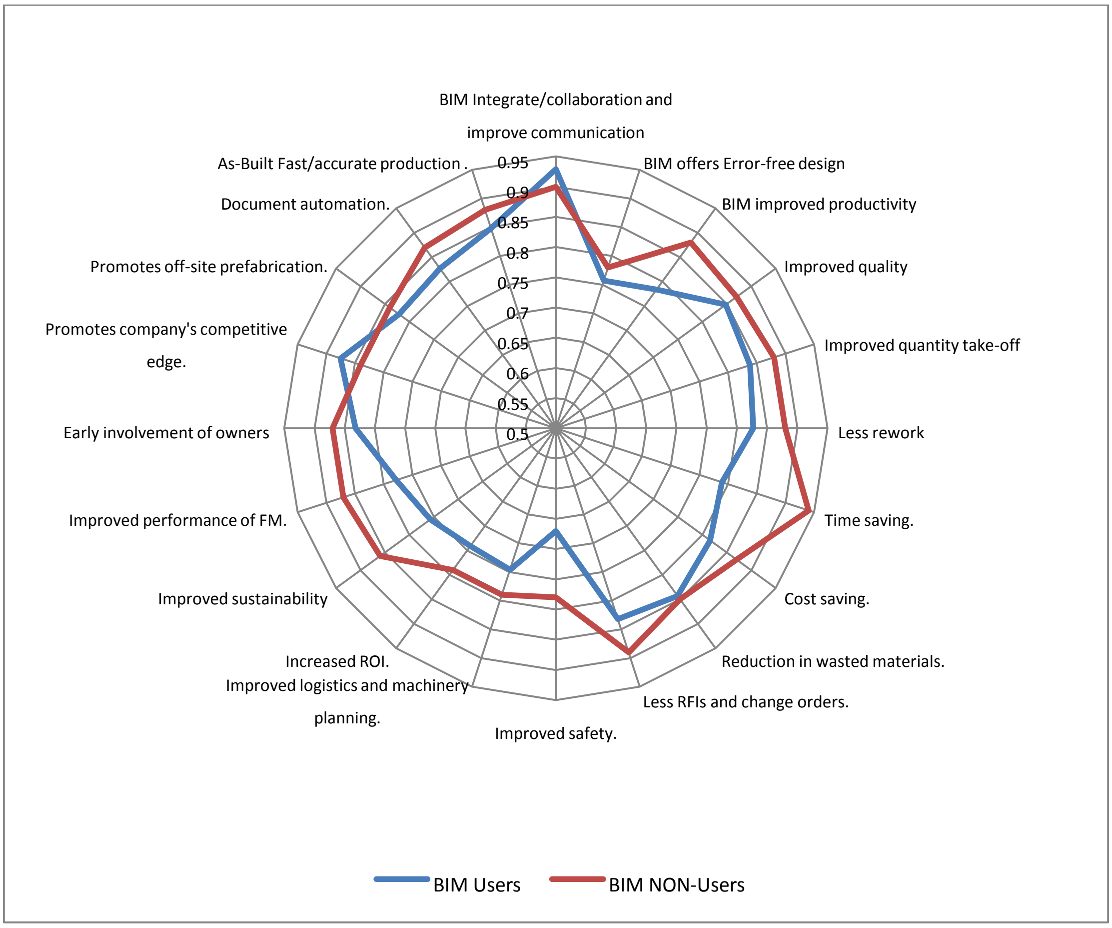


Figure 8: Perceived benefits of BIM (BIM users and BIM non-users)

The radar shape illustrates close understanding of the perceived benefits of BIM between the two groups, especially which are related to meet the client satisfactions.

However, BIM users considered the ability of BIM to integrate the team works and add competitive advantage to the company much higher that the BIM non-users, which is realistic because only BIM users can acquire these benefits.

In general the expectations of BIM non-users are much more than BIM users for the benefits of BIM. The biggest difference for the perceptions of the two groups is found in the ability of BIM to “save the time” which was ranked the 1st by BIM non-users and ranked the 13th by BIM users. Similarly, for the factor “BIM offers improved productivity” was ranked 4th and 14th by BIM non-users and users respectively. These big discrepancies can be understood from the ideal state that BIM non-users are considering, which can be achieved only after the UAE AEC market reaches the full maturity level of BIM.

However, BIM users are expressing their current opinion for the UAE market which still embarking to gain the BIM experience that is explicitly unveil the tremendous challenges that BIM users are facing now because of the low level of the utilization of BIM in the UAE AEC industry.

Table 4 will enable the calculation for the rank agreement factor (RAF) for the benefits of BIM for both groups.

Sr.	**Perceived benefits of BIM**							**Abs**
		Users Rank	**Non users rank**	**Ri1-Ri2**	**Abs**	**J**	**Ri1-Rj2**	
1	BIM offers Integration/collaboration and robust communication amongst different teams.	1	2	-1	1	**19**	-18	18
2	Promotes the company's competitive edge.	2	15	-13	13	**18**	-16	16
3	Improved quality	3	8	-5	5	**17**	-14	14
4	Fast and accurate production of As-Built	4	7	-3	3	**13**	-9	9

	drawings.							
5	Reduction in wasted materials.	5	14	-9	9	**20**	-15	15
6	Improved quantity take-off	6	6	0	0	**10**	-4	4
7	Early involvement of owners for quick decisions.	7	12	-5	5	**4**	3	3
8	Less RFIs and change orders.	8	3	5	5	**1**	7	7
9	Document automation.	9	11	-2	2	**3**	6	6
10	Less rework	10	5	5	5	**16**	-6	6
11	Promotes the off-site prefabrication.	11	16	-5	5	**5**	6	6
12	Cost saving.	12	9	3	3	**11**	1	1
13	Time saving.	13	1	12	12	**3**	10	10
14	BIM offers improved productivity	14	4	10	10	**12**	2	2
15	Improved performance of the Facility Management (FM).	15	10	5	5	**6**	9	9
16	BIM offers Error-free design	16	20	-4	4	**14**	2	2
17	Improved sustainability	17	13	4	4	**7**	10	10
18	Improved logistics and machinery planning.	18	17	1	1	**8**	10	10
19	Increased ROI.	19	18	1	1	**15**	4	4

20	Improved safety.	20	19	1	1	**2**	18	18
				Abs sum	**94**		**Abs max sum**	**170**

Table 4: RAF, PD and PA values for perceived benefits of BIM for BIM users and non-users

RAF=94/20=4.70 ∴ RAF=4.7

RAF max =170/20=8.5 ∴ RAF max=8.5

PD (percent disagreement) = $\frac{RAF}{RAF\ max}$= $\frac{4.7}{8.5}$=0.55294×100%=55.294%

PA (percent agreement) =PD-100

PA=100- 55.294= 44.70%

These results are realistic (Percent Agreement is 44.7%) which is relatively low percent, that is because of the big gap in the perceptions between the two groups. Both groups are having different experiences, BIM users already experienced several challenges that are not at all practically experienced by BIM non-users. Therefore the big difference between both groups comes from the high expectations of the BIM non-users who considered the ideal state of BIM, which can be achieved only after reaching the maturity level after a long time of using BIM in the AEC industry. However in fact, BIM still in the embarking stage and BIM users are struggling in the UAE market with tremendous challenges, because the majority of the UAE AEC players are not using BIM, which created frustrations for the BIM users in terms of reaping the full benefits of BIM.

The following table 5 provides an overall ranking after combining the two groups of BIM users and non-users for the perceived benefits of BIM.

The closer RII value to “1” the more important the benefits of BIM.

Sr.	Perceived benefits of BIM	**RII BIM users**	**RII BIM non users**	**Aver. RII**	**Rank**
1	BIM offers Integration/collaboration	0.929	0.90	**0.9145**	**1**

	and robust communication amongst different teams.				
2	Time saving.	0.789	0.94	**0.8645**	**2**
3	Fast and accurate production of As-Built drawings.	0.848	0.88	**0.864**	**3**
4	Less RFIs and change orders.	0.832	0.89	**0.861**	**4**
5	Improved quality	0.849	0.87	**0.8595**	**5**
6	Improved quantity take-off	0.838	0.88	**0.859**	**6**
7	Promotes the company's competitive edge.	0.875	0.84	**0.8575**	**7**
8	Less rework	0.827	0.88	**0.8535**	**8**
9	Early involvement of owners for quick decisions.	0.832	0.87	**0.851**	**9**
10	Document automation.	0.827	0.87	**0.8485**	**10**
11	Reduction in wasted materials.	0.843	0.85	**0.8465**	**11**
12	Cost saving.	0.816	0.87	**0.843**	**12**
13	BIM offers improved productivity	0.784	0.88	**0.832**	**13**
14	Promotes the off-site prefabrication.	0.821	0.84	**0.8305**	**14**
15	Improved performance of the Facility	0.778	0.87	**0.824**	**15**

	Management (FM).				
16	Improved sustainability	0.757	0.86	**0.8085**	**16**
17	BIM offers Error-free design	0.757	0.78	**0.7685**	**17**
18	Improved logistics and machinery planning.	0.746	0.79	**0.768**	**18**
19	Increased ROI.	0.741	0.79	**0.7655**	**19**
20	Improved safety.	0.670	0.78	**0.725**	**20**

Table 5: Overall ranking for the perceived benefits of BIM

Table 5 indicates that there are smooth transitions between the ranks with very minor discrepancies in their values of the average RII. The overall ranking for the perceived benefits of BIM shows that the factor “BIM offers Integration/collaboration and robust communication amongst different teams” is currently the greatest perceived benefits within the UAE AEC industry with the highest score of 0.9145. That is ranked as the first and “Time saving”, “Fast and accurate production of As-Built drawings” and “Less RFIs and change orders” are ranked second, third and fourth respectively.

This demonstrates that, the respondents consider the implementation of BIM resolve the operational daily work problems and driving to meeting the client satisfaction and promoting the organization competitive advantage.

However, the benefits which require completion of the project or culture change need long duration to be recognized are obvious ranked the lowest, whereas the implementation of BIM within UAE AEC industry is almost less than two years and all the projects that are utilizing BIM are not completed yet.

These least ranks for the perceived benefits of BIM are “Improved safety”, “Increased ROI” and “Improved logistics and machinery planning”.

The overall ranking of the benefits may be changed with time, once the UAE AEC industry becomes BIM professionals and all the benefits of BIM became tangible.

However, most of the countries that reached the maturity level for BIM such as Finland, Norway and USA considered the most important benefit of BIM congruent with UAE

AEC industry perception to be “BIM offers Integration/collaboration and robust communication amongst different teams”. However, the second rank is “error free design” (Bryde et al. 2013; Eadie et al. 2013; Elmualim and Gilder 2014; Love et Al. 2014) which is ranked as the 7th in UAE AEC industry as per the data analyses.

4.1.2 Challenges/Barriers and obstacles to implement BIM

To ranking the challenges for implementation of BIM within the UAE AEC industry the previous data analyses methodology will be utilized.

Table 6 shows the comparison between BIM users and non-users for their understanding for the challenges and barriers that hinder the implementation of BIM. BIM non-users considered the challenges associated with the implementation of BIM is more difficult and critical compared to the BIM users, with an overall score **48.15** for BIM non-users against **45.292** for BIM users.

Sr.	**Challenges and obstacles**	BIM **users (responses)**					BIM **non-users (responses)**				
		Mean	**No.=3**	**No.≥ 4**	**RII**	**Rank**	**Mean**	**No.=3**	**No.≥ 4**	**RII**	**Rank**
1	Owner/client did not ask to use BIM	3.706			**0.7412**	5	4.20			**0.84**	5
2	Inadequate BIM experience	4.147			**0.8294**	4	3.65			**0.73**	9
3	Inadequate top management support	4.206			**0.8412**	3	4.70			**0.94**	1
4	Resistance to change	4.529			**0.9058**	1	4.50			**0.90**	2
5	Significant changes in workflow	4.294			**0.8588**	2	4.35	3	17	**0.87**	3
6	Inefficient interoperability	3.411			**0.7294**	6	4.35			**0.75**	8
7	Who to manage the BIM model.	3.382			**0.6764**	12	3.60	9	10	**0.72**	11
8	Unavailability of BIM skilled resources	3.50			**0.7000**	8	4.15			**0.83**	6

9	Not all stakeholders are using BIM.	3.647			**0.6822**	11	3.75	2	17	**0.87**	4
10	High cost of BIM	3.412			**0.6824**	10	4.00			**0.80**	7
11	Unclear legal and contractual	3.470			**0.6940**	9	3.30			**0.66**	12
12	Project procurement	3.588			**0.7176**	7	3.60	6	11	**0.72**	10
	Total	**45.292**					**48.15**				
	Total Mean score	**3.774**					**4.012**				

Table 6: Mean and RII for the challenges hinder the implementation of BIM for BIM users and non-users

BIM non-users ranked the first five challenges for the implementation of BIM respectively as follows “Inadequate top management support”, “Resistance to change”, “Significant changes in workflow”, “Not all stakeholders are using BIM” and “Owner/client did not ask to use BIM”.

It is obvious that the first five ranked challenges from the BIM non-users point of view are pertaining to the change management challenges and the surrounding environment challenges.

“The lack of support from the top management” is ranked the first and the most critical barrier for the implementation of BIM. That means BIM non-users believe that without the top managements support the change initiative to implement BIM is going to face myriad of irresistible obstacles from all the employees. Therefore the implementation of BIM without the top managements support is an elusive target.

Moreover, BIM non-users considered “the resistance to change” is the second critical challenge to implement BIM, especially if this change is compounded with threaten of employments for senior managements or old employees or changing the organization’s culture.

The “changes in workflow” was ranked the third critical hindrance that impedes the implementation of BIM. The case studies confirmed that due to the implementation of BIM some employees will lose their employment such as QS, 2D draughtsman, and new positions with high authority will be created such as BIM manager. Hence the organization’s chart will be restructured with new patterns of power and authorities, therefore the employees who may lose their power and authority will attempt to deter the changes to BIM.

The second category is the surrounding environment, where BIM non-users considered “Not all stakeholders are using BIM” is the 4th rank for the critical hindrance to implement BIM. That diminishes the enthusiasm of the organizations to implement BIM, where the main premise of BIM is about collaborating all the project teams through using an appropriate communication channel i.e. BIM model. However if one or more stakeholders in the project are not using BIM that will cut-off the communication among the project teams, accordingly BIM users in many cases are forced to slip back to use the 2D CAD methodology, which is negatively impacting the BIM users.

The 5th critical rank was “the owner or client did not ask to use BIM as a compulsory requirement to win the projects”, therefore the organizations and the entire industry considered the implementation of BIM is an optional choice. In fact, the full benefits of BIM can’t be reaped unless all the organizations in the UAE AEC industry implement BIM at the same time. That is one of the important reasons that diminish the chances for the implementation of BIM in UAE.

On the other hand, BIM users ranking almost same of BIM non-users, where the first five ranking are “Resistance to change”, “Significant changes in workflow”, “Inadequate top management support”, “Inadequate BIM experience” and “Owner/client did not ask to use BIM”.

It is obvious that the first five ranked challenges from the BIM users are correlated to the challenges of the change management and the surrounding environment challenges, which demonstrate the organization’s difficulties during the implementation of BIM.

The similarity of the perceived challenges and obstacles for the implementation of BIM between the BIM users and non-users comes from the close watching for the challenges that BIM users are facing. In addition to the conservative nature of the AEC industry, that is forcing the decision makers to closely study the risks of the new change initiatives

It is not surprising to find that, the USA as one of the early adopters of BIM ranked the most critical three challenges for the implementation of BIM almost the same of the UAE AEC industry. An extensive study for the USA AEC industry conducted by Eadie et al. (2014, p.90) concluded that, the first three obstacles for BIM users are “doubts about ROI/lack of vision of benefits”, “scale of culture change required/lack of flexibility” and “ cost of training”. However the first four significant factors hinder the implementation of BIM in USA for the BIM non-users are “lack of supply chain buy-in”, “scale of culture change required/ lack of flexibility”, “software literacy of staff/lack of technical expertise” and “cost of software”.

The similarity in results between the USA and UAE AEC industries shows the conservative attitude of the AEC industry and its resistance to the change initiatives regardless of the location. However it is also obvious the level of resistance varies according to the AEC industry level of maturity, where USA is one of the early adopters of BIM. BIM is implemented in USA since 2002 (Eadie et al. 2013). However, UAE started to implement BIM almost two years ago.

In order to compare between the most critical factors for the perceived challenges and obstacles for BIM non-users and BIM users, the following radar in figure 9 demonstrates the degree of agreement and disagreement between the two groups.

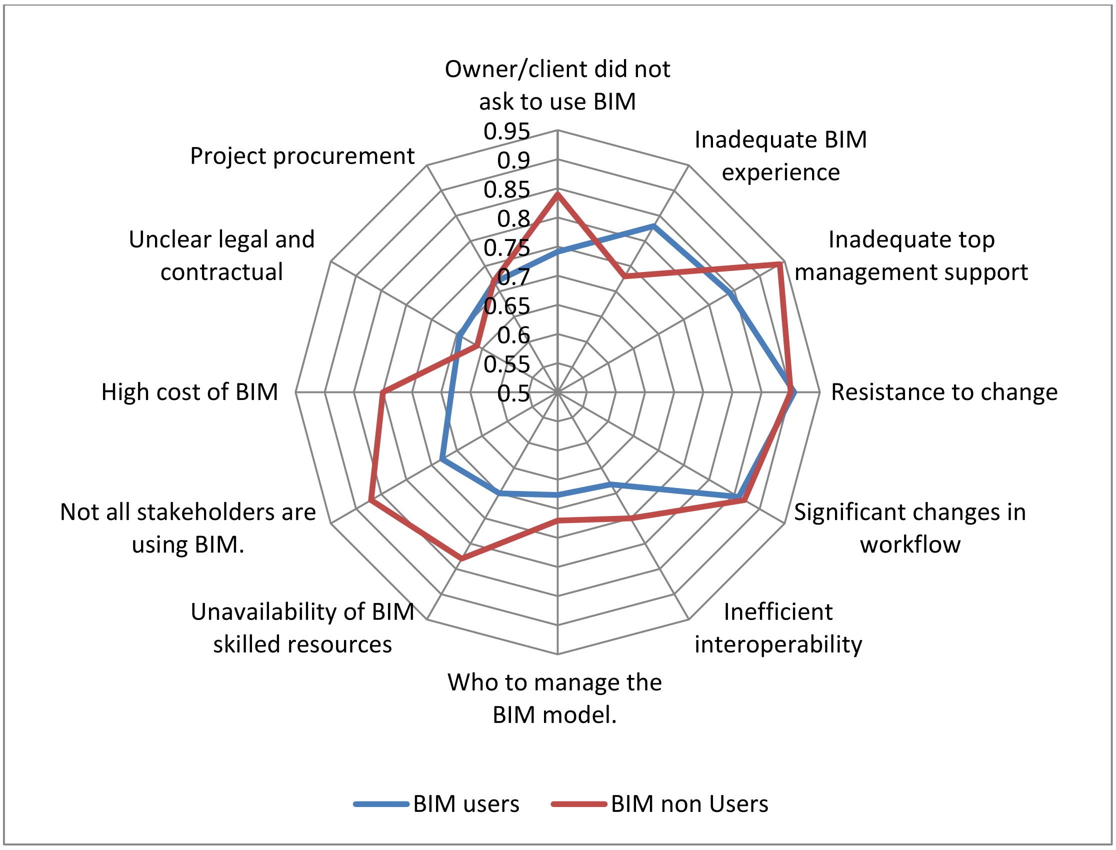


Figure 9: Challenges and obstacles for the implementation of BIM

The radar shape in figure 9 renders close understanding for a cluster of challenges of the perceived challenges and obstacles of BIM between the two groups, especially the challenges concern the change management.

Table 6 and figure 9 show the biggest disagreement between BIM users and non-users for the perception of the challenges pertaining to the implementation of BIM represented in “Not all stakeholders are using BIM” where BIM non-users have evaluated this risk as the 4th important challenge hindering the implementation of BIM. This evaluation can be understood from the close watching of BIM non-users to the problems that BIM users are facing, one of the recorded problems that causing frustrating to BIM users is “not all stakeholders are using BIM” which was ranked the 11th by BIM users. In addition, BIM non-users are considering the holistic and the ideal case of the utilization of BIM. Therefore they have considered the communication cut-off and the time waste in transferring the BIM 3D drawings to 2D or may be sometimes they are forced to produce drawings in the conventional 2D methodology as a big risk to the use of BIM.

It is obvious this challenge i.e. “not all stakeholders are using BIM” is creating additional risks to the BIM users who are losing time to communicate their ideas and sometimes they are forced to develop drawings in 2D traditional methodology. However the practical experience and the ability of BIM model to produce 2D drawings, can resolve many issues that reduces the risks created from this challenge. In addition to the capacity of BIM software to deal with the drawings produced by the conventional 2D CAD methodology to be directly converted into the BIM model. Therefore, BIM users especially the designers who represent 68% of the respondents considered the challenge “not all stakeholders are using BIM” is a manageable challenge.

There are gaps in the perceptions of the challenges that hinder the implementation of BIM between BIM users and non-users, where BIM non users have evaluated the challenge “unavailability of BIM resources” higher than BIM users. That can be understood from the practical experience of the BIM users and the training programs to their staff. And after almost two years of the implementing BIM in UAE, BIM users have the enough resources and expertise to run their business. However BIM non-users can obviously see the available BIM resources cannot cover the market demand.

The third gap between both groups noticed for the challenge “high cost of BIM” which was ranked as a critical challenge, BIM non-users evaluated this challenge in higher weight than that given by BIM users. That can be understood from the practical experience of BIM users who distributed the funding to implement BIM with the time span. However BIM non-users are lacking such experience and they think all the expenditures are required in a very short time i.e. in the first month. The literature and case studies confirmed that BIM is requiring high investment with short time, however many organizations managed to stretch the funding time span (distribute the expenditures on long timescale) to have less financial impacts.

The only challenge that was underestimated by BIM non users compared to BIM users was “inadequate BIM experience with know-how experience to change to BIM” where BIM users considered this factor as a very challenging factor (ranked as the 4th) however BIM non-users considered less impacting (ranked as 9th).

This can be explained as a time related factor, where BIM users implemented BIM in earlier stage i.e. before two years, where BIM in UAE was a novel approach in the AEC industry, and the availability of vendors and BIM services and consultations to assist the organizations to change to BIM were very rare in the UAE market, therefore BIM users experienced the negative consequences from this factor.

However, after two years the remarkable number of organizations available for BIM vendors, sourcing, services and consultancy made this factor easier with less impact than before.

The factor "Owner/client didn't ask to use BIM" was evaluated the 5th rank from both groups, however more weight was given by BIM non-users 0.84 against 0.741 from BIM users. That is realistic and elaborated by case study 3, the clients and government made the use of BIM as optional. In this case, many organizations are satisfied and clinging to the traditional construction approaches that they are following; hence they are not committed to a new change that is replete with uncertainties.

It is obvious the challenges correlated to the change management have a close understanding for both groups.

In order to find out the RAF for the challenges for the implementation of BIM for both groups, the following table 7 indicates the shared and contradicted opinions.

Sr.	**Challenges and obstacles**	**Users Rank**	**Non users rank**	**Ri1-Ri2**	**Abs**	**J**	**Ri1-Rj2**	**Abs**
1	Resistance to change	1	2	-1	1	**11**	-10	10
2	Significant changes in workflow	2	3	-1	1	**4**	-2	2
3	Inadequate top management support	3	1	2	2	**7**	-4	4
4	Inadequate BIM experience	4	9	-5	5	**12**	-8	8
5	Owner/client did not ask to use BIM	5	5	0	0	**6**	-1	1
6	Inefficient interoperability	6	8	-2	2	**10**	-4	4

7	Project procurement	7	10	-3	3	**8**	-1	1
8	Unavailability of BIM skilled resources	8	6	2	2	**5**	3	3
9	Unclear legal and contractual	9	12	-3	3	**9**	0	0
10	High cost of BIM	10	7	3	3	**1**	9	9
11	Not all stakeholders are using BIM.	11	4	7	7	**3**	8	8
12	Who to manage the BIM model.	12	11	1	1	**2**	10	10
				Sum of Abs	**30**		**Sum of Abs max**	**60**

Table 7: RAF, PD and PA values for the challenges hindering the implementation of BIM for BIM users and non-users

RAF=30/12= 2.50 ∴ RAF=2.50

RAF max =60/12=5 ∴ RAF max=5

PD (percent disagreement) = $\frac{RAF}{RAF\ max}$= $\frac{2.5}{5}$= 0.50×100%=50%

PA (percent agreement) =PD-100

PA=100- 50= 50%.

PA value supports the earlier proposition of moderate agreement for the understanding of the challenges and obstacles that impact the implementation of BIM in the UAE AEC industry for both groups i.e. BIM users and non-users. That is because, the implementation of BIM still in the early stage (the learning curve). Therefore the perceived challenges for both groups are similar.

However, once the UAE AEC industry become a BIM professional the analyzed results are likely to be changed.

The literature and case studies revealed that there is a consensus agreement among the BIM professionals concludes that the full implementation of BIM to reach to the maturity level in the AEC industry is a long process. That is requiring a long time, which varies from two to five years (UK, Cabinet office 2011; SmartMarket Report 2014).

The following table 8 provides an overall ranking from the combination of the two groups of BIM users and non-users for the perceived challenges for the implementation of BIM in the UAE AEC industry.

The closer RII value to "1" the more critical the challenges to implement BIM.

Sr.	Challenges and obstacles	**RII BIM users**	**RII BIM non users**	**Aver. RII**	**Rank**
1	Resistance to change	0.9058	0.9	**0.9029**	**1**
2	Inadequate top management support	0.8412	0.94	**0.8906**	**2**
3	Significant changes in workflow	0.8588	0.87	**0.8644**	**3**
4	Owner/client did not ask to use BIM	0.7412	0.84	**0.7906**	**4**
5	Inadequate BIM experience	0.8294	0.73	**0.7797**	**5**
6	Not all stakeholders are using BIM.	0.6822	0.87	**0.7761**	**6**
7	Unavailability of BIM skilled resources	0.7	0.83	**0.765**	**7**
8	High cost of BIM	0.6824	0.8	**0.7412**	**8**
9	Inefficient interoperability	0.7294	0.75	**0.7397**	**9**
10	Project procurement	0.7176	0.72	**0.7188**	**10**
11	Who to manage the BIM model.	0.6764	0.72	**0.6982**	**11**

12	Unclear legal and contractual issues	0.694	0.66	**0.677**	**12**

Table 8: Overall ranking for the challenges hindering the implementation of BIM

The first ranked as a critical challenge that impacts the implementation of BIM in UAE AEC industry is **"resistance to change"** on the organization and on the industry level. Which was seen by both groups as the corner stone for the implementation of BIM, resistance to change recorded the highest record with value of **0.9029**. Followed by "**the top management inadequate support to the change**" to switch to BIM with score of **0.8906** and the third rank was the impact of "**the significant change in the workflow and restructuring the powers and authorities map within the organization**" with score **0.8644** .

It is clear that, there is a slight difference between the first three ranks, which indicates the UAE AEC industry close perception for their critical impact on the implementation of BIM in UAE. Similarly the discrepancies between the factors from 4th to 12th are minor which indicates close understanding of their significance and critical impact.

However, there is a big transition gap between the 3rd and 4th factors with average RII as **0.8644** and **0.7906** respectively, where 3rd factor represents change management issues and 4thfactor represents surrounding environment. That means the change management issues are the most critical with the greatest impact on the implementation of BIM than the surrounding factors and the alike.

4.1.3 Driving forces and pressures imposing implementation of BIM

The following table 9 demonstrates that BIM non-users evaluations for the driving forces imposing the implementation of BIM are more critical than the BIM users' evaluations with an overall score of **12.90** against **11.186** for BIM users.

Majority of the BIM users in UAE are deemed early adopters that are not exposed to the pressures to use BIM. However, some clients such as DM, MASDAR, TDIC, and ADAC imposed BIM as a compulsory requirement; hence all the BIM non-users are exposed to pressures to use BIM.

Sr.	Driving forces and pressures	BIM **users (responses)**					BIM **non-users (responses)**				
		Mean	**No.=3**	**No.≥ 4**	**RII**	**Rank**	**Mean**	**No.=3**	**No.≥ 4**	**RII**	**Rank**
1	Government & client pressure	3.968			0.9736	**1**	4.60			0.92	**1**
2	Surrounding environment& competitive pressure	3.562			0.7125	**3**	4.3			0.86	**2**
3	Complexity of projects& profit declination	3.656			0.7312	**2**	4.00			0.80	**3**
	Total	**11.186**					**12.90**				
	Total Mean score	**3.7288**					**4.30**				

Table 9: Mean and RII for the driving forces imposed to implement BIM for BIM users and non-users

BIM non-users and BIM users ranked the "government and client pressure" as the most important driving force for the implementation of BIM in the UAE AEC industry. That means to mandate BIM in the UAE it has to be through the government(s) or the clients, where the AEC players has no choice but to respond and follow the compulsory requirements in order to survive in the UAE AEC market.

BIM non-users ranked the driving forces "Surrounding environment and competitive pressure" is the 2nd which was ranked the 3rd by BIM users. That is realistic because there are imposed pressures on the BIM non-users.

In this case the BIM users are considered the competitors that are having added advantages with greater chances to win new projects compared to the BIM non-users, because clients always prefer the BIM users. Therefore, BIM non-users are exposed to this kind of pressures which they considered the 2nd critical driving force that imposing the implementation of BIM.

However, BIM users are not exposed to this type of pressures from the competitors because they are already BIM-users. That is explaining why this driving force considered the least by the BIM users.

Moreover, BIM users ranked "Complexity of projects and profit declination" the 2nd critical factor driving to the implementation of BIM. The same factor was ranked the least by BIM non-users. That can be understood from BIM users' status, where BIM users are step ahead compared with BIM non-users. Therefore BIM users are always planning for continues improvements to promote their profits and utilizing BIM offers tools that assist them to respond to the project complexities to improve their profits.

It is not surprising to find that, the above results for the data analyses collected from the UAE AEC industry are identical with the study conducted in the USA AEC industry, where the most important driving factors found in the USA are "government pressure" and "competitive pressure and client pressure" that are ranked 1st and 2nd places (Eadie et al. 2013).

That reflects the AEC industry responses to the driving forces and the imposed pressures are almost the same regardless of the market place.

In order to compare the perceived challenges for BIM non-users and BIM users the following radar figure 10 demonstrates the degree of agreement and disagreement between the two groups.

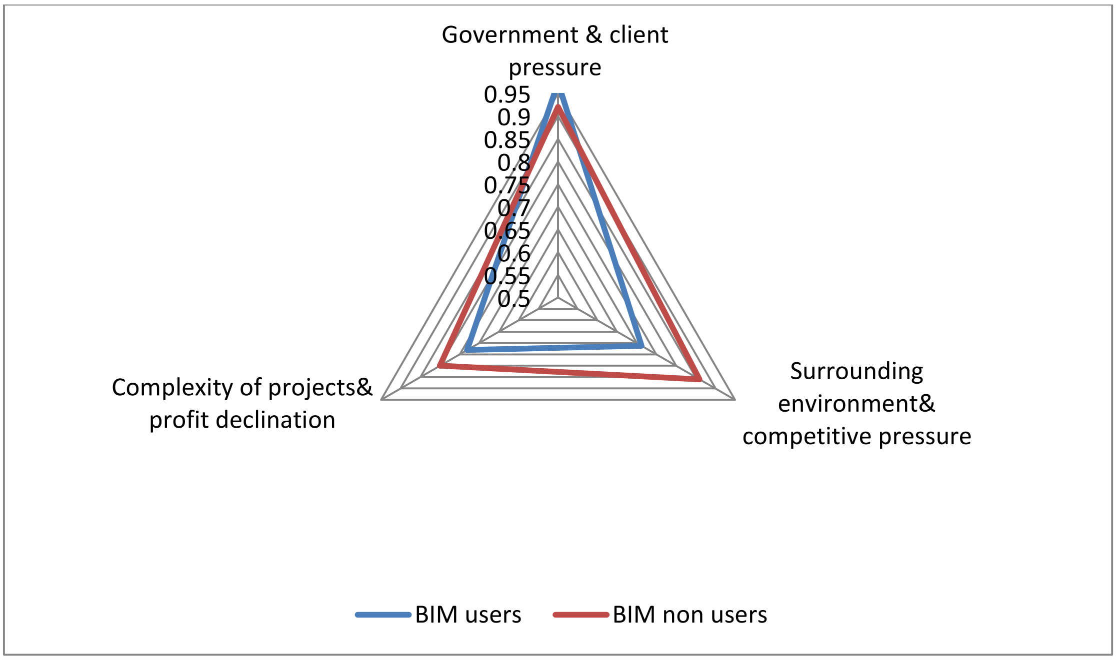


Figure 10: Driving forces imposed on the organization to implement BIM

The radar shape in figure 10 demonstrates close understanding with very minor discrepancies of the driving forces for the implementation of BIM between the two groups. However the biggest gap noticed in the driving factor “surrounding environment & competitive pressures” where RII for BIM non-users and BIM users respectively are **0.86** and **0.71,** which was elaborated in the previous section.

However, the driving force “government and client pressure” to impose BIM as a compulsory requirement weighted more critical by BIM users, where BIM users consider this driving force as the most important to mandate BIM, that comes from their holistic view of the UAE AEC industry.

In order to find out the rank agreement factor (RAF) for the driving forces for the implementation of BIM for both groups, the following table 10 indicates that.

Sr.	Driving forces and pressures							
		Users Rank	Non users rank	Ri1-Ri2	Abs	J	Ri1-Rj2	Abs
1	Government & client pressure	1	1	0	0	**2**	-1	1
2	Complexity of projects& profit declination	2	3	-1	1	**3**	-1	1
3	Surrounding environment& competitive pressure	3	2	1	1	**1**	2	2
				Sum of Abs	**2.0**		**Sum of Abs max**	**4.0**

Table 10: RAF, PD and PA values for the driving forces for the implementation of BIM for BIM users and non-users

RAF=2/3= 0.6667 ∴ RAF=0.667

RAF max =4/3=1.334 ∴ RAF max=1.334

PD (percent disagreement) = $\frac{RAF}{RAF\ max}$= $\frac{0.667}{1.334}$= 0.50×100%=50%

PA (percent agreement) =PD-100

PA=100- 50= 50%.

PA value supports the earlier proposition of the existence of moderate agreement between both groups, where 50% of the driving forces have the same understanding and concerns from BIM users and non-users.

The following table 11 provides an overall ranking for the combination of the two groups for the driving forces that influencing the implementation of BIM in the UAE AEC industry.

The closer RII value to "1" the more important the driving forces to influence the implementation of BIM in the UAE AEC industry.

Sr.	Driving forces and pressures	**RII BIM users**	**RII BIM non users**	**Aver. RII**	**Rank**
1	Government & client pressure	0.9736	0.92	0.9468	**1**
2	Surrounding environment& competitive pressure	0.7125	0.86	0.78625	**2**
3	Complexity of projects& profit declination	0.7312	0.80	0.7656	**3**

Table 11: Overall ranking for the driving forces

The first rank of the driving forces has recorded a significant value of **0.9468**. This driving force i.e. "Government& client pressure" is irresistible pressure, because it is imposed by the government or the client or both together. Therefore if the AEC organizations did not respond and follow the compulsory requirements imposed by the government or the clients, the company will not win any new project and may end up with shutdown or looking for other market not using BIM.

Second and third ranks are very close to each other with values of **0.786** and **0.765** respectively. The second driving force ranked for the "Surrounding environment and competitive pressure" which is important for BIM non-users to cope with the added competitive advantage from the competitors who implemented BIM. In addition, it seems that the same driving force has been experienced by some of BIM users prior to using BIM, because BIM in UAE AEC industry still in the embarking stage and new companies are still changing to BIM.

The third rank “Complexity of projects and profit declination” is much compounded with continuous improvement and promoting the profits, which may be the interest of big companies that are getting complex projects with sophisticated clients.

The average RII and ranking in table 11 shows huge discrepancy (18%) between the first rank in one side and the second and third on the other side. That reveals the government and client pressure to impose BIM in the UAE AEC industry is a viable solution to mandate BIM.

4.1.4 AEC industry and organizational internal readiness to implement BIM

The following table 12 demonstrates that BIM users and non-users have the same consideration and perceptions for the importance of the organization and industry internal readiness to implement BIM in the UAE AEC industry. Table 11 shows a very slight difference for the overall mean values for BIM users and non-users **4.592** and **4.575** respectively.

Sr.	Internal readiness for the AEC industry and organizations	BIM **users (responses)**					BIM **non-users (responses)**				
		Mean	**No.=3**	**No.≥4**	**RII**	**Rank**	**Mean**	**No.=3**	**No.≥4**	**RII**	**Rank**
1	Financial cost implication& readiness	4.35			0.87	**3**	4.40			0.88	**3**
2	early recognition of the benefits of BIM	4.32			0.864	**4**	4.25			0.85	**4**
3	Top management attitude	4.83			0.966	**2**	4.75			0.95	**2**
4	Flexibility to change	**4.87**			**0.974**	1	**4.90**			0.98	1

	Total	**18.37**					**18.30**				
	Total Mean score	**4.5925**					**4.575**				

Table 12: Mean and RII for the internal readiness for the implement BIM for BIM users and non-users

Both groups have the identical ranking for the four factors of the internal readiness factors, where the first rank concerns the “Flexibility to change” and its importance in the organizations and the UAE AEC industry to successfully implement BIM. The second influencing factor is “Top management attitude” to support the change. And the third important factor is “Financial cost implication” which concerns the organizations’ capability to funding the change initiative. The fourth is “early recognition of the benefits of BIM”.

The previous data analyses give rigorous and reliable results for the UAE AEC industry and to any organization intending to switch to BIM. These organizations should be flexible enough to adopt BIM with the full support from the top managements. The top management support and their active role to change from the current conventional CAD methodology to BIM are crucially important for the successful implementation of BIM.

Moreover, the organization’s financial stand is very critical to implement the change, where it is obvious BIM requires huge financial funds; hence the organization should be ready for the huge fund and any financial implications.

“Early recognition of the benefits of BIM” ranked as the least important driving force, which can be elaborated from the data collection which shows that 98% of the tested organizations are aware about the term BIM; however still the use of BIM in the UAE AEC industry is modest, where only 35% of the tested organizations are BIM users.

The implementation of BIM is highly influenced by many factors, where not only the awareness of the benefits of BIM will lead the organizations to implement BIM. Implementation of BIM influenced by a collection of many factors that driving the change, i.e. the resistance to the change or the negative attitudes of top management to support the change. In addition to the unavailability of funds are important factors hindering the implementation of BIM.

In other words, the benefits of BIM may be well recognized, however the organization and the industry lack of readiness can undermine the implementation of BIM.

The above data analyses in the UAE AEC industry are conforming to the results of the study conducted by Chwelos et al. (2000) for the USA AEC industry internal readiness to implement new technology i.e. Electronic Data Interchange (EDI).

In order to compare the internal readiness for BIM non-users and BIM users the following radar figure 11 demonstrates the degree of agreement and disagreement between the two groups.

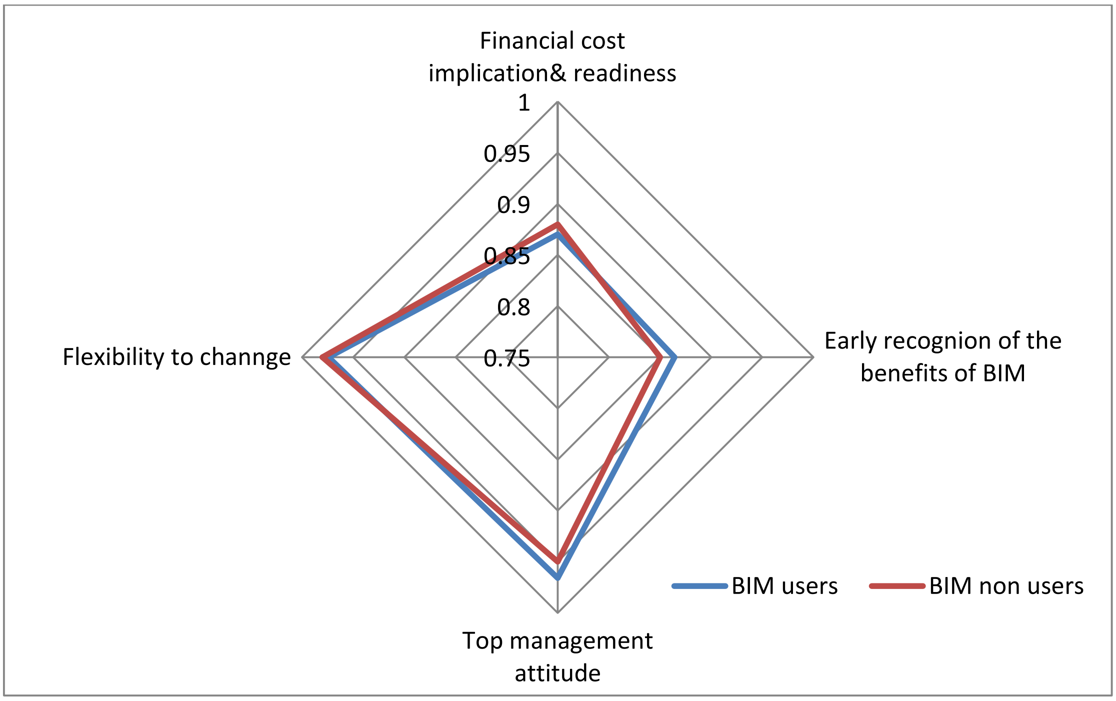


Figure 11: The internal readiness to implement BIM

The radar shape in figure 11 and table 12 demonstrate a very close understanding of the importance of internal readiness factors. And their influences on the implementation of BIM in the UAE AEC industry from the two groups i.e. BIM users and non-users.

In order to find out RAF for the internal readiness for the implementation of BIM for both groups, the following table 13 indicates that.

Sr.	Internal readiness	Users Rank	Non users rank	Ri1-Ri2	Abs	J	Ri1-Rj2	Abs
1	Flexibility to change	1	1	0	0	**4**	-3	3
2	Top management attitude	2	2	0	0	**3**	-1	1
3	Financial cost implication& readiness	3	3	0	0	**2**	1	1
4	early recognition of the benefits of BIM	4	4	0	0	**1**	3	3
				Sum of Abs	0		Sum of Abs max	8

Table 13: RAF, PD and PA values for the internal readiness for the implementation of BIM for BIM users and non-users

RAF=0/4= 0 ∴ RAF=0

RAF max =8/4=2 ∴ RAF max=2.0

PD (percent disagreement) = $\frac{RAF}{RAF\ max}$= $\frac{0}{2.0}$= 0×100%=0%

PA (percent agreement) =PD-100 ∴ PA=100-0= 100%.

The value of the PA is 100% supports the earlier proposition of the identical perceptions for both groups i.e. BIM users and non-users. Hence, this result concludes that the AEC industry and the organizations should be well prepared and ready to successfully implement BIM in the UAE AEC industry.

The following table 14 provides an overall ranking from the combination of the two groups for the internal readiness influencing the implementation of BIM in the UAE AEC industry.

The first and the second factors that have significant values of RII are **0.977** and **0.958** recorder for the "**flexibility of change**" and "**top management attitude**" respectively. That reveals the significant impacts of these two factors on the organization and the

AEC industry readiness to implementing BIM. Therefore, the decision makers should consider these two factors in order to successfully implement BIM in UAE.

The third and the fourth ranks are very close to each other, which are related to the “financial cost implication” and “early perception of the benefits of BIM” with RII values of **0.875** and **0.857** respectively.

That indicates after the acceptance of the change initiative to switch to BIM in the existence of the top management support and the organization financial stand is rigorous to withstand the financial impacts due to the required huge funds. All these factors should be linked to the appropriate perception of the benefits of BIM and what is suitable for the organization.

Sr.	Internal readiness	**RII BIM users**	**RII BIM non users**	**Aver. RII**	**Rank**
1	Flexibility to change	0.974	0.98	0.977	**1**
2	Top management attitude	0.966	0.95	0.958	**2**
3	Financial cost implication& readiness	0.87	0.88	0.875	**3**
4	early recognition of the benefits of BIM	0.864	0.85	0.857	**4**

Table 14: Overall ranking for the internal readiness

Table 14 indicates that the differences between the four factors are very small, which indicates the importance for all the factors. That means all the four factors as a cluster group has a significant influence on the implementation of BIM in the UAE AEC industry. Therefore any attempt to implement BIM in the absence of the internal readiness of the organization or the entire industry is doomed failure from the start.

4.2 Data analyses using SPSS-21 software

The quantitative approach based SPSS software has been used in order to measure the epistemological stance of the implementation of BIM in the UAE AEC industry. A positivist approach is applied to get an understanding paradigm for generalization for similar organizations within UAE AEC industry. The analyses of the data collected from 57 responses based on non-probability random sampling selected from anonymous total population.

The reliability test for 39 questions has been conducted to measure the reliability level for each variable. Table 15 shows a strong internal consistency for the reliability measures based on Cronbach alpha coefficient for all the five variables (four independent and one dependent). The lowest value for Cronbach alpha is 0.627 recorded for the driving force factor and the most significant value recorded for the perceived benefits of BIM as 0.94.

According to Field (2013, p709) the results of Cronbach alpha coefficient indicate an acceptable and satisfactory internal consistency levels for all the questions of the four independent variables. That indicates also all the posed questions are relevant to the topic, which are proposed in a way to rigorously measure the respondents' point of views with high reliability to check the hypotheses (Field 2013).

Each variable has been tested through structured survey questions i.e. *perceived benefits of BIM* variable tested by 20 structured questions, *challenges and obstacles that hindering the implementation for BIM* tested by 12 structured questions. Similarly the *driving forces and imposed pressure variable* tested by 3 structured questions and finally the *internal readiness* variable tested by 4 structured questions.

Scale	**Cornbach Alpha***	**Mean (X)**	**Standard Deviation**	**ANOVA**	
				F	*p*
Implementation of BIM	0.935	4.157	0.465	-	-
Perceived benefits	0.940	4.127	0.655	3.664	0.0004
Challenges	0.849	3.889	0.654	7.434	0.000
Driving forces	0.627	4.134	0.580	20.237	0.000
Internal readiness	0.853	4.478	0.505	8.437	0.000

* *All reliability coefficients are significant at 0.05 level or lower*

Table 15: Distribution and reliability coefficients along with the t-test:

The first stage of the statistical data analyses it enabled the ranking for each factor within the four independent variables. In this stage the SPSS software used to ranking the four independent variables themselves, in order to understand the ranking of the most influencing variables on the implementation of BIM in the UAE AEC industry. For that purpose the relationships among the five variables were tested using Pearson correlation coefficient, as shown in the following table 16.

	Implementation of BIM	Perceived benefits	Challenges	Driving forces	Internal readiness
Implementation of BIM	1				
Perceived benefits	.709**	1			
Challenges	.847**	.402**	1		
Driving forces	.830**	.409**	.692**	1	
Internal readiness	.714**	.323*	0.508**	0.482**	1

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

Table 16: Correlation coefficient between variables:

It has been found that there is a strong positive correlation between all the variables with a strong significance level at $p < 0.01$. The correlation between the dependent variable i.e. ***the implementation of BIM in the UAE AEC industry*** and the other independent variables *perceived benefits*, *challenges and obstacles*, *driving forces and internal readiness* was found strong positive with strong significant level at $p< 0.01$ which supports the proposed four hypotheses.

H1: The higher the appropriate recognition of the benefits of BIM the greater chances of the successful implementation of BIM.

H2: The higher the challenges and obstacles the lesser chances to the implementation of BIM.

H3: Higher external driving forces and pressure to adopt BIM leads to greater chances of the implementation of BIM.

H4: The appropriate internal readiness to adopt the change to BIM leads to greater chances for the successful implementation of BIM.

The following figure 12 derived from figure 16 demonstrates the implementation of BIM is highly affected by the four independent variables according to the aforementioned hypotheses.

In addition, the statistical data analyses unveiled that, the most critical factor influencing the successful implementation of BIM in the UAE AEC industry is the "**challenges and obstacles that hinder the implementation of BIM**". This critical factor creates several drawbacks to the implementation of BIM in UAE. Therefore, if the organizations succeed to manage these challenges and obstacles it will implement BIM successfully.

It is worth noting that, it is not necessary that all the challenges or obstacles are confronted by the organization that is intending to implement BIM. However the uniqueness of each organization will determine the challenges and obstacles they may face.

The second critical factor that is influencing the implementation of BIM in the UAE AEC industry is the "**driving forces and the imposed pressures to implement BIM**". This factor should be well considered from the UAE AEC decision makers as it is a perfect approach to mandate BIM successfully in a short time.

However, prior to mandating BIM in the UAE the third critical factor the "**organization and industry internal readiness**" should be well investigated to prepare the organizations and the AEC industry to accept the drastic changes, otherwise any change initiative will fail prior to starting.

In order to properly start mandating the change in UAE, it should start with the least influencing factor which is the perceived benefits of BIM. Notwithstanding this factor is the least influencing factor in the ranking for the implementation of BIM. However it is the most significant in terms of the starting point to motivate the organizations how to benefit from the implementation of BIM.

Moreover, the data analyses revealed lack of knowledge for the awareness of the authenticated benefits of BIM for the UAE AEC industry.

In addition to the lukewarm enthusiasm to adopt the emerged technologies, which unveil that the UAE AEC industry is very conservative and very sensitive to take risks especially from the local organizations. That can be understood from the great competitions among the local and international organizations in the UAE AEC market and the sever fear of failure.

Therefore, the UAE government hand in hand with the specialized BIM institutions and universities should promote the industry awareness for the real benefits of BIM. In addition to the challenges and obstacles and how to avoid or deal with these challenges, in order to swiftly reach the maturity level to be ready for the implementation of BIM.

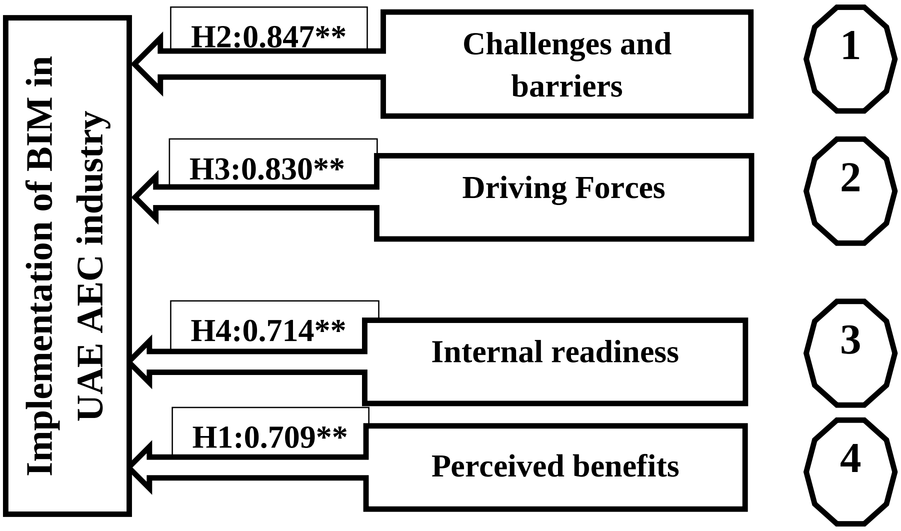


Figure 12: the ranking for the variables impact the implementation of BIM in the UAE AEC industry.

4.3 Case studies

The quantitative approach adopted as a first stage of data collection and analyses to rank the impact of the aforementioned four independent variables on the implementation of BIM in the UAE AEC industry. In addition, to show and rank the most influencing factors within each variable of the four variables.

The statistical results of the quantitative approach offered fair understanding of the factors impacting the utilization of BIM within the UAE AEC industry. However, these statistical results triggered some questions about the dynamics of the UAE AEC industry and its level of maturity to accept the utilization of BIM. In addition to, investigating the best way to mandate BIM in the UAE AEC industry based on its characteristics. Naoum (2013, p.43) argue that “the end product of quantitative research will be throwing up hunches and hypotheses, which can be tested more rigorously by further qualitative test". Therefore, to have deeper understanding and elaboration for these triggered questions, the case studies via qualitative approach was adopted.

It is found supporting the quantitative approach with the qualitative approach based case studies will add better understanding to the research. Naoum (2013, p.46) concluded that "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".

Therefore, the results of the quantitative analyses together with the profound understanding from the extensive literature survey were the bases for the qualitative study to develop the semi-structured questionnaire in Appendix 2.

The dissertation studied the UAE AEC industry readiness to implement BIM from two different stances i.e. BIM users and non-users. Hence in order to have an in-depth understanding for the factors influencing the implementation of BIM from these two different groups. It is seen that, face-to-face interviews with carefully selected professionals for several case studies will enrich the research; table 17 demonstrates the case studies and the qualifications for the selected interviewees.

The study involved three different cases, where case study 1 and 2 represent BIM users; case study 1 involved one of the most iconic running projects in Abu Dhabi, where case study 2 represents a public organization recently adopted BIM and imposed BIM as a compulsory requirement for specific buildings. In addition to case study 3 that represents BIM non-users.

The interviews for the three case studies involved five key AEC industry professionals, where three of the interviewees represent BIM users and two represent BIM non-users table 17.

An open ended questionnaire was found the best approach to avail a relaxed environment for the interviewees to elaborate their responses openly with examples from the real life (the case studies). Interviews were conducted at the interviewees' offices in Abu Dhabi and Dubai; the duration for each interview varies where the shortest interview lasted for 35 minutes with the head of BIM department in the public authority (case study 2). However, the other interviews lasted for 90-150 minutes. All interviewees' responses were carefully recorded and transcribed. All interviewees were top management except one was of middle management. The work experience for the interviewees in average is 25 years, with minimum of 13 years and maximum 31 years. The interviewees almost covered the significant areas such as two from contractor i.e. BIM manager (company **A**) and director (company **B**) who represented BIM users. In addition to, the head of BIM department in a public authority (company **C**).

And from BIM non-users side a senior architect who is working for a design organization (company **D**) and a director (company **E**) in one of reputed international contracting organization not using BIM.

All the interviewees given a brief presentation about the objectives of the dissertation, where all the interviewees were very open and cooperative in their responses except the head of BIM department of the public authority gave lukewarm responses.

	BIM users			**BIM non users**	
	Case study 1		**Case study 2**	**Case study 3**	
	Company A	**Company B**	**Company C**	**Company D**	**Company E**
Company Type	Contractor (Private)	Design/engineering (Private)	Public	Architect (Private)	Contractor (Private)
Company market	International	International	Local	National& International	International
Specialty	Building& Civil engineering	Building& engineering works	Building& Infrastructure	Building	Building
World Rank (ENR)	42	12	Nil	Nil	Nil
Market	Europe, north and south America,	Europe, north and south America,	Dubai	GCC& UK	North Africa& GCC

	Asia and Africa	Asia and Africa			
Founded on	1952	1969	1954	1995	1943
Position	BIM Manager	Director	Head of BIM department	Senior architect	Director
Qualifications	BSc. Architect	BSc. and MSc in civil engineering	BSc. Architect	BSc. Architect	BSc. Civil
Years of experience	30	27	25	13	31
Experience in UAE	6	15	20	7	18
Interview duration	$2\frac{1}{4}$ Hours	$2\frac{1}{2}$ Hours	35 minutes	$1\frac{1}{2}$ Hours	$1\frac{1}{2}$ Hours

Table 17: Demographic for the case studies.

4.3.1 BIM users:

4.3.1.1 Case study 1.

This case study represents one of the biggest projects not only in Abu Dhabi but also in the UAE at the time of the study. The project commencement date including the design stage was 28th February 2011, where 18 months dedicated for the design, the contract is design and build. The project's completion date is 17th July 2017 and the contract value is 11.77 Billion AED (3.2 Billion US dollars), the contract was awarded to a contracting Joint Venture (JV) consists of three world class international companies; the physical site construction activities commenced on 24th August 2012.

The project's BIM specification for case study 1 was written in collaboration with BIM professional party "BuildingSMART ME", where all the benefits of BIM were integrated within all the project phases.

The interviews for case study 1 conducted with two interviewees from two different organizations both are from the world top 100 contractors in 2014 ranking. The first company was ranked 24 in ENR ranking with total revenue of 5,289.4 Million US dollars (ENR 2014), the second company is the JV partner, and one of the world leading companies in contracting field, this company is ranked 83 in ENR worldwide ranking with total revenue of 1,268.3 Million US dollars (ENR 2014).

The interviews conducted for the company "**A"** with BIM manager and for company "**B**" with the project director, the interviews conducted separately which lasted for 135 and 150 minutes respectively. The semi-structured questionnaire involved six questions to cover the dissertation area of study.

The collected data explicitly manifested that, the switch to implementing BIM is not an easy task; however it requires a very careful and flexible plan that can interact with any uprising circumstances.

4.3.1.2 **Perceived benefits of BIM**

The literature emphasized on the importance of the implementation of BIM for its offered benefits for all the AEC industry players.

In this *case study 1* the interviewees for BIM users demonstrated a professional level of awareness for the perceived benefits of BIM and the challenges and the obstacles that may face organizations that is intending to implement BIM.

The interviewees confirmed that, the successful switch to BIM commences at the proper awareness of the benefits of BIM, compared to the conventional CAD method. Moreover the top and middle managements should firstly recognize the benefits of BIM and how it can benefit the organization to promote the ROI, integrate the fragmented team work to eliminate the waste in time and money.

Both interviewees summarized their understanding of the benefits of BIM where they consider BIM as the steering wheel for any project, where BIM creates a controlled flexible environment that can automate all the AEC processes and activities in an integrated pool to meet the client satisfactions. The use of BIM offers outstanding tools that can save the time and cost, in addition to error-free design and very satisfactory quality. The interviewees ranked their perceived benefits of BIM in Appendix 3.

However, the interviewees claimed that, in the embarking stage many stakeholders are yet to implement BIM, therefore not all the planned benefits of BIM can be reaped where lot of time wasted due to the stakeholders' unfamiliarity with BIM.

4.3.1.3 Challenges and obstacles for the implementation of BIM

The interviewees claimed that, notwithstanding their companies **"A and B"** are of the pioneering organizations and deemed BIM early adopters, where BIM was implemented in their organizations since 1997 and 2000 respectively in their companies in Europe where the companies' headquarters exist.

However, they described the problems that they confronted in the UAE market is the first of its kind, where the client made the use of BIM as a compulsory requirement in the tender stage. However the client, the client representatives and the stakeholders such as local subcontractors and many suppliers especially the local suppliers and the public organizations are not familiar with BIM. Therefore, in many occasions the BIM users i.e. the JV companies are forced to use the 2D CAD methodology to communicate and cope with the requirements from the project's BIM non-users. Similarly, in order to obtain the required work permissions that is dubbed in UAE as No Objection Certificates (NOCs') from the public authorities. BIM users are forced to submit and convert all the 3D drawings produced by BIM into the traditional 2D CAD format, because the public organizations are not using BIM and don't have any BIM software.

Therefore, the non-familiarity of BIM from the client, majority of project stakeholders and public organizations is hindering the full utilization of BIM.

The interviewees shared their thoughts why there are lukewarm enthusiasms from many organizations to utilize BIM in the UAE AEC industry, as those BIM non-users are not fully aware about the benefits of BIM; which creates unreasonable resistance and fear of the change to BIM. Therefore the change to BIM is not supported by the top management who considered BIM as a changing process full of risks and overwhelmed with uncertainties. That is because of the close watching to the BIM users which reveals that they are struggling instead of reaping the benefits of the utilized BIM.

The interviewees claimed also, the UAE government can play an active role to mandate BIM similar to the roles that several governments played in the developed countries such as UK, Australia and Singapore. The government should motivates the AEC industry players to implement BIM and then it should set an execution plans stipulating the time frame for all the UAE AEC industry to compulsory implement BIM. Therefore, and because of the absence of the binding actions from the UAE government, BIM in the UAE AEC industry is optional, which negatively impacts the BIM users and demotivate the BIM non users to switch to BIM.

The interviewees claimed that, one of the obstacles may hinder the implementation of BIM in UAE AEC industry is the unavailability of BIM operators in the UAE market, that are required to cover the demand of the implementation of BIM. The interviewees stated that, in the projects' outset the JV has strived to hire BIM operators from UAE market. However, no adequate number was found to cover the project requirements which forced the JV to bring many BIM operators from other countries with higher salaries which imposed uncounted pressures on the companies' financial plans.

The interviewees confirmed that, from several discussions with the stakeholders that are not using BIM; BIM non-users have claimed that, implementation of BIM in UAE requires huge funding with uncertainties of successes, especially in the absence of the successful examples of BIM users. That is because BIM users are obviously struggling to accomplish their plans, due to the lukewarm support from the UAE government to make the use of BIM as a compulsory requirement in the UAE AEC industry.

4.3.1.4 **Driving forces**

The *case study 1* is suffering from the client and stakeholders who are not fully aware of BIM. Therefore, the interviewees confirmed that, the government can play a significant role to mandate BIM in any AEC market, by making the use of BIM as a compulsory requirement to win the public and private projects.

The governments can mandate BIM by setting an appropriate execution plans by cascading the implementation of BIM to realistic levels according to the UAE AEC industry characteristics. In addition, studying the previous experiences and case studies of the countries that imposed the use of BIM as a compulsory requirement such as UK, Australia and New Zealand can be a good guidance and learn lessons from their experiences. The interviewees suggested that, the life example of the UK government initiative to implement BIM as s compulsory requirement in the AEC industry in 2016, the implementation of BIM segregated on three levels from 2011 to 2014 then 2016.

The interviewees concluded that, most of the organizations in UAE AEC market implemented BIM not due to the recognized benefits of BIM, but due to the driving forces imposed from the clients.

However, the unplanned driving forces to implement BIM may revert with negative results and severe consequences. That is tangible for the *case study 1*, where the JV is suffering from the client and stakeholders that are not using BIM and not fully aware about BIM and not committed to adopt BIM because nothing forcing them to do so.

4.3.1.5 Industry and organizations' internal readiness

The interviewees confirmed that, the main problem of the case study 1 is that the client imposed the use of BIM as compulsory requirement for some parties in the project, however other stakeholder and the client himself is not yet ready to use BIM. This case is obviously represents the UAE AEC market, where BIM users are struggling to reap the planned benefits of BIM among their stakeholders of BIM non-users.

Interviewees stated that, organizations as well as the whole AEC industry should be ready to implement BIM at the same time. And the first step of the readiness to implement BIM in the UAE AEC industry is raising the awareness of the benefits of BIM, which is the government and the BIM specialized institutions' responsibility.

Top managements in the organizations and the decision makers in the UAE AEC industry should be fully aware about the benefits of BIM as well as the challenges they are going to face while switching to BIM. The top managements and decision makers should first believe in BIM, also they should believe that all the huge funding is a real investment and will promote their companies' competitive advantage. Moreover they should believe in BIM's capacity of increasing the ROI and improving the UAE AEC industry performance to get rid of its persisting problems.

4.3.1.6 Mandating BIM in the UAE AEC industry

The interviewees confirmed that, majority of the UAE AEC players are not aware about the real benefits of BIM. However they are fully aware that the implementation of BIM is not an easy task, therefore many organizations are reluctant to take the decisions to utilize BIM.

The interviewees suggested that, the government and BIM institutions in addition to the BIM leading companies should contribute to raise the awareness and the essence of BIM to the UAE AEC industry, which is the first step towards the implementation of BIM.

Interviewees argued that, the most influencing factor to enable mandating BIM in the UAE AEC industry is driving and forcing BIM into the AEC industry by the government, where the organizations have no choice but to adopt BIM. Accordingly, organizations have to manipulate their processes and strategies to start the implementation of BIM at the earliest. Moreover, UAE government should mandate the use of BIM for all the UAE AEC players at the same time, where the government should set the execution plan cascading the implementation of BIM in several levels according to the characteristics of the UAE AEC industry.

Furthermore, UAE government should assist the organizations by initiating BIM standards and execution plans and further subsidize the BIM training programs for the organizations. Moreover, UAE government should include BIM in the undergraduates' syllabus to have a satisfactory number of BIM operators after 3-5 years with full and real awareness of BIM to bridge the gap of the market needs.

The discussion revealed that, the client of the case study 1 thought that an international JV with professional experience of BIM can transfer the knowledge of BIM to the project stakeholders and the client during the project construction duration. That explicitly reveals the very poor awareness level about the nature of BIM.

4.4 Case study 2

The *case study 2* involved an interview with the head of BIM department in a public authority that imposed BIM as a compulsory requirement for specific building projects.

The interview was short that lasted for 35 minutes only, and the responses were lukewarm and conservative due to the public authority's restrictions prohibiting disclosing any issues pertaining to the internal operations.

The discussion with the head of BIM department revealed that, he is lacking some of the fundamental knowledge about BIM such as the awareness of the benefits of BIM, the challenges and obstacles that organizations may face during the change to BIM. Moreover, he was lacking the knowledge about most of the actions that the organization or the AEC industry should take to be ready for the implementation of BIM. That reflects the poor level of awareness from the head of BIM department which means poor performance for BIM and its correlated decisions on the organizational level for this public authority.

In addition, it is obvious prior to establishing the BIM department in the public authority of the case study 2 the resources for the BIM department did not get the enough training for BIM and there is lack of BIM professionals.

The interviewee reported that, due to the rapid growing of the implementation of BIM worldwide, the top management decided to implement BIM for specific building projects under their authority. The decision makers were encouraged to take such decision because majority of the organizations working in the building industry in UAE market are international organizations that are already using BIM in their home-countries.

Dubai Statistics Center (2013, p.1) via the industrial survey report mentioned that, 83% of the organizations working in the building sector in Dubai are multinational organizations. This survey for Dubai only, however the researcher strived to find similar survey on the UAE level but cannot find. Therefore, by considering this percentage or closer, that reveals the majority of the organizations working for the building sector and the AEC industry in the UAE are multinational organizations.

Moreover, the interview revealed that, the public authority didn’t propose any execution plans to mandate BIM, and what made the matter worse is that the public authority instructed the contractors and consultants to use and mandate BIM within one and half month only . However the literature emphasized that, the implementation of BIM is a long process which requires in average four years (Eastman et al. 2011).

He added till the moment most of the organizations are using the traditional 2D CAD either because the organizations did not implement BIM yet. And it is obvious other reason can be due to the lack of resources (software, hardware and BIM operators) from the public authority end to check the submissions of the BIM models.

It is clear that BIM non-users are still suffering and striving to implement BIM, some of the well-known local organizations requested more time to enable them to implement BIM and other organizations already quit to find other market not imposing the use of BIM as a compulsory requirement.

The discussion unveiled, the decision to mandate BIM primary taken based on the reported benefits of BIM from the developed countries that implemented BIM and numerous presentations from vendors of BIM software. Therefore and due to the recognized rapid mandating of BIM worldwide, the public authority thought that the implementation of BIM is just utilization of software which involves training for the staff only. However, they did not recognize the challenges and the impacts on the organizations and the entire AEC industry due to the lack of readiness, which requires long duration to switch to BIM.

Accordingly, many organizations including the public authority of the case study 2 are suffering from the negative consequences of mandating BIM in the absence of the organizations and the AEC industry readiness. Therefore, as a corrective action from the public authority they are planning to propose an execution plan to mandate BIM, considering the nature of the UAE AEC industry.

4.4.1 Mandating BIM in UAE AEC industry

Case study 2 explicitly manifested that, to mandate BIM in the UAE AEC industry imposing BIM as a compulsory requirement is the best way. However, before doing that the organizations and the UAE AEC industry should be ready to mandate BIM. That can be done by raising the awareness of BIM in terms of the benefits of BIM, challenges and how to prepare the organization and the entire AEC industry to implement BIM. In addition to, setting appropriate execution plans that are considering the UAE AEC industry status quo and characteristics.

4.5 Case study 3-“BIM non- users”

It was seen that, investigating a case study from the counter point of view for the BIM non-users will enrich the understanding of the hindrances and the resistance to implement BIM in the UAE AEC industry. Therefore two separate interviews conducted with senior designer architect that represents the design team of the company “D” and the director from the contractor to represent the company “E”. Both Interviewees are working for the same project of case study 3; the interviews lasted for 90 minutes for each interviewee.

4.5.1 Perceived benefits of BIM

The discussion with the two interviewees for the *case study 3* revealed that, the BIM non-users have different opinions about the benefits of BIM; where the senior architect shown an excellent awareness of the benefits of BIM. However the director doesn’t have the fundamental knowledge or awareness of the benefits of BIM.

The director stated that, he does not believe in the capacity of BIM to make that difference to improve the construction performance, because there are no successful examples of running or completed projects used BIM. He added that, most of the companies those implemented BIM are suffering from several problems such as quit of the key staff due to severe changes and impacts on the organization chart. In addition to, the huge funding required for the implementation of BIM with myriads uncertainties of success.

The director argued that, most of the knowledge about BIM is gained from BIM software vendors who are keen about selling their software products and their presentations are carrying lots of doubts and contradictions, which triggers questions about the BIM "is it fact or myth?"

4.5.2 Challenges and obstacles to implement BIM

The discussion with the interviewees of the case study 3 revealed that, the BIM nonusers' point of view towards the most important obstacles and challenges that are hindering them to implement BIM are highlighted as follows:

"**The client is not requesting BIM as a compulsory requirement in the projects**". In addition to the AEC industry and the organization internal "**resistance to the change**" and the "**lack of support from top managements**" that are reluctant to take such important decision which requires "**lots of funding**". Especially in the absence of the successful examples of BIM users in the UAE AEC market.

4.5.3 Driving forces to implement BIM

It is obvious from the interviews with BIM nonusers they believe that, the main driver to implement any new change such as BIM in the UAE AEC industry is by forcing the change by the government for all the AEC players at the same time. Accordingly, the risk of the new change will be almost equal to all the AEC players in the rival market such as UAE AEC market.

4.5.4 Internal readiness to implement BIM

The interviewees claimed that, implementation of BIM is not an easy task. This task requires long time to change the current processes and culture. In addition to, the required huge funding, especially at the early beginning of the change to implement BIM to purchase the software and hardware. Moreover, hiring BIM operators and training the existing staff. Therefore, the organizations should be ready to yield the adequate time to do that tremendous change; otherwise the change will be an impossible target.

Moreover, the interviewees suggested that, due to the uncertainties correlated with the change to adopt BIM, they believe the implementation of BIM should be tried internally first in a pilot project, i.e. small or medium size project. Hence the funding for such project will not be huge and the resistance to change can be managed by selecting the flexible staff, and the overall success to the pilot project experiences can be generalized to the entire organization. Moreover, close monitoring for the pilot project, in addition to careful studying for the lessons learned from other experiences within UAE and overseas will highly assist the soft and swift transition to BIM. Accordingly, the top managements' support will be gained. Therefore, further improvement could be achieved especially after avoiding the experienced lapses to mandating BIM on the entire organization.

4.5.5 Mandating BIM in the UAE AEC industry

The discussion revealed that, the main hindrance to implement BIM is that the UAE government didn't impose BIM as a compulsory requirement to force the organizations that is expressing lack of commitment to change to BIM. Moreover, the absence of the stipulated execution plans from the government that guides the organizations to the key issues to implement BIM makes the change initiative vague and difficult task.

BIM nonusers shared their thoughts about BIM; they believe BIM will mandate the UAE AEC industry sooner or later. Therefore, and to accelerate this process, the government should to take the necessary actions to assist the organizations to change smoothly to BIM. The UAE government can support the organizations by offering periodical sessions to promote the awareness of the benefits of BIM. In addition, the UAE government should raise the organizations' awareness for the challenges that organizations may face and the best way to respond to these challenges during the journey to change to BIM. These sessions should be offered by specialized BIM institutes not BIM software vendors; all these sessions should be under the patronage of the UAE government.

Chapter 5

5 Conclusions

BIM is rapidly growing and sooner will mandate the AEC industry worldwide, therefore the organizations that are not using BIM will be out of the competition game. Hence, to assist the UAE to keep pace with the latest AEC revolution, this study examined the UAE AEC industry readiness and the factors that influence the mandate of BIM.

The study concluded that, in order to efficiently and swiftly implement BIM, there are four factors controlling the implementation of BIM in the UAE AEC industry, these factors are as follows;

- ✓ Perceived benefits of BIM,
- ✓ Challenges and obstacles that hinder the implementation of BIM,
- ✓ Driving forces and pressures impose the implementation of BIM,
- ✓ The level of the internal readiness for the organizations and the entire AEC industry to utilize and mandate BIM.

The chances for successful mandate of BIM in the UAE begin with the recognition of the benefits of BIM. And then, proper assessments to prepare the plans to mitigate the likely impacts for the challenges and obstacles that may face the organizations while converting from the conventional 2D CAD methodology to BIM.

The study revealed that, there is a moderate level of awareness for the essence of BIM in the UAE AEC industry, especially for the local organizations and the public authorities. Because, most of the awareness sessions for BIM in the UAE AEC industry offered by BIM software vendors. Those vendors exerted their efforts to elucidate the benefits of BIM and correlated these benefits to their software, to increase their sales rates. Therefore, most of the decision makers in the UAE AEC industry are aware about the BIM and its benefits from the vendors' point of view.

That means there is a crucial need to escalate the UAE AEC industry awareness about the real BIM especially for the decision makers, considering the AEC market characteristics and the abovementioned four factors. Furthermore, raising the UAE AEC industry awareness for BIM will significantly increase the chances for swift mandate of BIM.

There are several challenges and obstacles hinder the implementation of BIM, however the most critical two factors in the UAE AEC industry are related to the resistance to change where the "***lack of support from the top management to accept the change initiative to implement BIM***" is the most critical factor. And the second critical factor that hinders the change to BIM is "***the resistance and fear of the change in addition to clinging to the old ways of working***".

The study also concludes that, the challenges and obstacles don't differ significantly from country to another due to the similarity of the construction culture regardless of the location. This deemed as a great advantage for the UAE to learn lessons from other countries that already implemented BIM to easily mandate BIM in the AEC industry.

The UAE AEC industry is having many successful factors to mandate BIM, because the majority of the big AEC organizations in UAE are international organization with excellent experience of BIM in their home-countries. Therefore, bringing their global experience of BIM into the UAE will assist in transferring and sharing BIM knowledge from these international organizations to the local organizations. That will significantly assist the smooth transition to implement BIM and will shorten the duration to mandate BIM in UAE.

Moreover, for rapid mandate of BIM in UAE the fastest approach is by imposing pressures on the AEC industry players and driving the implementation of BIM as a compulsory requirement, provided that introducing suitable execution plans together with adequate time for organizations and the AEC industry should be ready to accept the drastic changes.

There were few attempts from some clients and authority to impose BIM as a compulsory requirement in the UAE AEC industry, however most of these endeavors were not well planned which reverted with negative consequences. These attempts didn't achieve their goals because; forcing BIM successfully in the UAE AEC industry should follow a well-studied execution plan that must consider the nature of the AEC industry. Moreover this execution plan should determine a realistic cascaded timeframe for the implementation of BIM.

All previous factors that control the mandate of BIM in the UAE revolve around "**the appropriate readiness"** from the organizations and the AEC industry to adopt the change to BIM. Therefore, any attempt to mandate BIM in the absence of rigorous readiness will fail.

Readiness in this study meant the capability of the organizations to fully recognize the benefits of BIM and to be fully aware about the challenges and its implications and how to avoid or respond to these challenges.

Traditionally, all the AEC players are reaping the benefits of BIM; however the client/owner is the most benefit from the implementation of BIM. That means the government and clients should take the initiative to motivate the AEC industry to mandate BIM.

5.1 Recommendations

For successful implementation of BIM in the AEC industry, the UAE government can play a great and active role to officially mandate BIM, by introducing execution plans and training programs. The government should mandate BIM at the same time for all the AEC industry players to avoid any negative implications.

To swiftly mandate BIM the clients together with the UAE government should forthwith start to raise the awareness for the AEC industry decision makers for the essence of BIM. By sponsoring awareness sessions and seminars that should be introduced by specialized BIM institutions, these sessions should continue and extended to include all the AEC industry players.

Implementation of BIM is relatively a complex process. Therefore, the UAE government should prepare guidelines for the organizations to facilitate the transition to BIM and to introduce a know-how mechanism for organizations to follow. Several guidelines are available based on the previous experiences and lessons learned from the developed countries, therefore UAE government may develop these guidelines to match the UAE AEC industry characteristics.

Organizations should gradually change to BIM in a pilot project i.e. small or medium project that will significantly increase the chances for quick and easy success with the minimum implications. In addition, offering a successful example will draw even the unsupportive top management attention to fully support the change to mandate BIM in the organization's level. Moreover the lapses and lessons learned from the pilot project will be a great experience that will assist the smooth transition to implement BIM at the stage of generalizing the experience in the organization.

Implementation of BIM requires huge funding especially at the early stage, for which SMEs' may not be able to afford these expenditures. Therefore, the UAE government should fully or partially subsidize the software training programs for the organizations' staff, which will highly encourage these organizations to implement BIM. Or to have a mutual agreement between the UAE government and the SMEs', stating that the government will fund the software training programs and the SMEs' will pay the training costs in monthly installments or as a levy to the government.

Moreover, the UAE government can build a new AEC generation with perfect knowledge of BIM by including BIM in the AEC under and postgraduate students' syllabus.

5.2 Limitation of the research

The study has some limitations; first limitation is the geographic representation, where the study investigated how to pave the way to assist the entire UAE AEC industry to mandate BIM. That is due to the BIM's remarkable benefits to make a paradigm shift in the AEC performance. However, the collected data did not cover all the seven Emirates, where data collected from Dubai (40 responses), Abu Dhabi (25 responses), Sharjah (5 responses) and Ras Al khaimah (1 response), however there are no responses from the following three emirates Ajman, Umm Al Quwain and Al Fujairah.

The second limitation represented in the timing of the study, where the study proved that UAE still in the embarking stage of utilizing BIM, where 35% of the respondents reported that they are using BIM one to two years ago. It is obvious, this is not a sufficient duration to reap all the benefits of BIM or to recognize all the challenges of BIM. Therefore some of the collected responses were based on theoretical knowledge rather the practical experiences.

The third limitation encountered in the limited numbers of the organizations who correctly filled in the questionnaire survey (57 out of 362) and only five organizations accepted to conduct the face to face interviews. In addition the difficulties in conducting some interviews, especially with the public authorities because they are very conservative and their responses are succinct and lukewarm due to the organization's policy prohibiting any direct communication with externals such as media or even academic researchers.

5.3 Recommendation for further studies

This study unveiled that; several areas related to BIM need to be studied to bridge the knowledge gap either in local or international AEC industry.

i. To enhance the switch to mandate BIM, a study should be conducted to propose a detailed paradigm model together with a check list for the organizations intending to switch from the traditional 2D CAD methodology to adopt BIM. That will save the time and cost for the organizations that is intending to switch to BIM especially for the organizations do not "*know-how*" to change to BIM.

ii. Changing the entire AEC industry from the 2D CAD methodology that is been used for many decades to BIM, will have some negative impacts on the organizations as well as individuals. A study should be conducted to investigate these implications on the AEC industry due to the mandate of BIM.

iii. Further studies should be conducted because of the noticeable lack of research that investigated how to amalgamate BIM with the daily construction site activities. This study should be done to propose effective solutions to improve and automate the daily construction operational activities. This automation of the construction site activities should avoid loss of information and should enable the contractors to recognize their weaknesses. In addition, it should promote the trust between the site teams; moreover it should enable immediate update of the progress reports, program of works and the production of the payment statement to be just one click away.

Chapter 6:

6 References

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7 Appendix 1

Questionnaire survey can be accessed via the below link.

https://www.surveymonkey.com/s/BIM-haniomar

Perceived benefits, barriers, driving forces and internal readiness for implementation of BIM.

Demographic and personal information

1. Is your company public or private?

○ Public
○ Private

*

2. In what city is your company currently headquartered?

3. about how many employees work at your company?

4. Which of the following best describes the principal industry of your organization?

○ Building and real estate
○ Infrastructure/utilities
○ Transportation (Road and railways)
○ Water and waste water
○ Power/electricity
○ Programme management
○ Other (please specify)

5. Which of the following best describe your job function?

○ Architecture
○ Structural design/Engineer or MEP design
○ Contractor/Sub-contractor
○ Consultant/supervision
○ Owner/client
○ Supplier/Manufacturer
○ Project Management
○ Academia/Training

○ Other (please specify)

6. Which of the following best describes your current occupation?

○ Manager Level (Manager, Senior Manager, Head of Department)
○ Senior Management Level (Director, Senior Director)
○ Operational Level
○ Executive Level (CEO, Vice-president)
○ Technical support
○ Academic
Other (please specify)

7. How many years of experience do you have?

○ 0-5
○ 6-10
○ 11-20
○ More than 20

8. How many years did you spend in the current organizations?

○ 0-3
○ 4-8
○ 9-15
○ 16-20
○ More than 20

9. In what country do you currently work?

☐ United Arab Emirates
☐ UK
☐ USA
☐ Other (please specify)

10. At which location (City) do you work?

3. Knowledge of BIM

11. Did you hear/know about Building Information Modeling (BIM)?

○ Yes

○ No

12. Does the organization where you are currently working is adopting BIM?

○ Yes

○ No

13. Did the company decide to utilize BIM?

○ My company already using BIM.

○ Yes, But not in the near future.

○ Yes, in the near future.

○ No.

14. My company already using BIM.

○ 1-5 years ago

○ 6-10 years ago

○ 11-16 years ago

○ More than 16 years

○ 0 years (my company is not using BIM)

15. How many years of experience do you have as BIM user?

○ No experience

○ 1-5

○ 6-10

○ 11-20

○ More than 20

16. Who is the <u>MOST</u> benefited from BIM?

○ Owner/client

○ Architect/designers/engineer

○ Contractor/Sub-contractor

○ Manufacturer/supplier

○ Facility management

○ All the above

○ Other (please specify)

17. Is it necessary the project manager should be BIM expert?

○ Yes

○ No

○ Other (please specify)

18. Do you think BIM is important for (Architect, Engineering and Construction) AEC industry?

○ Yes
○ No

19. After How many years BIM can mandate the AEC industry?

○ 0-5
○ 6-10
○ 11-20
○ BIM will never mandate AEC industry
○ Other (please specify)

4. Perceived Benefits of BIM

20. Please rate the degree of significance, in your opinion, the BENEFITS of BIM utilization to the project?

	Extremely Significant	Significant	Moderately Significant	Slightly Significant	Not at all Significant
BIM offers Integration/collaboration and robust communication amongst different teams.	○	○	○	○	○
BIM offers Error-free design	○	○	●	○	○
BIM offers improved productivity	○	○	○	○	○
Improved quality	○	○	○	○	○
Improved quantity take-off	○	○	○	○	○
Less rework	○	○	○	○	○
Time saving.	○	○	○	○	○
Cost saving.	○	○	○	○	○
Reduction in wasted materials.	○	○	○	○	○
Less RFIs and change orders.	○	○	○	○	○

	Extremely Significant	Significant	Moderately Significant	Slightly Significant	Not at all Significant
Improved safety.					
Improved logistics and machinery planning.	○	○	○	●	○
Increased ROI.	○	○	○	○	○
Improved sustainability.	○	○	○	○	○
Improved performance of the Facility Management (FM).	○	○	○	○	○
Early involvement of owners for quick decisions.	○	○	○	○	○
Promotes the company's competitive edge.	○	○	○	○	○
Promotes the off-site prefabrication.	○	○	○	○	○
Document automation.	○	○	○	○	○
Fast and accurate production of As-Built drawings.	○	○	○	○	○

5. Barriers of BIM adoption.

21. Please rate the degree of significance, in your opinion, the <u>BARRIERS</u> of BIM utilization?

	Extremely Significant.	Significant.	Moderately Significant.	Slightly Significant.	Not at all Significant.
Owner/client did not ask to use BIM, i.e. BIM is not mandatory.	○	○	○	○	○
Inadequate BIM experience, *Do not Know-How to start*.	○	○	○	○	○
Inadequate top management support to adopt BIM.	○	○	○	○	○
Resistance to	○	○	○	○	○

	Extremely Significant.	**Significant.**	**Moderately Significant.**	**Slightly Significant.**	**Not at all Significant.**
change of utilizing new technology.					
Significant changes in workflow, roles and responsibilities.	○	○	○	○	○
Inefficient interoperability of BIM different software.	○	○	○	○	○
Difficulties and conflict of interest who to manage the BIM model.	○	○	○	○	○
Unavailability of BIM skilled resources and complexity of software.	○	○	○	○	○
Not all stakeholders are using BIM.	○	○	○	○	○
High cost of BIM implementation.	○	○	○	○	○
Unclear legal and contractual liabilities.	○	○	○	○	○
Project procurement methodologies, especially traditional i.e. Design-Bid-Build.	○	○	○	○	○

Driving forces for adoption of BIM

22. Please rate the degree of significance, in your opinion, the <u>DRIVING FORCES</u> of BIM utilization?

	Extremely Significant	**Significant**	**Moderately Significant**	**Slightly Significant**	**Not at all significant**

	Extremely Significant	Significant	Moderately Significant	Slightly Significant	Not at all significant
Government/Client Pressure to adopt BIM.	○	○	○	○	○
Surrounding environment and competitive pressure from competitors (competitors are using BIM).	○	○	○	○	○
Complexity of projects and profit declination.	○	○	○	○	○
Internal organizational decision, due to the recognized benefits of BIM.	○	○	○	○	○
Organization desire for continuous innovation and improvement.	○	○	○	○	○

Organizations and UAE AEC industry readiness for the implementation of BIM.

23. Please rate the degree of significance, in your opinion, of the AEC industry & organizations readiness of the implementation of BIM in UAE.

	Extremely Significant	Significant	Moderately Significant	Slightly Significant	Not at all significant
Financial cost implication& readiness	○	○	○	○	○
Early recognition of the benefits of BIM	○	○	○	○	○
Top management attitude.	○	○	○	○	○
Flexibility to change	○	○	○	○	○

8 Appendix 2

Qualitative semi-structured questionnaire:

1. What are the benefits gained from the implementation of BIM? Did the recognized benefits prior implementations of BIM are gained?
2. What are the challenges hindering the implementation of BIM in general and in UAE? What are the most important challenges you faced and how did you overcome?
3. What are the driving forces that can force the organizations to implement BIM? How did you react with these driving forces especially you are not ready?
4. What are the actions required from the organizations and the whole AEC industry to be ready for the implementation of BIM?
5. How to promote the implementation of BIM in UAE?
6. Please rank each element for the four factors?

9 Appendix 3

Comparison between the interviewees' ranking for the four factors:

	Perceived benefits of BIM	Quantitative results	Case study 1 (BIM users)		Case study 3 (BIM non-users)	
			BIM manager	**Director**	**Sr. Architect**	**Director**
1	BIM offers Integration/collaboration and robust communication amongst different teams.	1	1	1	2	1
2	Time saving.	2	5	5	4	4
3	Fast and accurate production of As-Built drawings.	3	15	15	18	18
4	Less RFIs and change orders.	4	8	4	6	5
5	Improved quality	5	6	12	13	7
6	Improved quantity take-off	6	3	3*	14	13
7	Promotes the company's competitive edge.	7	17	8	8	12
8	Less rework	8	5*	3	3	4*
9	Early involvement of owners for quick decisions.	9	13	11	7	2
10	Document automation.	10	14	19	11	10
11	Reduction in wasted materials.	11	19	13	16	14
12	Cost saving.	12	4	6	4*	5

13	BIM offers improved productivity	13	7	9	17	8
14	Promotes the off-site prefabrication.	14	16	10	10	6
15	Improved performance of the Facility Management (FM).	15	12	14	9	15
16	Improved sustainability	16	18	17	12	16
17	BIM offers Error-free design	17	2	2	1	3
18	Improved logistics and machinery planning.	18	9	16	19	17
19	Increased ROI.	19	1*	4	5	2*
20	Improved safety.	20	20	20	20	20

Comparison of challenges& obstacles

	Challenges& obstacles of the implementation of BIM	**Quantitative results**	**Case study 1 (BIM users)**		**Case study 3 (BIM non-users)**	
			BIM manager	**Director**	**Sr. Architect**	**Director**
1	Resistance to change	1	3	2	2	2
2	Inadequate top management support	2	4	3	3	3
3	Significant changes in workflow	3	9	5	7	5
4	Owner/client did not ask to use BIM	4	1	1	1	1

5	Inadequate BIM experience	5	6	4	4	11
6	Not all stakeholders are using BIM.	6	8	6	6	6
7	Unavailability of BIM skilled resources	7	7	7	5	7
8	High cost of BIM	8	10	8	9	4
9	Inefficient interoperability	9	5	10	11	10
10	Project procurement	10	11	11	10	8
11	Who to manage the BIM model.	11	2	12	8	9
12	Unclear legal and contractual issues	12	12	9	12	12

	Driving forces imposing the implementation of BIM	**Quantitative results**	**Case study 1 (BIM users)**		**Case study 3 (BIM non-users)**	
			BIM manager	**Director**	**Sr. Architect**	**Director**
1	Government & client pressure	**1**	**1**	**1**	**1**	**1**
2	Surrounding environment& competitive pressure	**2**	**2**	**2**	**3**	**2**
3	Complexity of projects& profit declination	**3**	**3**	**3**	**2**	**3**

	AEC industry& organizations readiness to implement BIM	**Quantitative results**	**Case study 1 (BIM users)**		**Case study 3 (BIM non-users)**	
			BIM manager	**Director**	**Sr. Architect**	**Director**
1	Flexibility to change	1	2	2	2	2
2	Top management attitude	2	1	1	1	1
3	Financial cost implication& readiness	3	4	4	4	4
4	Early recognition of the benefits of BIM	4	3	3	3	3