The Uptake of Advanced IT with Specific Emphasis on BIM by SMEs in the Jordanian Construction Industry

Omar Al Awad

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Omar Al Awad

School of the Built Environment, College of Science and Technology
University of Salford, Salford, M5 4WT, UK

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DECLARATION

This thesis is presented as an original contribution to earn a Doctorate of Philosophy degree at the University of Salford. This work has not been previously submitted to meet requirements for an award at any higher education institution under my name or that of any other individuals. To the best of my knowledge, the thesis contains no materials previously published or written by another person except where due reference is made and acknowledged.

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GLOSSARY OF TERMS AND ABBREVIATIONS

2D – Tow Dimensions

3D – Three Dimensions

4D – Four Dimensions

5D – Five Dimensions

AEC - Architectural Engineering and Construction

AEC – Architecture Engineering Construction

AHP – Analytic Hierarchy Process

AI - Architect’s Instruction

AIA - American Institute of Architects

AIACC - The American Institute of Architects California Counsel

APCC - Asia-Pacific Conference on Communications

BIM - Building Information Modelling

BIMTG - Building Information Modelling Task Group

BOQ – Bill Of Quantities

CAD – Computer-Aided Design

CAM - Computer-Aided Manufacturing

CATO - Computer Coded Taking Off

CD - Compact Discs

CEO – Chief Executive Officer

CMP – Commercial Marine and Piling

COBie UK - Construction Operations Building Exchange UK

CPM - The Computer-Based Critical Path Method

DOS – Disk Operating System

ECTP - European Construction Technology Platform

ECTP – The European Construction Technology Platform

EDMS - Electronic Document Management Systems

EES - Engineering Estimating System

EJEP - The Euro-Jordanian Export Programme

ERP – Enterprise resource planning

ES - Expert Systems

ESRC - Economic and Social Research Council

FIATECH – Fully Integrated and Automated Technologies for Construction

GEST – Global Embolization Symposium and TechnologiesBOQ

GIS – Geographic information system

IAI - The International Alliance for Interoperability

ICEPAC – Interest Comprehension Emphasis Participation Accomplishment Confirmation

ICT- Information and communications technology

IDEA - inspiring Digital Enterprise Award

IFC – Industry Foundation Classes

IFCs - Industry Foundation Classes

IFD – International Framework for Dictionaries

IPD - Integrated Project Delivery

IPS - Integrated Project Systems

IT - Information Technology

ITAA - Information Technology Association of America

JCCA – Jordanian construction Contractor association

JCT – Joint Contracts Tribunal

JD – Jordanian Dinar

JEA - Jordan Engineers Association

JEDCO – The Jordan Enterprise Development Corporation

JUMO - Jordan's Upgrading and Modernization Programme

KBS - knowledge based-system

KPI - Key Performance Indicators

MEP – Mechanical Electrical and Plumbing

MHC - McGraw Hill Construction

MPWH - Ministry of Public Works and Housing

MS – Microsoft

NBIMS - National Building Information Modelling Standards

OBG – Oxford Business Group

QS – Quantity Surveyor

QSDS – The Quilt Surface Design Symposium

R&D - Research and Development

REF - The Research Ethics Framework

RFI - Request for Information

ROI - Return on Investments

SMEs - Small and Medium Enterprises

SPE - Single Purpose Entity

SRA - Strategic Research Agenda

SWOT – Strengths, Weaknesses, Opportunities and Threats

UAE – United Arab Emirates

UK – United Kingdom

UK GCS - UK Government Construction Strategy

USA – United State of America

USCS – United States Commercial Service

VR - Virtual Reality

VS – Vector Software

WBPMS - Web-based Project Management Systems

ABSTRACT

Construction industry within Jordan (whilst it is sensitive to changes in economic activity; demographic factors and social development) it is progressively becoming more successful, as Jordan itself modernizes. As a result of this, there is agrowing need for specialized Information Technology (IT) software. The SMEs in the Jordanian construction industry are facing many challenges including competition from regional and international contractors. SMEs needs to change and modernize, especially in terms of using advanced IT as it can enable them to perform better and increase their ability to reach a high standard and have more credibility in the eyes of clients. The findings showed that SME contractors in Jordan are behind in the use of advanced IT such as Building Information Modelling (BIM) and that AutoCAD dominated the production of engineering drawings and Microsoft application packages, e-mails and web browsers were among the top software utilized by the industry. The use of such technology is still lacking and this is mainly attributed to a number of social, cultural, financial, technological and legal factors.

Therefore this research embarked on a journey to develop a framework for the Uptake of Advanced IT with Specific Emphasis on BIM by SMEs in the Jordanian Construction Industry. Using a mixed method research, interviews and questionnaires were conducted to find out why BIM adoption in Jordan is so slow and why the status quo, which is no adoption of BIM among SMEs at all. The research found that there were several barriers hindering the adoption of BIM among SMEs. The number of barriers spanned from product issues (i.e. the technology itself), process issues, to people or cultural issues. Some of these barriers are: Lack of Awareness of BIM, cost and time of investment, low level of education, lack of knowledge and skill, culture, training, etcetera. Therefore, using these findings and also with the help of literature, the research developed and tailored this framework to the context of construction SMEs in Jordan. The framework is structured in such a way to allow construction SMEs to adopt BIM properly. The framework was validated using Member Checking technique and the participants approved of the usefulness and the applicability of the framework. The hope is that the framework will serve as a stepping-stone to the future adoption of BIM among construction SMEs in Jordan and even the large construction

companies may find it useful. Lastly, it was resolved that in order to resolve the issues of adoption, Project Owners; Public sector (government) and Private sector clients; Construction Associations; and Large construction companies would have to join hands to create awareness through training, seminars, courses, other programmes, practical adoption of BIM on projects and documentation of results.

1 CHAPTER 1| INTRODUCTION

1.1 Research Background

Over the years, the construction industry has been criticized for its low performance improvements, with the main problem being that there are poor cross-disciplinary communications and the special fragmented nature of the industry and its supply chain (Aouad and Wafai, 2002). Especially when compared to other industries such as manufacturing and the services industries, construction, falls way behind (Gann, 2000 and Winch, 1998). The Latham and Egan reports of the 90s have stated the issues very clearly. Industry sponsored researchers have started to understand the reason behind the construction industry under-performing, highlighting the issue of integration within the sector (Latham, 1994; Egan, 1998) and the solution being an aim to achieve an integrated environment in the industry using Information Technology (IT) as a key tool. Over the last decade, the industry, researchers have found, has been experiencing a paradigm shift, mentioning increased productivity, increased efficiency, and infrastructure value; improved quality and sustainability while reducing; lifecycle costs, lead times and duplications via effective collaboration and communication of stakeholders in construction projects (Arayici, et al, 2012). Building Information Technology (BIM) is one tool, which has gained traction as the solution to the construction industry's lack of integration and collaboration and has been said to be the panacea to addressing the interdisciplinary inefficiencies in construction projects.

Vanlande and Nicolle (2008) defined BIM as *"a tool that enables storage and reuse of information and domain knowledge throughout the lifecycle of the project"*. Or in succinct terms, it is the utilization of a database infrastructure to encapsulate built facilities with specific viewpoints of stakeholders (Arayici et al, 2012). Singh, et al (2010) also described BIM *"as an Information Technology (IT)-enabled approach that allows design integrity, virtual prototyping, simulations, distributed access, retrieval and maintenance of the building data."* BIM is the latest tool that can most effectively and most efficiently play the main role of information and knowledge of exchange between different disciplines by coordinating and integrating these disciplines through out phases of the project life cycle. However, the pace of adoption is off the mark due issues and difficulties in putting technologies into practical use within the construction sector (Sun and Aouad, 2000).

While there are various definitions of Building Information Modeling in literature, Arayici and Aouad (2010) gave a comprehensive definition of BIM encapsulating all the objectives behind the momentum of the BIM initiative. In this definition, BIM was defined as "the use of ICT technologies to streamline the building lifecycle processes to provide a safer and more productive environment for its owners throughout the building lifecycle."

The construction industry has been characterized by a slow uptake of IT advances (O'Connor and Yang, 2004). This is as a result of the wide skepticism shared by industry professionals of IT and its fast changing nature (Gyampoh-Vidogah 2003). Typically, software packages are designed to deal with data processing and task management rather than aiding processes and developing knowledge (Egbu & Botterill, 2002). However, the use of Information technology within the construction industry has progressively increased throughout the years. In the 1960's where it was initially being used for simple tasks, this being the calculation of the projected costs involved within a project, and was limited to a use of separate, commercial, "standalone" software packages which are purchased or developed for short-term technical or financial requirements (Forse and Grobler 2000). Information technology was then used for designing algorithms and producing drawings, and this is where the potential of the implementation of IT had within the sector become evident. Expectations became high when considering the ways in which IT software and hardware could support and aid in the design and construction processes.

Throughout the 1970's and 1980's expectations became more realistic regarding IT solutions and its use within the construction industry. At this time the costs involved in purchasing and implementing hardware and software was high, furthermore the software available was still inadequate in its capabilities and as a result, the use of IT was limited to more basic packages. This changed in the late 1980's. However, there was a decline in hardware prices, better off-the-shelf software, improved hardware reliability and an increased numbers of computer-literate employees have fuelled much of this growth (Aouad and Wafai 2002). It was at this point that academics, economists and industry specialists started promoting the use of Information Technology (IT) within this industry declaring that it will help the industry to capture substantial gains (Sun & Aouad, 2000; O'connor &Yang, 2004).

According to Sun & Aouad (2000) it is widely believed that IT, especially knowledge based-system (KBS), presents a powerful tool to achieving the desirable level of integration. This level of integration appears easier to attain due to the rapid developments in IT.

The way in which business is conducted, according to Peslak (2005) depends upon recent developments and advances in technology, processes and procedures are constantly updated to make the most of the technology available, and since the 1950's the use of IT software and hardware has reduced the costs involved a number of different areas, including, production, operations and sales, along with improving businesses customer services, network and communications (Michaloski and Costa 2010). A good example of the enhancements an Information Technology system can have in an industry is the manufacturing trade, the implementation of software and hardware, such as Virtual Reality (VR),), Computer-Aided Manufacturing (CAM), Expert Systems (ES) and Computer-Aided Design (CAD) has been invaluable. IT has completely changed the way that employees work, time efficiency has improved drastically, employees have access to more information, and with the improvements in communications employees can share data and information quicker. Furthermore, the Internet has enabled the company to communicate directly with their customers easier.

1.2 The BIM Solution

BIM is seen as the tool that can solve the problem of low productivity and fragmentation of the construction industry as it is designed with a methodology that integrates digital descriptions of all (the) building objects and their relationships to others with acute precision, so that stakeholders can query, simulate and estimate activities and their effects on the building process as a lifecycle entity (Arayici et al, 2012). Traditionally, in the construction industry, interoperability and multi-disciplinary collaboration has revolved around 2D and paper-based documents (Singh, et at. 2010). 3D models and applications for visualization and design development existed only for this purposes. Today, 3D drawings contain enormous information ranging from material specification, dimensions, cost, etc. According to Singh, et al (2010) object-oriented Computer-Aided Design (CAD) packages and increased constructability and level of automation in construction processes has provided medium through which the exchange of 3D data can be disseminated in the collaboration effort. And, BIM is seen as the major tool upon which this goal can be actualized. BIM is a major break-through in the industry as its advanced object-oriented approach to CAD includes, but not limited to, establishing intelligent relationships between elements in a building model, object attributes and specifications, automated extractions of 2D drawings, documentation, etc. It also has the built-in intelligence of reducing modeling errors and preventing technical flaws in design. Furthermore, the scope of BIM has progressed from the current intra-disciplinary collaboration through specific BIM applications to multi-disciplinary collaboration through a BIM-server (Singh, et al. 2010). An example of this is EDMmodelServer, which provides a platform for direct integration, storage and exchange of 3D model data with embedded intelligence from multiple disciplines. With all the positive that BIM can bring, it is safe to say that BIM helps with making the right judgment for a more robust infrastructure and for the benefit of the owners and occupants.

Although the economic and environmental benefits of BIM are widely acknowledged, there is a slow adoption of this technology (Lindblad, 2013). A trusted and most common strategy for changing an economic sector on a national level is through the government. Arayici et al (2011) asserts that government pressure, through policies, is one very effective method of making the building industry to maintain a reasonable standard of value for money. Governments around the world are now putting pressure on the construction industry to adopt BIM when tendering for any public works. In the UK, the government in making Level 2 BIM mandatory on all publicly funded projects from 2016 onwards (Eadie et al, 2013). In a document published by BuildingSMART, (2012), the Australian government has also taken the stand on making 2016 the threshold for compulsory BIM use on public sector projects (Eadie et al, 2013). The governments of the USA, Europe, Asia, and Middle East are reported to be having in-house discussion and also national deployments of BIM.

"*Level 2 BIM is a series of domain specific models (e.g. architectural, structural, services etc) with the provision of a single environment to store shared data and information (e.g. COBie UK 2012)"* (BIMTG, 2014).

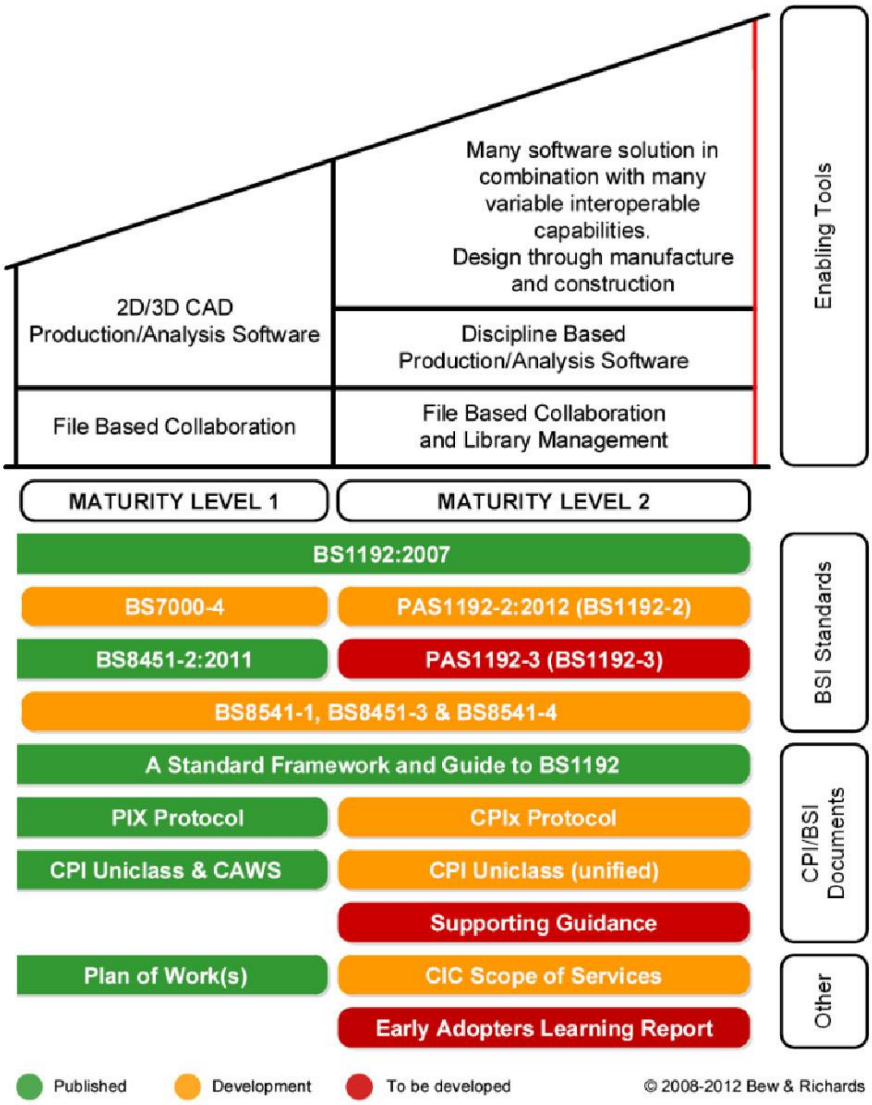


Figure 1.1: Level 2 BIM Maturity (Source, BIMTG, 2013)

The purpose of this research is to develop a framework for the uptake of BIM by Small and Medium Enterprises in the Jordanian construction industry thereby enabling efficient and effective management of construction projects, in especially issues relating to material management systems and on-demand design cost information on construction works. The findings are based on detailed interviews and questionnaires conducted amongst Jordanian contractors. The proposed framework for BIM adoption in Jordan will and better facilitate the transition and management of the technology leading to greater support for intelligent and automated collaboration in design and construction amongst Jordanian construction SMEs.

1.3 The Construction Industry in Jordan

According to the minister of public works and housing (JCCA 2012), the construction industry in Jordan is a major contributor to the Jordanian Gross Domestic Product (it contributes to about 15% of the Jordanian economy). The industry is considered one of the key drivers in building a strong local economy. A high level of professionalism and organization characterizes the sector, and it includes 1716 Jordanian contractors graded by expertise and capabilities (OBG, 2011). Assistance is available for specialized and highly qualified staff of engineers and technicians. Materials and expensive equipment/resources, and specifications highlight the scale of the financial investment put into the construction industry. The development of this sector is evident both institutionally and technically, as is the development in other sector of the economy. The construction industry is valued at hundreds of millions of Jordanian dinars per year, consisting of more than a thousand construction companies along with engineering consultancy businesses with over ten thousand engineer's working for them.

1.4 IT Utilization In The Jordanian Construction Industry

El-Mashaleh (2007) asserts that Jordan will see an aggressive plan to make full use of Information Technology capabilities. In his survey of 207 construction firms in Jordan on their use of IT, he found that: AutoCAD dominated the production of engineering drawings with most firms utilizing the software almost 100% of the time; Microsoft application packages, e-mails and web browsers were among the top software utilized by the industry. He also found that 85% of the sample population was committed to invest more money into IT and that commitment was driven by demand from customers for new IT.

1.4.1 The Jordanian Construction Industry Amidst The Financial Crisis

In 2011, the rot effect of the global financial crisis became evident and pointed to tough time ahead. However, the Central Bank of Jordan figures showed that bank lending to the construction sector in 2010 totaled JD3.2bn ($4.54bn), a 19.4% increase on 2009 representing 22% of total lending (OBG, 2011), only second after the department of Trade and Industry with 24.7% of total lending. The Jordanian Construction industry employs about 140,000 workers, supporting 14% of the population. According to the OBG (2011), at least a third of this total number is unskilled Egyptian laborers. This is because the industry in Jordan offers better pay to unskilled worker than other regional markets. The Jordanian Construction industry is characterized with highly skilled expertise and it has been boosted in recent years by the entry of Gulf and International firms that require a higher level of technical knowledge, such as high-rise towers, which are new to Amman.

Table 1.1: Output of the Jordanian Construction Industry

Construction work, 2010	
Type	Value (JD m)
Building	631
Roads	116
Electro-mechanical	38
Water & sewerage	63
Other	1
Total	849
SOURCE: Jordanian Construction Contractors Association	

Table 1.2: Output of the Jordanian Construction Industry by City

Projects by location & value, 2010		
Mohafaza	No. of projects	Value (JD m)
Amman	4154	534
Irbid	98	78
Kerak	41	15.3
Tafleh	17	4.8
Aqaba	80	170
Mafraq	43	5.6
Zarqa	245	19.5
Ajloun	13	0.44
Balqa	65	5.3
Jerash	29	1.9
Maan	37	9.1
Madaba	47	5
Total	4869	849
SOURCE: Jordanian Construction Contractors Association		

SME's are at the heart of the economy in Jordan. They are usually of small clusters of about 19 employees and form about 98% of businesses in Jordan. In order to meet up with growing competition locally and abroad, they need to be innovative to get ahead of the game. And one sure way of being innovative is through technology improvements. Some of these technologies are very expensive. That is why the government and other donors have made some funds to encourage SME's in their innovations (JEDCO, 2013).

According to the Ministry of Industry and Trade of the Kingdom of Jordan, Small and Medium Enterprises can be defined as:

Table 1.3: Definition of Companies according to size (JEDCO, 2013)

Classification	Capital Investment (JD)	No. of Employees
Micro	Less than 30,000	1-9
Small	30,000	10-49
Medium	30,000	50-249
Large	30,000	250 and above

There are a number of reasons behind the recent growth of the construction sector within Jordan, the most significant being that of the political situation prevailing in neighboring countries which has impacted on money not being checked when deposited in from the outside, lower interest rates from financial institutions, a secure investment environment and a good infrastructure, amongst other things. The number of companies/facilities that have registered and been given grants by the banks and financial institutes, for use within the construction sector, has now reached an unprecedented level. 1158 million dinars have been invested in total. This comes second after the trade sector, and reflects the revenue of the Department of Lands and Survey of Jordan, which amounts to 220 million dinars in 2005. This was also due to rise in real estate prices.

The Jordanian construction contractors association (JCCA) (2012) has remarked that Jordan is in the midst of a vast boom in construction activity, primarily due to huge real estate investments with most of the construction activities being within the capital city (Amman), the Dead Sea, and the Red Sea port of Aqaba. The Jordanian Ministry of Public Works and Housing estimates that there has been real estate investments worth over $30 billion in the last five years; the United States Commercial Service (USCS) reports (USCS, 2008). This is a huge increase when compared to the previous

20 years where the market has seen just $2 billion of investment. The tourist, residential, and commercial sectors have greatly impacted this increase in the construction industry investments, and have provided the construction sector with a volume of large-scale projects. As these projects are still within the emerging stages, this recent demand for construction in Jordan will be a continuous and on-going thing.

1.5 The Rationale For Research

As the types of construction projects and varying styles of real estate are changing and modernizing, the demand for new and improved construction equipment, specialized materials and advanced engineering skills are also on the rise. The Jordanian construction sector has experienced such a growth throughout the last few years that it has sparked an interest in and has encouraged investment within the construction sector, this has placed even more importance in the integration and use of technological advancements such as Building Information Modeling (BIM). The introduction of Information Technology (IT) has now become vital to the construction business (El-Mashaleh, 2007) because it has improved productivity of the design process and eliminated much of the efficiencies the industry has endured without it.

In June 2011, the Kingdom of Jordan’s Ministry of Public Works and Housing (MPWH), the Jordan Engineers Association (JEA), BuildingSMART MENA, BuildingSMART ME, and BIM Journal, all signed an agreements to initiate a BuildingSMART forum to promote BIM in the Jordanian construction industry with an aim to curb waste, improve the construction process, and save cost on projects. In this regard, BuildingSMART took a survey on the penetration of ‘Building Information Modeling’ (BIM), in the Jordanian construction industry. They found that the penetration was “moderate”, and 25% of participants were “familiar” with BIM processes but only 5% were using it (BIGPROJECT, 2014). SMEs that make up 98% of the Jordanian construction industry were found to be the least informed about BIM. These companies are facing many challenges including competition from regional and international contractors. The SMEs needs to improve in terms of efficiency, especially with regards to using IT as it can enable them to perform better and increase their ability to reach a high standard and have more credibility in the eyes of clients.

The researcher has had pilot interviews with a few SME contractors in Jordan, in order to find out the situation of adopting BIM on their projects. The findings showed that SME contractors in Jordan are behind in the use of BIM. The use of such technology is still lacking and this is mainly attributed to a number of social, cultural, financial, technological and legal factors. This research aims to investigate the barriers limiting the implementation of BIM amongst Jordanian Construction SMEs and to propose a framework that enables the proper uptake of BIM to support the proper integration of design and construction information.

1.6 Research Aim

The aim of this research is to develop a framework for the adoption of Building Information Modeling (BIM) by SMEs in the Jordanian construction industry.

1.7 Research Objectives

I. To interrogate and elaborate the previous related research studies and best practices in the fields of Information Technology (IT) and BIM in the Jordanian construction industries.
II. To explore the current construction practice and theory of BIM in the Jordanian construction industry, particularly in SMEs.
III. To critically examine the internal and external factors proactively considered for the adoption of BIM by the Jordanian construction SMEs.
IV. To develop a framework for the adoption of BIM by the Jordanian construction SMEs.
V. To Refine and Validate the BIM Adoption framework.

1.8 Change Management

Hollenbeck (2006) highlighted the impact that work-systems have within an industry. There is no doubt that businesses that support new technology benefit the most. However, there will always be an initial discomfort period, in which employees will struggle with the impact the new technology has on their training programs, their work ethics and the restructure of their bonus/pay increase targets to accommodate this new technology. Rivard, 2000, Irani et. al., (2002), researched into this idea of an initial discomfort period when studying the difficulties construction companies were having in implementing IT systems within their buildings and throughout their employees, processes and procedures. Their findings confirmed initial discomfort. 'These difficulties are made more pervasive with the lack of integration among key actors involved in the construction processes' (Michaloski and Costa, 2010).

1.9 Contribution To Knowledge

The study seeks to make a constructive contribution to knowledge by exploring the place of BIM in Jordanian construction SMEs. SMEs in the Jordanian construction industry stand to enjoy the benefits, promised in literature, of adopting BIM. Therefore, this research seeks to provide a framework for adopting BIM in SMEs which gives impetus to the benefits of IT and which eludes contextual barriers. In the end, it is hoped that this framework will help the Jordanian SMEs in the construction industry to comfortably adopt BIM, as it will enable the Jordanian companies to perform better locally and compete with foreign companies in the domestic market.

1.10 Conceptual Framework

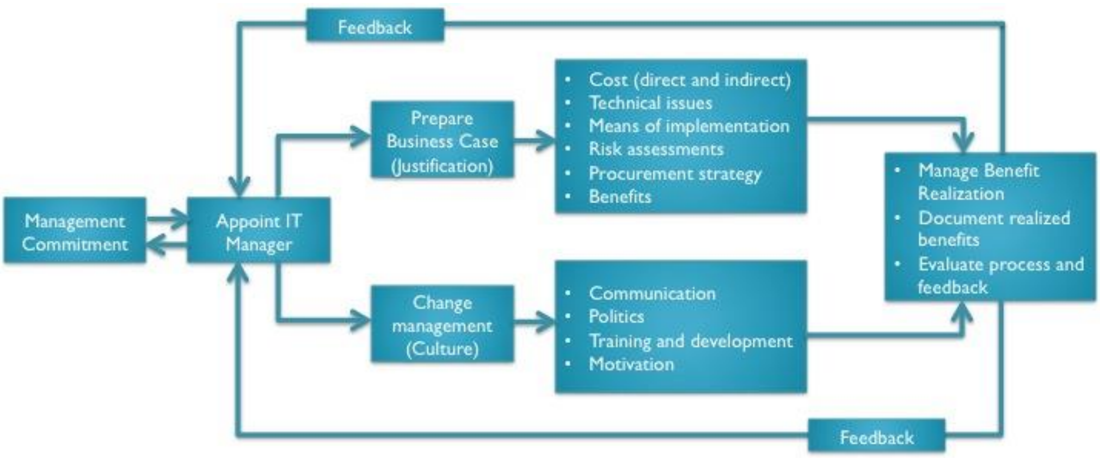


Figure 1.2: IT Adoption in Jordan (Conceptual Framework)

1.11 Originality Of The Research

To the researcher's knowledge, this study is the first academic research study to be carried out in the adoption of BIM by SMEs in the Jordanian construction industry.

1.12 Ethical Issues

The individuals that form the sample size are members of Jordanian construction community. As such, this research only referred to the Position/Office they hold and not their individual names. To ensure anonymity and confidentiality, this research adopted code names such as Contractor, Owner, Small company, Medium sized company, and so on. Also, other important information exclusive to companies, which could easily give away their identities, was excluded from the research. The participants were provided with a letter explaining the reason for conducting the interview and for what purpose their answers will be used (see Appendix 7). The letter contained a section seeking their voluntary consent to participate in the interviews. Participants were told, roughly, how much of their time was needed to answer all the questions as part of the informed consent. Additionally, they were made aware of their right to quit anytime during the interview and/or not answer any question they were not willing to answer.

Furthermore, the participants were assured confidentiality, as all data collected will be encrypted. And no one but the principal researcher and the research supervisor will know the decryption key. The research also promised to respect their wishes in whichever way they wanted confidentiality. After the research is done and finished, whatever information not relevant to the final copy submitted to the university will be destroyed – deleted. The Research Ethics Framework (REF) set out in the Economic and Social Research Council (ESRC, 2010) informed the Ethics of this research.

1.13 Guide to thesis

Chapter 1 – Introduction: This chapter introduces the background to the research and rational of the research. It spells out the gap in knowledge i.e. creating a framework adoption of information technology (IT) with specific interest in Building Information Modeling (BIM) amongst small and medium sized enterprises (SMEs) in the Jordanian construction industry. It also outlines the aim and objectives of the research, contribution to knowledge and the ethical issues surrounding the research.

Chapter 2 – Information Technology and Construction: The Chapter proceeds with an insightful discussion of the main related literatures and previous research studies regarding the construction industry. Consequently, the subject of IT in construction management is explored and made explicit as a broad subject area of the research. This is then followed by an exploration of the area of Building Information Modeling (BIM) in construction (discussed in the next chapter). But this chapter will focus on issues related to IT within the construction industry as they are examined through previous research studies.

Chapter 3 – Building Information Modeling and Construction: Over the course of this chapter, we will discuss the BIM concept as the panacea for the inefficiencies and collaboration issues of the AEC industry. The chapter will discuss benefits and criticisms/challenges of adopting BIM, drivers and barriers to implementation of BIM in the AEC industry. Adoption of BIM on construction projects enables the production of sustainable designs of buildings and construction processes, ultimately improving the product quality.

Chapter 4 – Research Methodology: Selecting an appropriate research method that best answers the research question is essential to the concreteness and validity of the research. This chapter iterates how the research intends to achieve its aim and objectives. The research begins with an overview of the selected research philosophy. The research philosophy will be followed by a discussion about the research method used, which includes an overview of quantitative, and qualitative research methods, selection criteria, and the research strategy. A detailed justification of the data collection method will be provided by looking at access to the field and interview schedule, interview style and questions, selection of the companies, and lastly, a description of the data analysis method used.

Chapter 5 – Diagnosis of SMEs for IT Use and BIM Adoption in Jordan: This chapter introduces the context of the study – the Jordanian construction industry and the corporate culture of business and IT adoption within the SMEs in that context. The chapter emphasizes that the decision to investment in IT must most not be for the sake of the technology itself but because the technology will supports existing business strategy, and will focus on the people and their needs. The above served to pave the way to a thorough understanding of what is to follow, i.e. the data analysis of the interviews conducted with SMEs in Jordan on the adoption of IT with specific interest in BIM.

Chapter 6 – Development of Framework: The decision to investment in IT must not be "*technology for technology sake*", but must supports existing business strategy, and people, it means a framework for the uptake of BIM, must focus of business strategy and the needs of people. That's exactly what the research did and developed the BIM adoption framework based on the research findings that captures both the samples' business and people's needs. The chapter starts by exploring 'awareness' and 'JEDCO grant' to address some of the issues revealed in chapter 5, and concludes with an amicable change management strategy to handle process and project issues within a company attempting to adopt BIM.

Chapter 7 – Validity and Reliability of the Research: The reliability of any finding is when upon accurate retesting, it holds to be true, irrespective of who tests it. The chapter outlines the validations process of the framework using the 'member checking' strategy. The research is a qualitative study and as such, a qualitative evaluation strategy was used to achieve; validity, and credibility. The feedback was then used to improve on the framework.

Chapter 8 – Conclusion and Recommendations: the research concludes by going over the key research findings with recommendations embedded within the discussions and closes with recommendations on how to address barriers to uptake of IT and BIM, further study and contribution to knowledge.

2 CHAPTER 2| INFORMATION TECHNOLOGY AND CONSTRUCTION

2.1 Introduction

The knowledge boom and IT revolution of the 21th century has lead to the globalization of economies where international trade is not only possible within a virtual environment but seemingly a very effective and efficient medium of trade. The Latham report widely known for critically analyzing and juxtaposing the construction industry with other industries in the UK places the construction industry behind, manufacturing, finance, aerospace and telecommunication industries with regards to the development and use of IT. Unfortunately, IT in construction is no longer a luxury because in the modern age, it is a necessity. Most construction processes now rely on IT systems and tools to design, manufacture, inform, communicate information and process (Sarchar and Connolly, 2000). The competitive advantage attainable with IT cannot be overemphasized. It offers new opportunities for strategic decision-making, improving productivity and performance, and better management for organizations. Therefore, there is a need for the construction industry to close the gap. However, there is the argument among construction professionals that the pace of change of IT is one that the industry cannot catch up with not to talk about the cost of implementing the system. But among these arguments, one thing remains constant – the benefits of information technology such as improved; communication, efficiency, quality and competitive advantage; are undeniable.

2.2 Information Technology (IT)

Information Technology (IT) has been defined in many ways depending on the body of knowledge that has taken up such a task. In succinct terms, IT is the use of computer and software to manage information. Physicists' defined IT as *"the application of computer and telecommunications equipment to store, retrieve, transmit and manipulate data"*. However, the entrepreneur encyclopedia (2013) added an important factor missing in the above definition, which is the 'creation' of information. It defines IT as *"a term that encompasses all forms of technology used to create, store, exchange and utilize information in its various forms including business data, conversations, still images, motion pictures and multimedia presentations"*. Another definition by TechTerms.com (2013) included perhaps the most profound and indispensable factor – the human factor. It defined IT as "anything related to computing technology, such as the Internet, hardware, networking, software, or the people that work with these technologies". The introduction of 'people' in this definition exposes that which was subtle or perhaps absent in other definitions - people are needed to make information useful. A more rounded definition though is that by the Information Technology Association of America (ITAA) who defined IT as *"the study, design, development, application, implementation, support or management of computer-based information systems"*. This research has chosen to subscribe to this definition because of its robustness and its framing within a business context

2.3 The Construction Industry And Its Role In National Economy.

"Traditionally, construction companies have not fully perceived the importance of increasing the dynamism and the complexity of its external environment. That could be attributed to the special and the rigid nature and structure of the industry and also to the lack of a long term corporate strategic thinking'' (Arayici and Aouad, 2005).

Economic environment and governmental regulations are the most important and influential factors impacting on the construction industry, particularly, at national and institutional levels (Bossink, 2004). The construction industry has been difficult to improve due to its highly fragmented and complicated nature and structure. Complications in the introductory stages have been followed by difficulties in the implementation stages. Without the help of the central government, it would be difficult to add any improvements to the industry or any of its parts. This however, would still be a long shot if the national economy itself is not in good health (Brandon and Ruddock, 1997). Aouad and Wafai (2002) affirm that in order for improvements to be sustained, the appropriate environment has to be created.

The construction industry combines an array of activities that make the whole. However, there are four major categories: Infrastructure and heavy construction; Institutional and Commercial building construction; Specialized industrial construction; and Residential housing construction (Hendrickson and Au, 2003).

The infrastructure and heavy construction projects include several types of construction activities such as bridges, tunnels, pipelines, storm water and drainage systems, highways and mass transit systems popularly known as Civil Engineering construction. This type of construction projects requires a high level of mechanization and hence makes use of heavy and specialized plants and equipment. Institutional and commercial building construction include: medical clinics and hospitals; large shopping centers and retail stores; warehouses and light manufacturing plants; schools and universities; recreational facilities; and tower blocks for offices and hotels. While this type of construction activity requires the use of plants and equipment, the extent to which they are used is slightly less than in heavy construction. On the large-scale spectrum, specialized industrial construction is the most complex. This type of projects includes Steel mills; Coal-fired or nuclear power plants; Oil refineries; and Chemical processing plants, offshore military bases. Their owners are usually heavily involved from inception to completion, then, Residential-housing construction, (categorized into multi-family dwellings, single-family housing, and high-rise apartments). This sector is somewhat less complex and less capital intensive than the other three sectors.

2.3.1 The Culture of the Construction Industry

The prevalent culture of the construction industry underpins the inefficiency and the ineffectiveness of its processes and procedures. The industry is characterized by its strong and unchanging culture, which holds deep roots in its practice's and traditions. This robust and firm culture is often considered to be the main factor for the industry's inability to introduce a change and make improvements.

Management literature provides numerous cultural frames and references, which could be applied in the context of the construction industry. Six levels have been identified including individual level, divisional level, institutional level, industrial level (sometimes known as industry recipe) and national level. The importance of each of these levels should not be overlooked (Aouad and Wafai 2002).

2.3.2 The Scope of Information Technology in the Construction Industry

The use of computer applications within the construction sector has been traced back to the early 1960s, with the initial purpose being the calculating of costs involved in the project and enterprise. Since then, IT has been further developed providing quicker and more accurate computation of design algorithms (Thorpe, 1995). As a result of this, more advanced applications were then developed for designers aiding in the production of drawings and engineering graphics. Researchers and industry specialists, therefore, had relatively high and positive expectations about the potential an IT system has as a supportive tool for design and construction along with the time it would take to achieve these potentials. The 1970s and early 1980s saw a more realistic understanding of the impact Information Technology would have on the construction industry, and so the initial excitement was gone. Industry specialists realized that there is high capital costs involved in IT, coupled with only moderately useful software being available and this was restricting the widespread use of computer systems. Since the mid-1980s, the use of IT in the construction industry has started to re-accelerate quickly. Hardware prices started to decline, hardware reliability was greatly improved upon, the choice of off-the-shelf software was much more satisfactory, and the numbers of computer-literate employees greatly increased, and this is what has fuelled much of this growth. Since then, it has been widely preached that expanding the use of computer technologies in construction sectors will help the industry to capture substantial gains (Sun & Aouad, 2000).

The possibilities and roles of computing within the construction sector, however, present an issue, which must be directly addressed. Reports from studies within the industry show that the typically IT usage in the construction industry is limited to the use of separate, commercial and "standalone" software packages which are purchased or developed for short-term technical or financial requirements (Aouad and Wafai 2002). Some of these software packages perform data processes, others for cataloging of information and knowledge. According to Mak (2001) the usefulness of these software are to improve productivity, enhance presentation, strengthen capabilities and data processing during some design and construction processes. Egbu & Botterill, (2002) assert that, the construction industry is yet to exploit (at a strategic level) broad and intelligent technological solutions that enable knowledge capture and sharing, and which would boost the internal and external competitiveness of construction firms.

It is not news to reiterate that the construction industry has been continuously noted for its slow performance improvement. To mention a few; poor communications, the uniquely fragmented nature of the industry and its supply chain are some of the major problems of the industry. Recent research studies have identified a number of solutions to overcome these highlighted problems the construction industry faces.

Most of these solutions center on a notion of "a virtual organization" which is based on the principle of the integration of construction information and processes in its wider supply chain. Integration and process change are at the heart of industry improvement needs (Aouad and Wafai 2002). It is widely agreed in literature that IT presents a powerful tool to achieving the desirable level of integration the industry needs (Sun & Aouad, 2000).

2.3.3 Evolution of IT in Construction

The first electronic computer used in construction was built after the 1950s from which spurned several other construction computer applications in the decades that followed. An example of an application at the time was in the area of project management techniques – the computer-based critical path method (CPM). However, computer applications in the construction industry have been changing more rapidly. Kajewski and Weippert (2000) highlighted that the rapid change in technology has made the construction industry slow to keep up (Kajewski and Weippert, 2000). Evidently, the construction industry has failed to defy the odds. The industry has continued to register a progressive increase in the cost per unit cost of construction since the inspite of computers and mechanization.

2.3.4 Characteristics of the Construction Industry

The nature of the construction industry is significantly different from that of industries such as Finance and Manufacturing. The industry is generally known for its heterogeneous and highly fragmented nature (Latham, 1994; Egan, 1998). More than 90% of the industry firms are small and medium size that tends to respond to local market needs and control one element of the overall building process (ECTP, 2008). No construction project is the same. Unlike manufacturing, construction products (projects) are 'one-off' (prototypes), and non-transportable. They must be approached with respect to the characteristics of the new geographical location. This makes it difficult to duplicate knowledge learnt on previous projects in new projects. However, with the advent of IT, the industry is breaking new grounds in the transferability and management of knowledge (Alsahli, 2011). As a result of this one-off nature of the industry, business relations tend to be temporal and often short-term to the projects. This leads to loss of individual 'tacit knowledge' because the partners on one project may never be able to combine know-how on a different project (Hannus et al, 2003).

Furthermore, the sector is highly regulated and complex due to the stake held by not only the primary actors on the project (client, industry professionals, contractor and subcontractors), but also that held by the government (local, provincial, and national). Hence, by virtue of this nature, the industry is slow to change. Slow in adopting new innovations. By implication, slow to adopting ICT infrastructures, innovative ICT support for internal processes, supply-side e-business activities, and electronic marketing and sales. According to the European Construction Technology Platform (ECTP, 2008) the reasons for the construction industry's lag in taking up IT, among others, are its: locally limited competitive environment project-based operations structure, non- professional clients, temporary business relationships, and complex one-of-the-kind products.

2.3.5 Industry requirements for ICT support

Hannus et al, (2003) assert that people, processes and technology are the prime consideration when adopting an IT system. On the ROADCON project, they proposed the following ICT needs for the construction industry.

- *Brief formulation:* solutions to support the capture of requirements from the client, end-users, and other relevant stakeholders.
- *Project management (including risk management):* solutions to assist in the efficient and effective use of various resources needed to deliver and operate a building/facility (including human resources, supply chain, financial aspects and costing), solutions to manage risk and control the occurrences of contingencies.
- *Decision support*: solutions to assist in process and product compliance with regulations across the building/facility lifecycle, selection of best design, construction and facility operation options (in the large), selection of sustainable product components achieving best performance and buildability.
- *Knowledge sharing*: solutions are expected to provide easy access to relevant information while improving the decision-making process.
- *Communication and collaboration*: solutions to facilitate communication and collaboration between geographically dispersed actors (including in different time zones).
- *Assets management*: solutions are required to better manage the asset of the facility during the exploitation while improving its global impact on the environment.

Source: Hannus et al, (2003)

Computer has promised to be a reliable tool in all spheres of human endeavor including construction. Therefore, professionals in the construction industry must be open to the possibilities (Castle, 2002). Shash and Al- Amir, (1997) has documented the relevance of computer/computing to the construction industry IT Systems and in particular Electronic Document Management Systems (EDMS) is the answer to many paper related problems primarily because they seem to offer an opportunity to exercise control over the ways in which current paper based documents are handled and distributed (Raynes, 2002). Rivard et al, (2004) predicted that the evolution of IT would have a profound impact on how organizations and professions in the construction industry fields operate. This is the case today. For example, design is now electronic led- rather than paper-based. Basically, there is less dependency on paper-based processes and more adoption of computer processes that lead to greater efficiency.

For example CSSP, an international software producer, specializing in applications for the Construction Industry that provide support for professionals through the whole-life-cycle of the project from concept to disposal. RIPAC & ICEPAC and the Engineering Estimating System (EES) are two products specifically designed for the engineering sector, particularly within the Water Industry. ICEPAC is Estimating and Cost Planning software. Between these software are functions ranging from bill preparation, digitizing using tablet or imported images, takeoff from graphic images, earthworks calculations, electronic tendering, ball park estimates, feasibility estimates, cost planning, cost modeling, measurement estimating, price databases, carbon accounting and modeling, resource analysis, on to whole life costing, and so on (Hannus et al, 2003; ECTP, 2008).

2.3.6 Software by Trade

There are many IT and systems and software applications available to enhance and improve many activities and operations within the construction industry (Alsahli, 2011).

Measurement and Estimating Software

It is imperative for contractors and subcontractors to be on top of things with regards to Cost control and estimation, in order to achieve a successful project. Both contractors and subcontractors must first calculate reliable estimations, and then a precise project accounting and spending can be monitored (Alsahli, 2011). Numerous Quantity Surveying dedicated software have been produced in Britain from 1971 to date. This software have been modified and improved to current demands. Various QS practices have engaged the use of such software. They includes: Snape PLT/Vector software, Vector, RIPAC, CATO, WinQs, CatoPro, MasterBill, QS Elite, Snape Vector and FBS-Estimator, Esti-Mate and PRESTO, including several In-house software.

CATO software: CATO software is an acronym for computer coded taking off. Numerous versions of this software exist and they include CATO, CATO Pro, CATO Pro 98, and CATO Pro 2000. This software like most others supports the use of different SMM edition libraries. It objectives are to simplify through computerization the following QS activities: bill preparation, financial management, sensitization analysis, cost planning and estimating, and cash flow analysis.

Snape PLT is a QSDS developed by snape computers limited. It was a DOS based software and was designed to ease the preparation of BOQ. Experienced users who prepare valuation and final accounts can maneuver it. The software was the first developed by snape computers in the 70s and over the years have been modified as the need arises.

Vector Software: Snape computers Limited also developed Vector software. This software was developed to improve and add more power to the capabilities of the snape PLT. Differing versions of this software exist which includes vector for DOS and vector for windows. The vector for DOS is from version 1.X to 2.X. Like Snape PLT, Vector (initial version) was also designed to cater for bill preparation. However, latest versions like Vector for Windows incorporates different functions like preparation of valuations, final account, tender analysis, cash flow analysis, sensitivity analysis, and approximate estimates, as well as Bill preparation.

RIPAC software: this software was developed by construction software services partnership (CSSP) one of the world's leading software houses catering exclusively for construction industry. CSSP maintained that the software objective is to improve the efficiency and speed with which the following can be processed: bill preparation, estimating, tender appraisal, variations, re-measurement, interim payments, and final accounts.

Project Planning Software

Planning software are used by project and construction managers for scheduling and planning to monitor progress through the life cycle of a project from inception to post completion. Construction planning software such as Primavera and Microsoft Project Power are the most prominent used in devising and scheduling detailed construction tasks. Other Software known for internal process control and planning are: GEST, ICON and JobMaster.

Word Processing and Accounting Software

A vast quantity of data is produced and utilized within project stages, briefing, design, pre-construction, construction, and post-completion to demolition. Such data include but not limited to documents, correspondence, facsimiles, site surveys, design drawings, cost analyses and emails. Electronic Document Management Systems (EDMS) (Mocrosoft Word Office, Word Perfect); Web-based Project Management Systems (WBPMS) and other document-oriented applications are responsible for the creation and documentation of information during these stages.

Presentation Software

Microsoft PowerPoint and Adobe PageMaker are presentation applications utilized by industry professionals to condense large amounts of information in an articulate manner for presentation at meetings, for example, a clients briefing or update session.

Architectural/Engineering Design and Drawing Software

Computer Aided Design (CAD) softwares are mostly utilized by architects to support them in their design and drawings. CAD applications are of varyng types examples are: AutoCAD, ArchiCAD, MiniCAD and FastCAD (Alsahli, 2011). CorelDraw is another software for design and drawing.

2.3.7 *Creating Cost Certainty in 5D*

Certainty assurance is the most desired factor in construction to all parties involved in a project - in design, in time and, in cost. Achieving certainty in cost, design and construction is the desire of all professionals in the construction industry and more so the client's. This is because certainty in cost, design and construction reduces risk and creates better projects with sustainable profits. The 5D Cost creation has moved the industry close to this ultimate goal. Before 5D, we had 3D designs, which create certainty in projects, and then there was 4D, which adds the element of time to a model (Foster, 2008) and assembles the project delivery timeline and finally, the 5th Dimension, or 5D, which is all about cost (Brandtman, 2014). 5D has a number of advantages but not limited to integrating all disciplines in the industry, interrogating data to generate savings, and creating greater transparency and trust amongst all project partners. 5D emphasizes, the need for cost certainties before the point where costs increases with variation.

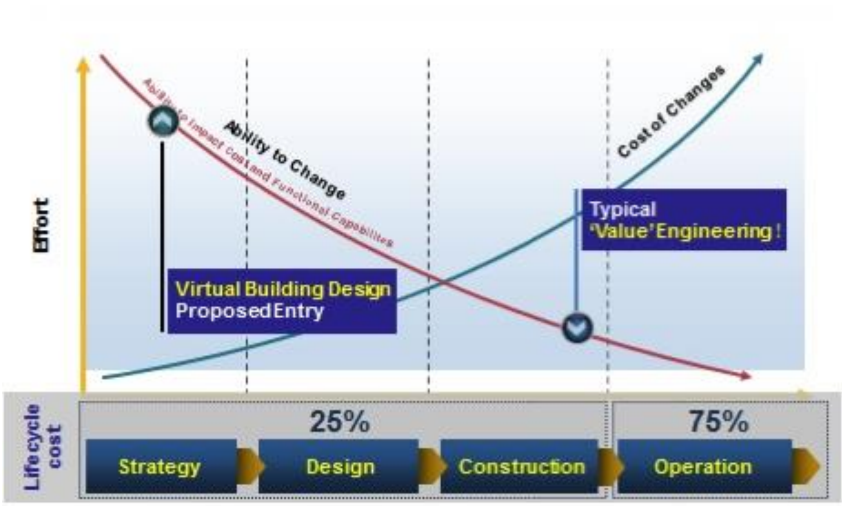


Figure 2.1: Influence vs. Cost Curve

2.4 The Benefits of IT to the Construction Industry

The more generic benefits of IT are that it: makes complex tasks easier to perform, improves productivity, facilitates decision making, saves time, saves cost, improves quality of work,, (Sun and Howard, 2003) enhances public image,. With respect to construction, Tucker et al, (1999) described the role of information technology in nine specific areas: tendering, design, communication, dissemination of information, process re-engineering, construction management, facilities management, performance benchmarking, simulation, visual graphics, and planning. Information Construction has also been classified according to six-project phases i.e. planning, construction management, procurement, design, construction execution and startup/operations/maintenance (Appendix 1). And within each phase, IT plays specific roles to make the process efficient and successful (O'Connor and Yang (2004).

However, the benefits extend beyond the project and onto the stakeholders as well. According to Hannus et al, (2003), ICT places the building owners and users, designers, contractors, suppliers, and ICT vendors a WIN-WIN situation.

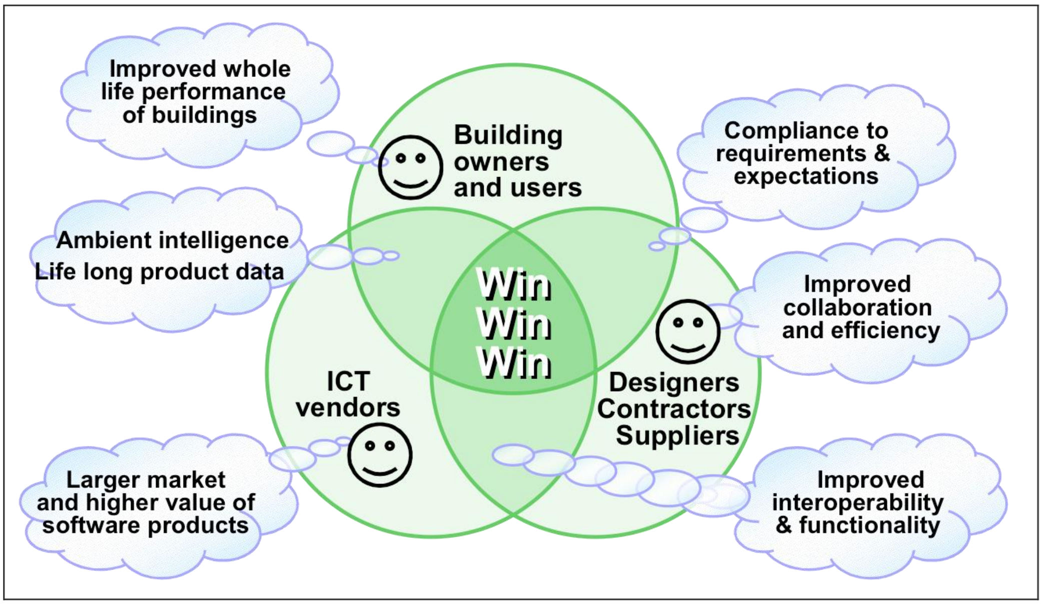
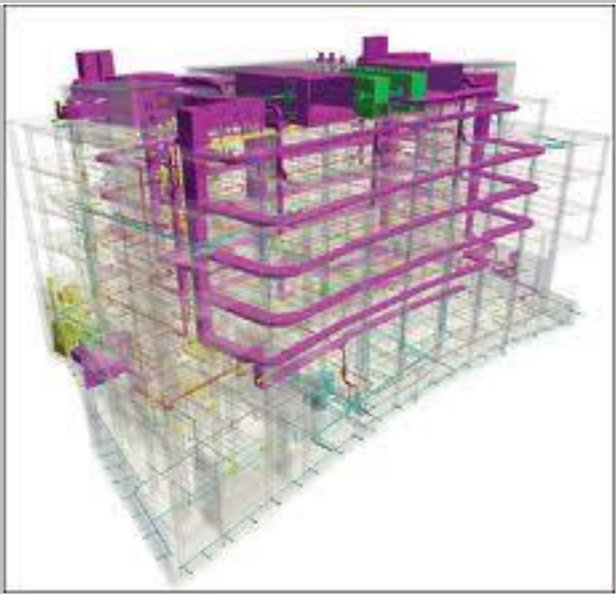
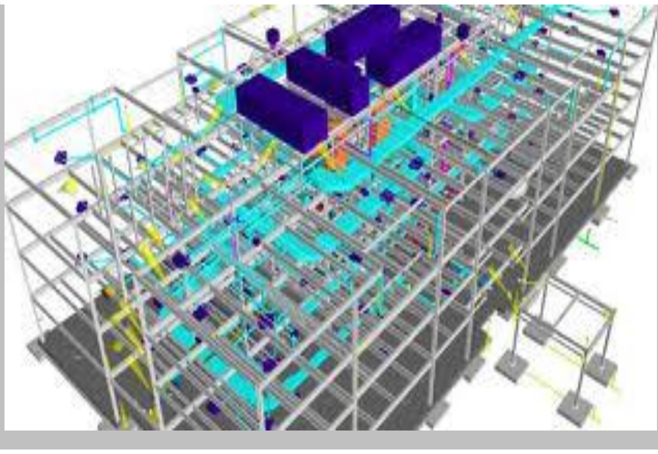


Figure 2.2: Benefits of Key Stakeholders (Hannus et al., 2003)

Table 2.1: Stakeholder benefits

Stakeholders	Visual
A client walking through a realistic model of his/her building before a sod is turned on site	
Members of the community are able to look at options for a school and vote on their preferred option	
The Planning Authority can examine sun shadow patterns in reviewing a Building Application	

A subcontractor is able to examine his work in relation to other subcontractors on the project



Investments in IT are often argued with the benefits it can bring. But it is not easy to measure such benefits (Lautanala et al, 2013). With the advent of new state of the art networking, information technologies, and the Internet there has been a major shift in how business is conducted in many industries. Sarshar (2000) and ECTP (2008) argues that the construction industry is yet to realize a positive shift partly due to under-investment in IT developments, and the complex nature of information formats and the supply chain arrangements within the industry. Lautanala et al (2013) undertook a research in Finland to analyze the maturity of capability of the use of IT in the Finish construction industry and documented its respective benefits and cost. At the end of their research, they found that an increase of investment in IT brought about proportionate increase in benefits over time. They made use of a metrics they called the IT maturity analysis methodology to achieve their objective. There are six criteria that are assessed.

	Aspect	Max points	%	points
Enablers	Management commitment	200		
	Processes	150		
	IT skills	150		
Technologies	Inform. structures	250		
	Infrastructure	100		
	Software	150		
	Total	1000		

Figure 2.3: Scoring table (Lautanala et al., 2003)

Information structures	Weight 250

Levels	Description	%
Level 1	Paper documents	0-10
Level 2	Digital data, no formal classification, paper based data exchange	10-30
Level 3	Formal classification, internal integration with main applications	30-60
Level 4	Formal classification, electronic data exchange	60-80
Level 5	Object based data exchange, interoperability	80-100

Figure 2.4: Simplified description of the levels for information structures criterion

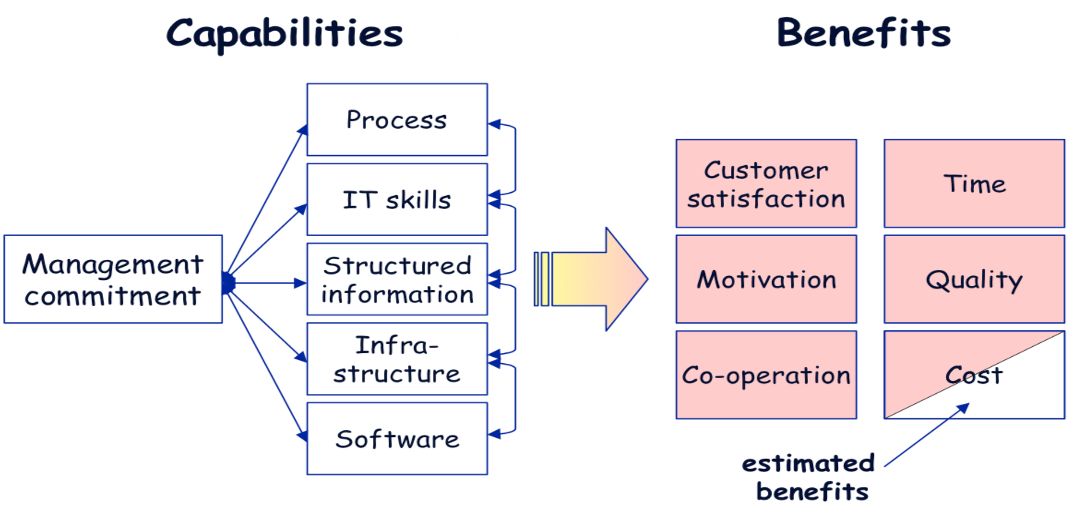


Figure 2.5: Estimated Benefits of IT (Lautanala et al., 2013)

2.5 Challenges

2.5.1 Justification Of Cost And Maintenance Of The IT Systems

The justification of IT investments is one of the many challenges managers of construction companies are confronted with today (Love and Irani, 2001). According to Love and Irani (2001), traditional appraisal techniques used by managers to justify investment in IT lack precision and do not capture in full the ‘hidden’ or indirect costs surrounding IT. They assert that the ‘indirect’ costs (human and organizational) of IT is sometimes four times greater than its 'direct' IT cost component. Examples of human indirect costs as listed by Love and Irani (2001) are: "management/staff resource, management time, cost of ownership: system support, management effort and dedication, employee time, employee training, employee motivation, changes in salaries, and staff turnover; while organizational indirect costs" are; productivity losses, strain on resources, organizational re-structuring and business process re-engineering. The consequences of ignoring 'indirect' costs can detrimental for construction firms. Hence, there is a need for management to find more accurate ways of determining the 'true' cost of IT investments. Love and Irani (2001) proposed Taxonomy of investment appraisal that will aid construction firms to measure to reasonable certainty the cost of their investment in IT.

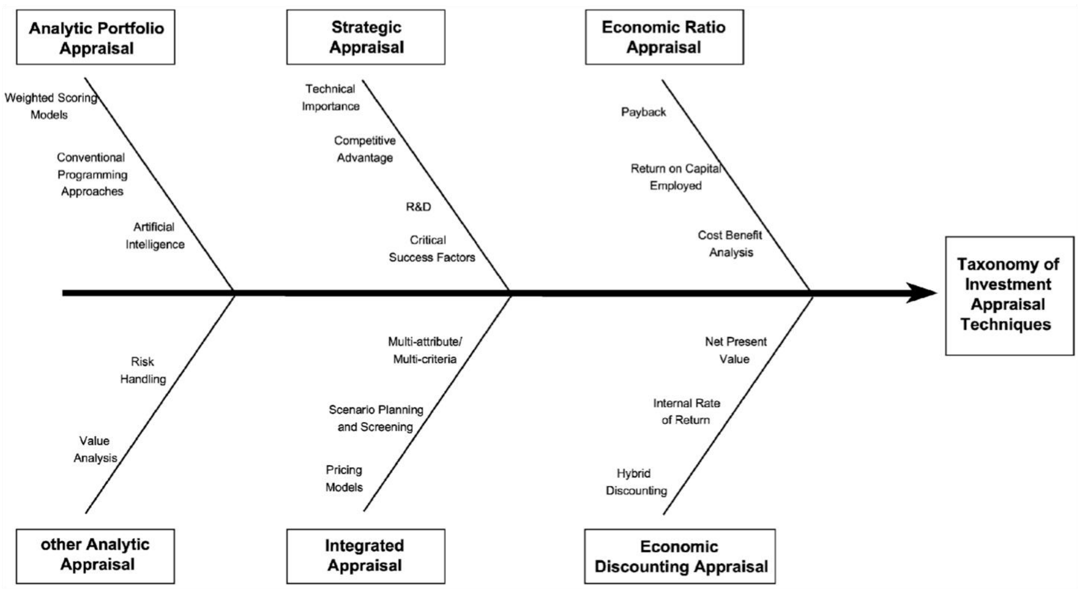


Figure 2.6: Taxonomy of Investment appraisal techniques (Love and Irani, 2001)

2.5.2 Business process change

It was reported; by Sarshar and Connolly (2013) that several construction companies faced critical challenges in implementing IT systems. This is because IT adoption requires some business process changes and these changes, sometimes, do lead to a transformation of the entire process. For example, the traditional "paper based" approach of the industry might prove difficult to overcome.

2.5.3 Degree of effectiveness of IT adoption

This degree of effectiveness is most of the time a subjective matter as different people enjoy differing levels of values from IT adoption. The true degree of effectiveness of the proposed IT system might not be certain (Love and Irani, 2001).

2.5.4 Weaknesses of Information Technology in Construction

The ROADCON project listed a number of barriers to the adoption of ICT solutions in the construction industry (Hannus et al, 2003). These barriers documented by ROADCON were industry-wide problems and did not do much justice to construction firms' specific barriers to adopting IT. However, Love and Irani (2001) produced a collection of factors impacting the adoption of IT by construction firms. They are: set-up cost, system malfunctions, data entry, cyber cranks, security and privacy, and loss of human contact.

Table 2.2: Factors impacting the adoption of IT

Authors	Factors
Hannus et al. (2003)	• There is no global actor to enforce the use of standards and ICT on projects. • Lack of a legal framework to enforce and regulate the use of ICT. • General end-users (practitioners) ICT maturity and preparedness for change. There is a general need for cultural change in the Construction industry. While the potential gains anticipated through proper adoption of ICT are desired, the necessary changes are resisted. • Lack of long-term partnering between actors that could result in proper ICT strategy adoption and ICT infrastructure adoption. • Lack of IT strategy in most Construction organizations (composed of a majority of SMEs with less than 20 employees). • Robustness, flexibility and scalability of existing ICT solutions (most of which are non- construction specific). • Interoperability problems due to the complexity and diversity of the Design and Construction process that requires multi-dimensional solutions highly likely to involve ICT solution from several vendors. • ICT solutions tend to be expensive with low immediate return on investment (the industry is mainly project orientated). Licencing conditions are not feasible for multi-participant projects. • Lack of adapted solutions for site-based work (high performance nomadic and mobile solutions). • Lack of visibility and convergence between numerous research and development initiatives, compounded with national issues and interests.
Love and Irani (2001)	• Organisational risk, definition uncertainty, technical uncertainty, IS infrastructure risk • Cultural, technological, educational, communication, and business. • Project size, experience with technology, project structure. • Governance, project management market/economic need, learning ability, size, complexity, and long timespan. • Techno-were: devices and tools, orga-were: technology institutions, info-were: know-how and technical/technological knowledge, and human-were: human skills expertise and person-embodied technology. • IT culture gap, the strategic IT challenge, the traditional delivery approach, emphasis on output rather that outcome. • Motivation breakdowns, ability breakdowns, execution breakdowns • Management's motivation towards the short-term, limitations and generic nature of traditional appraisal techniques, changing portfolio of benefits and costs, and inadequate/outdated cost accounting systems

Table 2.2 captures a number of barriers to adopting IT of which would be interesting to see which ones are dominant in the Jordanian context. However, from the literature, and the researcher's knowledge of the Jordanian construction context, a number of barriers do standout. Barriers such as; interoperability and cultural problems would definitely be pertinent in the Jordanian context.

2.6 ICT Opportunities and Trend

The construction industry perceives ICT as an enabler that allows industry to achieve desirable benefits via its business processes. ICT has changed the dynamics of business processes and activities across all industries. These changes have also been catalyzed by the evolving ICT opportunities. Recent has highlighted the prospects for its widespread penetration of. The major findings of research by ROADCON on the future of ICT in the construction industry are:

2.6.1 Semantic Web Opportunity

Semantic Web Opportunities refers to the representation of data on the internet is a well-defined, meaningful way to better enable computers, and people to work in cooperation. The architects, engineers and quantity surveys lead the industry in the application of IT in their different fields and all use the Internet for collaboration.

2.6.2 Web Services Opportunity

Web Services offer a web-based way of enhancing communication between project participants over the web (Hannus et al, 2003). These functions allow construction professionals to publish any application over the Internet for end users, in this case. They provide the data and the application generate the information they need.

2.6.3 IAI IFC Opportunity

The International Alliance for Interoperability (IAI) are sets of classes run in different countries including: United State, UK, Germany, French, Iberia, Japan, Singapore, Korea and Australia. The mission of the IAI is: “To provide a universal basis for process improvement and information sharing in the construction and facilities management industries, using Industry Foundation Classes (IFCs)”.

Developing countries’ use of computers in the construction industry is still at the rudimentary stage but it is fast growing. In spite of the current rudimentary state of computer use in these developing countries, most of the professionals are very optimistic about the future of ICT use in their respective fields (Oladapo, 2006).

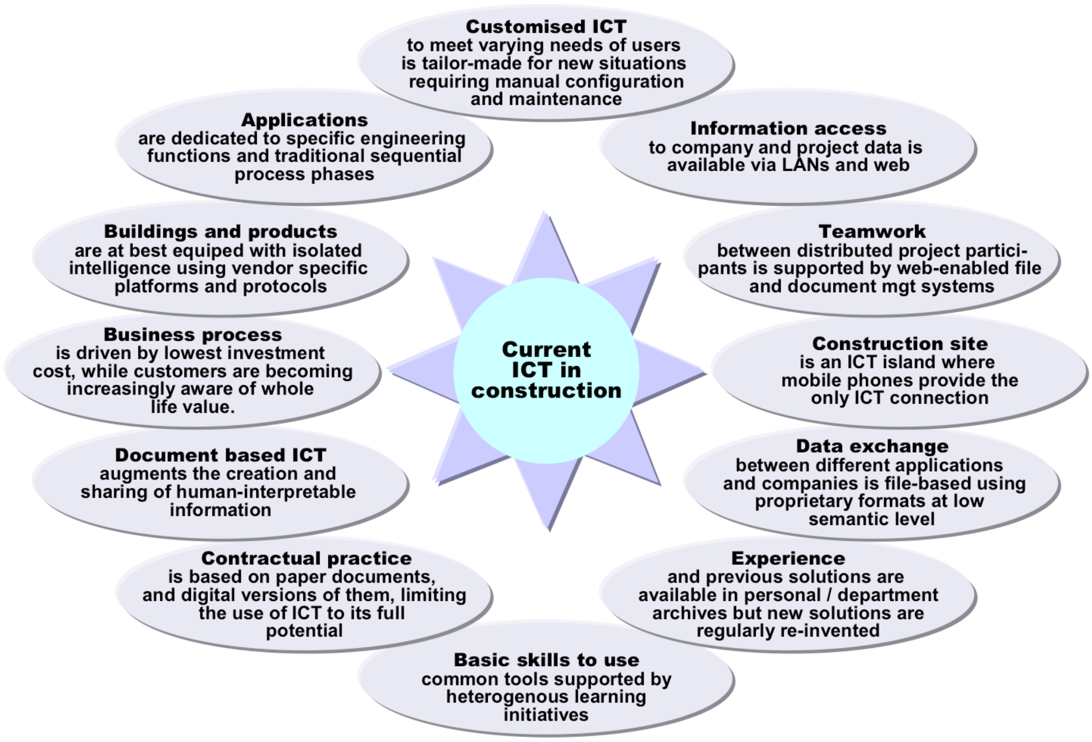


Figure 2.7: Current state of the construction industry (Hannus et al, 2003)

2.7 Application Of IT

There are three main areas in which construction professionals are encouraged to apply IT; Project Database, Communication Networks and E-commerce and electronic procurement.

2.7.1 Project Database

This is a database that contains all of the project information, from design, finance to project management data. All project participants are privy to this central pool of information (Asia-Pacific Conference on Communications (APCC), 2013). An example can be seen in Appendix 2.

2.7.2 Communication Networks

Most countries and organizations are investigating the use of tools that enable collaboration between authorities, designers, suppliers, clients, and the community through a web browser popularly known as Cloud Computing. Here, all project participants are able to access all project documents, upload and download documents and also communicate with each other in a virtual environment mainly the Internet.

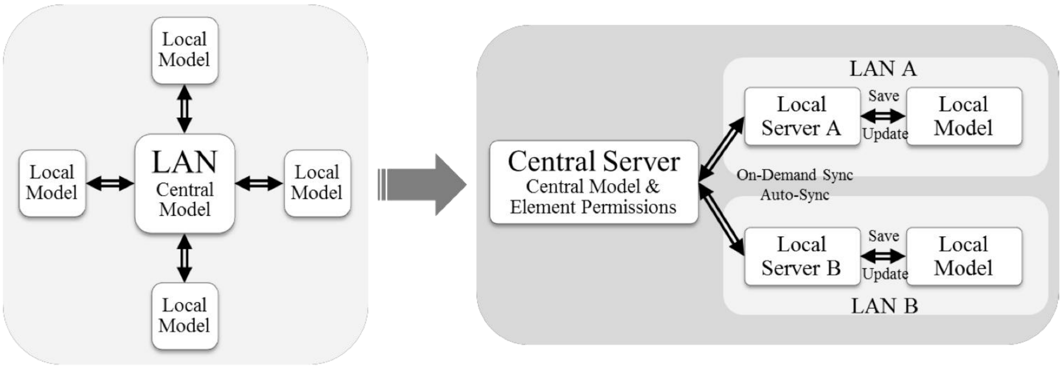


Figure 2.8: File-based work sharing to server-based collaboration (Khemlani, 2010)

2.7.3 Procurement

There is a call on the construction industry to implement electronic marketplaces for procurement of their goods and services. Buyers and sellers can interact in this marketplace. For example, public and private buyers can procure services from contracted suppliers, and preferred suppliers. Buyers can place and track orders, make electronic payments and monitor improvements (APCC, 2013). Electronic procurement is now being utilized by many governments around the world for transparency and accountability. Business transactions, management of supply chains, internal and external communication and alliances are other main activities electronic commerce can be used for.

2.8 Legal Admissibility

Another great criticism of IT is the legal admissibility of document as evidence in the court of law. Generated or stored electronic information is scrutinized when presented as evidence in a court of law because it is difficult to prove integrity in a court of law. And that's why paper is still favored when it comes to contract documentation.

2.9 Implementation of IT

Information technology is a necessary effective tool for organizations with regards to gaining competitive advantage in today's global business environment. According to Monk and Wagner, (2009), the fundamental requirement for Information Technology in organizations is to process, manage, and share a huge amount of data and activity efficiently and effectively between customers, suppliers and the internal functional departments. This is achieved via effective implementation plans for information systems.

According to Trivedi (2012), when choosing to implement IT, there needs to be focus around the creation and distribution of project based information and documentation. Trevedi described seven key stages in preparing IT implementation;

2.9.1 Setting goals and objectives

Assessing the needs of the organization and the needs of the individuals who will be using the implemented system and also how it will be matched with the existing system to aid co-ordination of activities and processes between systems.

2.9.2 Review current document and information management processes

It is imperative that the implemented system fit within the core values of the company and hence produces the expected or desired result. To make this happen, it is important to evaluate current working processes using process-mapping method to determine the need and value of the IT system to be implemented. Needless to say the waste that would be accrued if this is not done right.

2.9.3 Understanding the information and documentation exchanged

Great effort should be made to understand the whole process of document creation then match exiting processes to the working processes of the IT system.

2.9.4 Cost justification of IT

The issue of IT implementation cost and ROI can be a major barrier in the adoption of any IT technology. Again this is where ‘value’ comes in. The company should assess the value of the IT system not only on profitability in terms of cash but also the ROI on intangible benefits such as walk force motivation, company atmosphere, company image etc.

2.9.5 IT infrastructure required

After the assessment of the need, it is important to choose the right platform on which the system would be installed.

2.9.6 Formulating specific requirements

This involves writing a specification with regards to the features and functions that the system should have. They are performance, implementation, operational, and quality requirements.

2.9.7 Implementation options

It is important to assess all possible options of achieving the set value and make a decision on which option to go with as choosing the right option would mean better value and cost savings.

However, a critical success factor for any organization to successfully implement IT in its processes is its ability to manage the appropriate organizational changes and the redesign of its processes.

2.10 Readiness Gap

Saleh and Alshawi, (2005) defined the “Readiness gap” as “the difference between the current and expected organizational capabilities to plan, implement, operate and maintain IS successfully.” While it is important for organizations to successfully implement IT, monitor and measure the impact of the initiative on the company, it equally important to measure the ‘readiness’ of the organization before implementing the IT project otherwise, investments could be wasted if the company is not ready. Saleh and Alshawi, (2005) developed a holistic measurement model, for managers to determine their organization’s state of readiness prior to IS investment. This model focuses on four organizational elements: People; Processes; IT infrastructure; and Work environment.

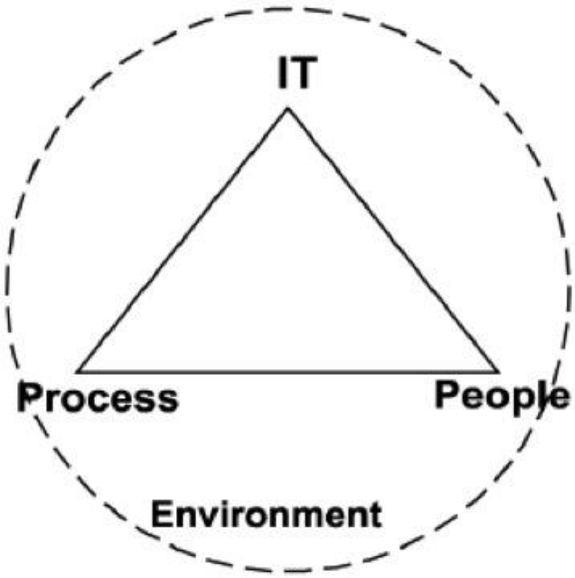


Figure 2.9: Key organizational elements (Saleh and Alshawi, 2005)

Table 2.3: The Key elements of the GPIS model

Key Elements	Attributes	Comments
IT infrastructure	System	IT physical assets (hardware, networks) and their related software
People	Head of IT/IS	Represented by the authority and role of the "Head of the IS/IT" department
	Staff	Staff of the organization who are involved in the implementation, maintenance and use of the proposed IS
	Skills	Skills available/required to effectively implement the IS in the organization
Process	Business processes	Represented by the process "Practices" within the organization
Work environment	Culture	The cultural style of the organization
	Leadership	Characterization of managers' behavior in achieving the organization goals
	Structure	Characterization of organizations' structural chart (i.e. functional, centralized/decentralized, etc.)

Source: Saleh and Alshawi, (2005)

The model serves as a tool that can be used by organization's desiring to implement IT. The way it works is that there are six maturity levels within the IS/IT model where each element has certain attributes (Saleh and Alshawi, 2005). Now, if the organization's state of readiness, based on the attribute of the four key elements, match the overall description of the corresponding attributes of the model, then that is the level the organization falls into. Saleh and Alshawi (2005) defined the levels as "appropriate readiness stages required for the organization to ascertain before the implementation of that specific IS project, where, the difference between the current organizational situation and the required/target situation in terms of all four key elements is the readiness gap."

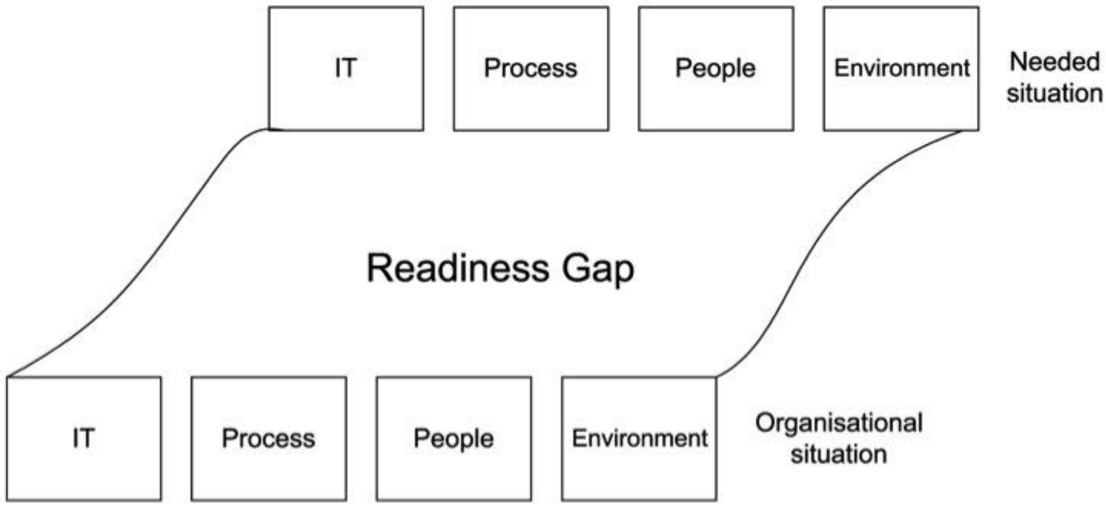


Figure 2.10: Readiness Gap (Saleh and Alshawi, 2005)

2.11 IT Benefits

According to Andresen et al, (2000), the lack of investment IT in the construction sector has been the barrier to the more effective exploitation and application of IT. And this low level of investment is because construction business managers do not believe they can benefits much from IT investment. This perception obviously affects the pace of development of the industry compared to others, like manufacturing. Therefore, this translates into missed business opportunities as the industry refuses to innovate. Findings by Attar and Sweis, (2010) suggest that technology improvements would increase employee job satisfaction in construction companies. The growth of the construction industry before the recession has encouraged the deployment of information technology to the industry, which in turn has improved productivity (El-Mashaleh, 2007). This low level of investment is not only an obstacle to productivity in construction, but also a barrier to effective adoption and application of IT in the industry. But there are a vast number of benefits of IT in construction only if it was easily comprehensible to the industry professionals. Andresen et al, (2000) produced a list of benefits that arise from IT investment, which they categorized, into three groups:

Table 2.4: Typical IT Benefits

Construction Business Process	Typical Efficiency Benefits	Typical Effectiveness Benefits	Typical Performance Benefits
Business Planning	Reduced planning times	Increased Sales Minimizing business risk Strategic competitive advantage Increased business flexibility Maintaining competitive capacity Reduced risk in new business ventures	Providing space and capacity for business growth Safeguarding future flexibility Overcoming obsolescence Increasing responsiveness of senior management to business problems
Marketing	Reduced marketing costs Ability to handle more enquiries	Improved company image Generating new business Increased market share	Improved strategic intelligence for new markets Improved public relations targeting and delivery
Information Management	Reduced communications costs Reduced paperwork Reduced IT costs	Easier international links Fewer information bottlenecks Improved quality of output Sustaining market share	Improving external access to stock levels and price information More effective identification and assessment of new suppliers
Procurement	Reduced storage requirements Reduced transaction times Reduced transaction costs Improved delivery scheduling	Maintaining competitive capacity Faster response to supplier quotations Ability to provide instant price quotations to clients	Improving external access to stock levels and price information More effective identification and assessment of new suppliers
Finance	Faster invoicing Reduced transaction costs	Minimizing business risk Better control of cash flow Reduced lead times for financial reporting	Improved/new transaction methods Improved forecasting and control Greater integration with other functions
Client Management	Quicker response to client enquiries Quicker response on current project progress	Improved quality of output Faster delivery of services Improved focus on client requirements	Improved information exchange with clients Increased client satisfaction Strategic competitive advantage
Design	Reduced lead times for design Reduced rework Increased information exchange	Improved quality of output Reduced technology risks More responsive ability to arrange meetings Increased speed of new design development	Improved idea sharing among project teams Improved integration
Construction	Reduced construction times Improved productivity Reduced waste	Improved quality of output Reduced technology risks Ability to exchange data	Improved idea sharing among project teams Improved integration Improved project relationships with strategic partners
Operation and Maintenance	Reduced operating costs Quicker access to operation and maintenance data	Improved quality of output Ability to refer back to data	Improved capture of design and construction decisions Improved full life-cycle information management
Human Resources	Reduced staff requirement Reduced training requirements	Improved record of staff skills Improved ability to select appropriate team members	More effective assembly of project teams Enabling of cross-functional teams Improved human relations Regularized working arrangements

Source: Saleh and Alshawi (2005)

2.12 Measurement of IT Benefits

A framework proposed by Andresen et al, (2000) for the evaluation of IT investment in construction gives eight stages that are integrated and each stage is dependent on the completion of the stages that came before it. The first stage involves “identifying the business case for a new IT innovation.” The “so what” question is answered at this stage. It may also be called the “why” stage – why an IT investment is needed? The second stage involves “checking the fit between the proposed innovation and the company’s business and information strategies.” The nest stage is to assign responsibility for the benefits to be realized through proactive action and prevention of any hindrances or barriers to the realization of the benefits. An appropriate appraisal technique is then necessary to allow predicted benefits to be calculated and documented in advance. Such documentation acts as benchmark and enables for any subsequently realized benefits could be measured (Andresen et al, 2000).

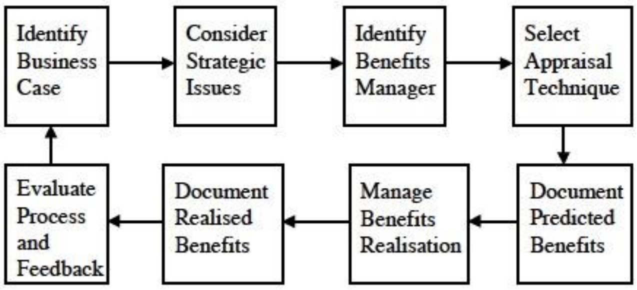


Figure 2.11: The IT Benefits measurement process (Andresen et al, 2000).

2.13 IT Investment

It is imperative to classify IT investments in order to accurately calculate the return on investments. Pena-Mora et al (1999) classified IT investments into five categories: hardware, software, training, support and personnel. They also asserted that these categories would be weighted differently depending on the situation. In their case studies, Pena-Mora et al (1999) found ‘personnel costs’ to be more than 60% of the total IT investment. To illustrate this point, Andresen et al, (2000) gave an example of Project Management software that is being introduced into a company. While the software and hardware are cost factors, staff training often costs more than the system. However, the benefits of the training generally outweigh the costs. Personnel costs may be comprised of the users of the technology, semi-trained professionals who are involved in administration, pre-trained experts, and expert consultants to champion the implementation process. Therefore, the uniqueness of the IT implementation will determine the mix of the team. Some small implementation may not require pre-trained or semi-trained personnel. It may just be a direct link between the IT consultant and the untrained end user.

Value added IT implementation is primarily evident in three places: increased productivity, increased quality, and risk reduction (Venkatraman, 1997). These benefits are usually seen and felt at the latter phases of the project. However, at the deployment phase of the project, IT investment can have a negative return, and these can be felt also throughout the development phase. Sometimes these losses could be significant. It is also possible to lose trained staff from the project after the investment. How this is perceived depends on the overall objective of the project. It could be perceived as a direct loss to the project. That is, after spending so much on the training of the particular staff, he/she is lost to their respective parent company. Or it could be perceived as in-direct benefit to the project participant's parent company. This is also known as the "Spill over" effect. Indirect aspects of IT investment, which may have, both benefit and loss angles are: trained staff, employee turnover, hardware, software, IT methodologies developed over the duration of the project, and knowledge management.

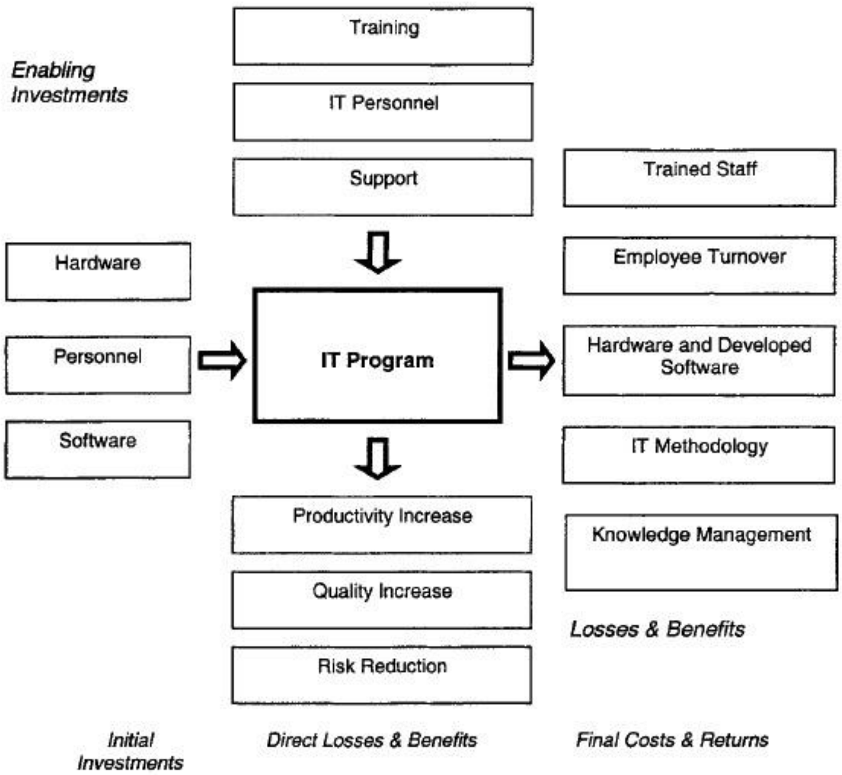


Figure 2.12: IT Program inputs and outputs (Pena-Mora et al, 1997)

2.14 IT Implementation Frameworks In Construction

According to Monk and Wagner (2009), information systems are the tools needed for the effective & efficient sharing and management of data and activities between suppliers, customers and internal functional department. There are a number of methods and techniques designed to implement IT successfully in construction. However, studies have also shown that not all companies that implement IT successfully reap immediate benefits as it may take a long time for some companies to accumulate benefits (Stewart and Mahammed, 2003; Talari et al, 2007)

Pena-Mora et al, (1999) were concerned with the issue whether large-scale Architectural Engineering and Construction (AEC) organization were receiving adequate return for their investments in information technology. Based on an adapted framework by Weber (1997), Pena-Mora et al, (1999) proposed a strategic planning framework "based on four essential steps for maximizing the value of investments in strategic capabilities." These steps include environmental scanning, IT diffusion analysis, IT investment modeling and internal scrutiny. The first step involves understanding the internal businesses of the AEC projects as well as the external dynamics of the overall economic environment. The second step in the strategic-planning framework is the analysis of the relevant processes and functions within large AEC projects. The third step consists of developing an IT investment model that is then integrated into the overall strategic planning framework (Pena-Mora et al, 1999).

Although the framework seems thorough, it is partly ambiguous and could be simplified. Some steps could be absorbed into others.

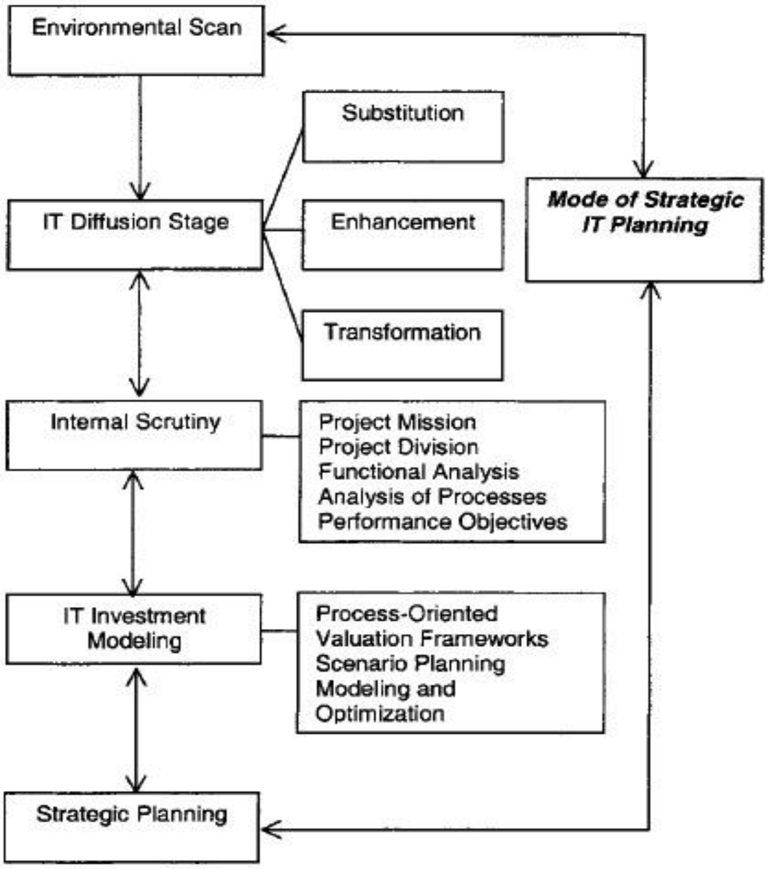


Figure 2.13: IT Strategic Planning Framework (Weber, 1997)

Rodney Stewart and his colleagues proposed another IT strategic implementation framework in 2002. The case study was a multi-national construction organization looking to implement PMES for the project management of telecommunications infrastructure in Australia. This framework contains six steps that supports the organizational planning and helps manage the change across people, structure and processes. They are: SWOT factors, SWOT and AHP analysis, IT diffusion strategy (story telling), implementation strategy and operational strategy, (Action Plan).

According to Stewart et al, (2002) central to the framework is the “scale of values” of the corporate management of the organization such as organizational objectives, perceptions, beliefs, challenges etc. The activity of SWOT is important because it defines the way the organization is managed and the criteria under which strategies are evaluated. Here, the IT team would need to examine weaknesses and the internal strengths as well as external opportunities and their threats, then, go on to do a SWOT analysis. The next step is then the IT/IS diffusion strategy also known as “Story telling". Here, the information sought and gathered in the previous steps is carefully analyzed, and recommendations reviewed by all stakeholders to the IT implementation. To establish the fourth step, an operational strategy is developed. After the operational strategy methodology, the implementation strategy is then formulated. This step is the most important as it *"requires the definition of actions, the evaluation of budgetary requirements, the study of time and organizational constraints, the elaboration of human resource issues, management and plan coordination, and migration, diffusion, and risk assessments"* (Stewart et al, 2002).

Table 2.5: Possible SWOT Factors

SWOT Groups	SWOT Factors
Strengths	• Skilled/experienced staff, workforce • Market leader in the provision of operations and maintenance and facilities management services • Top project managers with high commitment to innovative IT/IS • High value of projects, increases IT/IS budgets • Extensive IT/IS support • Diversified company • Strong business development team
Weaknesses	• User resistance to change • IT/IS staff turnover: quality staff being poached by other companies • External contractors having low IT/IS capability • Changing technologies requiring staff to be retrained • Short construction timeframes preventing IT/IS training • Poor relationship between divisions of organization • Lack of corporate management direction/orientation
Opportunities	• Facilitates international strategic alliances • International access to project information • Improved communication and coordination between project participants/divisions/managers • Ability to attract more local and international projects • Electronic storage of project information from conception to completion • Improve the document control process which reduces administration costs • IT/IS-induced rapid mobilization of workforce on project • Paperless office reducing administrative overheads
Threats	• Very competitive industry • Possible financial losses if IT/IS project is mismanaged • Depressed economy causing IT/IS budget cuts • Increasing hardware/software costs • IT/IS budget blow-out • Negative image created if IT/IS fails to deliver improved construction objectives.

Source: Stewart et al, (2002)

Table 2.6: Risk factors and coping strategies

Risk factors	Process gap	Outcome gap	Coping strategies
Possible financial losses if IT/IS is mismanaged	Poor management of IT/IS on project	• Management decides not to use IT/IS on future projects • Increased project overhead costs • Resort to traditional document management procedures	• Dedicated IT/IS professionals on project • Heighten status of IT/IS professional • Development of an extensive IT/IS implementation strategy at project conception
IT/IS budget blow-out on project	Poor management of IT/IS budget on the project	• Management decides not to use IT/IS on future projects • Increased project overhead costs • Negative sentiment towards technology by management	• Management decides not to use IT/IS on future projects • Increased project overhead costs • Negative sentiment towards technology by management
Short construction timeframes preventing IT/IS training	Project managers ignoring IT/IS training commitments to focus on short term project issues	• Lost opportunities for reengineering tasks • Poor utilization of proposed IT/IS • Resort to traditional document management procedures	• Dedicated IT/IS professionals on project • Heighten status of IT/IS professional • Develop an extensive IT/IS training program at project conception • Integrate IT/IS training program with construction program
User resistance to IT/IS	IT/IS implementation strategy resisted by project participants	• Lost opportunities for reengineering tasks • Poor utilization of proposed IT/IS • Resort to traditional document management procedures	• Awareness sessions for project participants • Extensive IT/IS training programs for users • Accessible IT/IS support to users • Dedicated IT/IS professionals on project
Lack of resource to implement IT/IS	Limited resources or resources do not have skills for implementation	• Lost opportunities for reengineering tasks • Poor utilization of proposed IT/IS • Resort to traditional document management procedures	• Heighten status of IT professional • Assigning responsibilities to strategic plan • Dedicated IT professionals on project • IT contract staff to fill gaps where necessary

Source: Stewart et al, (2002)

The last step is the monitoring plan. Having a plan does not guarantee success. Things have to be tweaked, adjusted and perhaps changed depending on the circumstances and unforeseen events. Also, humans are rational beings and therefore feedback is inevitable which then helps the IT manager to adjust the implementation plan accordingly. According Stewart et al (2002) "applying the measurement concept to construction is not as straightforward as it is for the manufacturing sector where a clear "bottom line" exists." In order to assess performance improvement, the IT management must select easily definable and limited number of Key Performance Indicators (KPI).

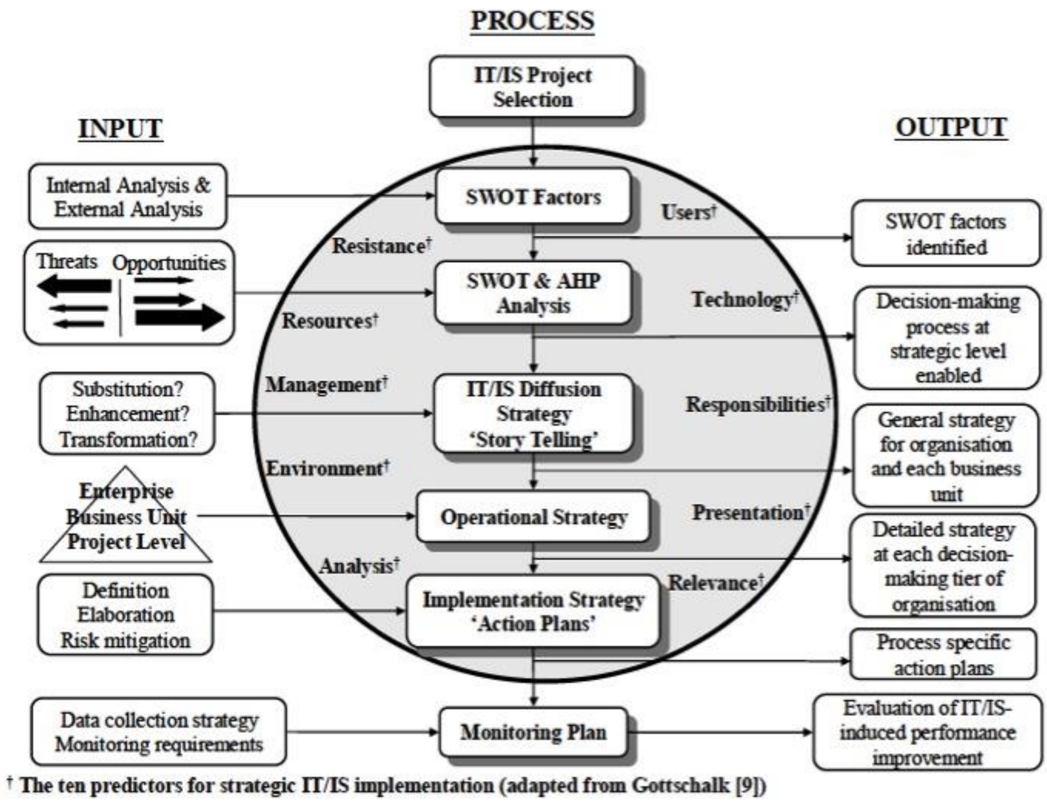


Figure 2.14: Strategic IT/IS implementation framework (Stewart et al, 2002)

Similarly, Alsahli (2011) developed a framework for the successful implementation of IT in the Saudi Arabian Construction industry. The framework takes into account factors such as people, culture, firm's abilities, resources, strategies, and technological level. The proposed framework focuses on five different elements in order to improve IT implementation. They are: readiness gap, resources, change management, IT alignment with the business, and IT implementation strategy. Alsahli (2011) asserts that managing the five elements require involvement right from operational level up to the executive level, with managerial level in-between. Each element of the framework begins with an investigation and identification of possible gaps that could adversely affects IT implementation, followed by actions to address identified gaps, which will enable the company to progress to the next element. E-readiness emphasis the need for early identification of organizational readiness for IT implementation which then facilitate better planning and outcomes for the required actions in each stage of the framework. The assessment of readiness must cover both structural business readiness, and readiness of the company components such as people's readiness culture, etc. This assessment then forms a basis for planning the necessary elements of the frameworks; including identifying and selecting the most appropriate resources for the IT implementation. It is imperative that this is thorough because a poor understanding of people's readiness could lead to difficulties in controlling people's resistance to IT implementation.

A point of emphasis by Alsahli (2011) is the alignment of the IT strategy with the company business strategy. It would be of no use if the IT strategy does not fit well with the business strategy. In most cases this usually costs a company a great deal and can even cause the demise of the company. An understanding of the organizational capabilities can help the management fill the alignment gaps to achieve the required business objective. Lastly, the IT implementation required company management and board to look at the developed IT alignment with business and develop business competencies to plan successfully for the most appropriate IT strategy that can fit the company's vision and strategic plan.

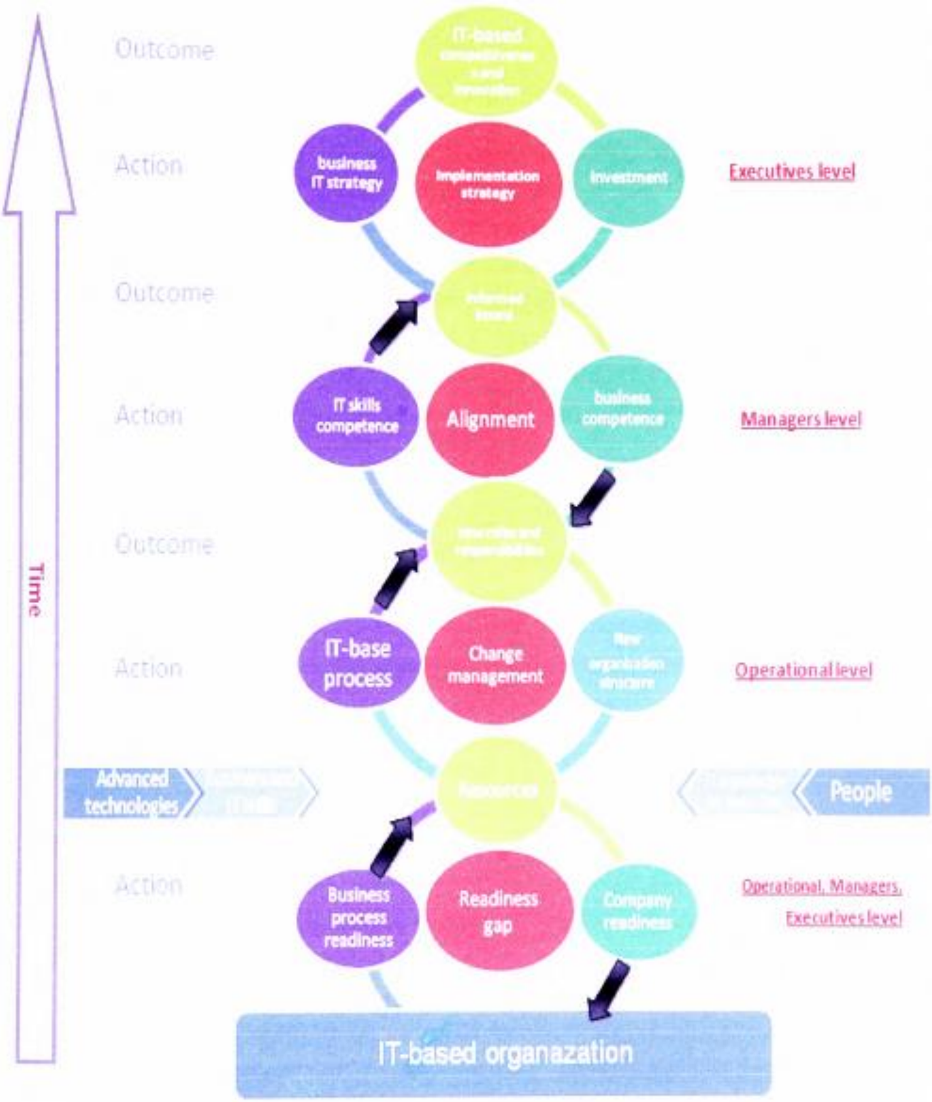


Figure 2.15: A framework for successful implementation of IT within the construction industry (Alsahli, 2011)

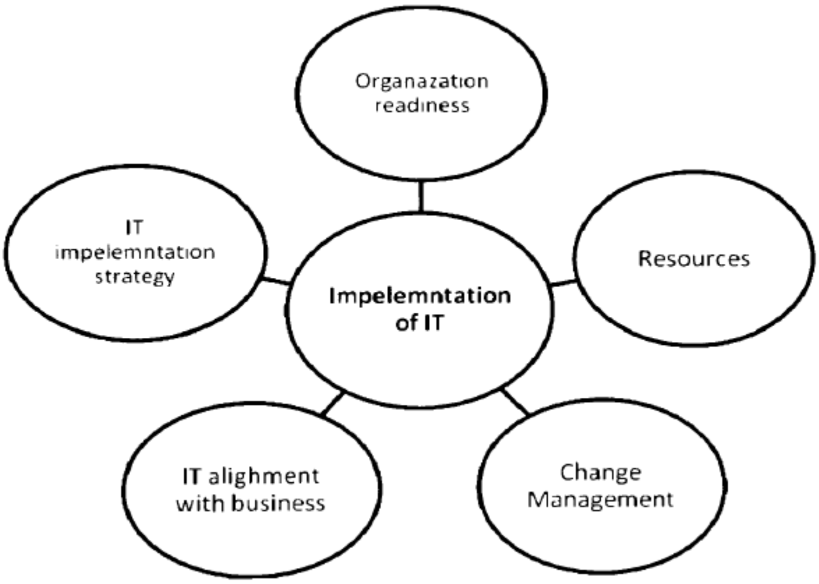


Figure 2.16: IT Implementation framework elements (Alsahli, 2011)

2.15 Barriers to Successful IT Implementation

Several factors can cause the failure of an IT implementation. These factors could be internal or external to the organisation. They are, but not, limited to the following: business process, change management, management structure, culture and people, and limited availability of resources (Stewart et al, 2002; Alshawi, 2007). Stewart and Mohammed (2003) also found 12 barriers to implementing IT in the construction industry. They are the following (ranked in order of significance).

- Relatively low level of IT awareness (exposure to IT)
- High cost associated with IT applications
- Poor quality and/or quantity of telecommunications infrastructure
- Lack of personnel skilled in the management, use and support of IT
- Cost-driven and/or ill-informed client organizations
- Poor compatibility between different applications/organizations
- Lack of leadership by major client organizations
- Low profit margins
- Fragmented nature of the industry
- Cyclical variations in workload activity levels
- High rate of computer illiteracy amongst employees
- Web-based information primarily in English

Table 2.7: Industry Level Barriers

Barriers	Causes
Fragmented nature of industry	• Numerous disciplines of specialists • Limited centralization of expertise
Relationship-related implementation barriers	• Industry is reluctant to adopt partnering or alliance based relationships, which promote communication
Cyclical variations in workload activity levels	• Government funding fluctuations in budgeting for public infrastructure • Cyclical demand for property and real estate
Relatively low level of IT awareness	• Companies want to safeguard their competitive advantage • Poor interoperability between IT applications of different companies, especially small and medium organizations.

	• Engineering and construction management degrees have limited IT component
Lack of leadership by major client organizations	• Numerous client organizations which expect varying sophisticated information
Low profit margins	• Competitive industry • Traditional processes inefficient • Client organizations working on tight budgets • Lowest price culture to tendering
Lack of skilled personnel in IT	• Lack of IT training courses available • Limited available people with necessary experience
Poor quality and/or quantity of telecommunications infrastructure	• Lack of government spending on telecommunications infrastructure
Web-based information primarily in English	• Western culture leading world markets • English accepted as the universal language
High rate of computer illiteracy amongst employees	• Limited training provided by employers • Lack of exposure to IT

Source: Stewart and Mohammed (2002)

2.16 The Future of ICT in Construction

Erdogan et al, (2009) proposed an ICT vision for the year 2030 using a scenario planning approach methodology while also taking into consideration the forces driving the future as it relates to society, technology, environment, economy and politics. Erdogan and his colleagues built the vision on four pillars: People, processes, technology and places, asserting that people and processes constitute a very important part of the future vision and that the construction industry's best practice in 2030 will be integrated with goals relating to people, technology and place.

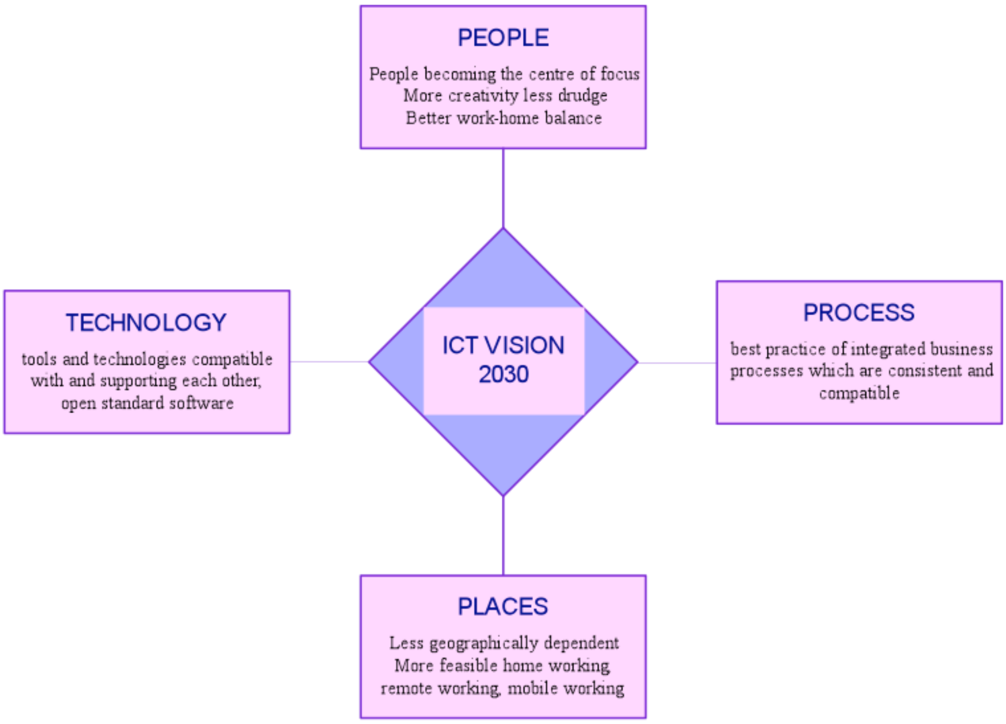


Figure 2.17: ICT Vision 2030 (Erdogan et al., 2009)

The future in 2030 will be based on people with a broad range of skills who will use IT for design and innovation to ease their workload rather than enduring physical strain to do work. Erdogan et al, (2009) predict that in 2030, (a) robots will substitute manual workers in the factories, implying that off-site construction will increase (b) It will be possible to integrate elements such as acoustics and odor into visual simulations creating the 'n' dimension. (c) Facilities management will reach groundbreaking performance level through sensor fitted, self-healing/self-correcting intelligent buildings. (d) Greenhouse gas reduction, cost and energy efficiencies will be possible through the IT systems embedded in intelligent buildings. (e) with greater collaboration and efficiency in the supply chain, project planning and resource management will improve (f) double loop learning facilities will spring up from Intelligent or semi-intelligent software. And, (g) the era of meeting over blueprints in portacabins will be obsolete rather learning will be achieved through on the job simulation, role-plays and games. For example, site inductions providing a walkthrough in the 3D site models.

Their vision for the construction industry describes how the industry will change by 2030. These changes include but not limited to people's roles, skills, and activities;

collaboration and communication, working practices, and IT-people-process. In summary, Erdogan et al, (2009) assert that:

"Enhancements in technology will enable the construction of smart lego style design and construction processes, and off site construction. People will have more time to do creative work and the new technologies such as ubiquitous computing, collaboration tools, decision making tools will enable a more flexible working style"

In 2003 the European Commission launched the ROADCON project whose main objective was to develop a vision for agile, model-based/knowledge driven construction. The vision by ROADCON states:

"Construction sector is driven by total product life cycle performance and supported by knowledge-intensive and model based ICT enabling holistic support and decision making throughout the process by all stakeholders".

As if to emphasize the need for this vision, Hannus et al, (2003) asserts that the construction industry merely responds to its ICT needs by making use of available ICT as against taking charge of creating and developing its own ICT requirements. And therefore a Model-based system is the core vision of ROADCON. It will have a fundamental impact on the way the construction industry uses ICT (Hannus et al, 2003).

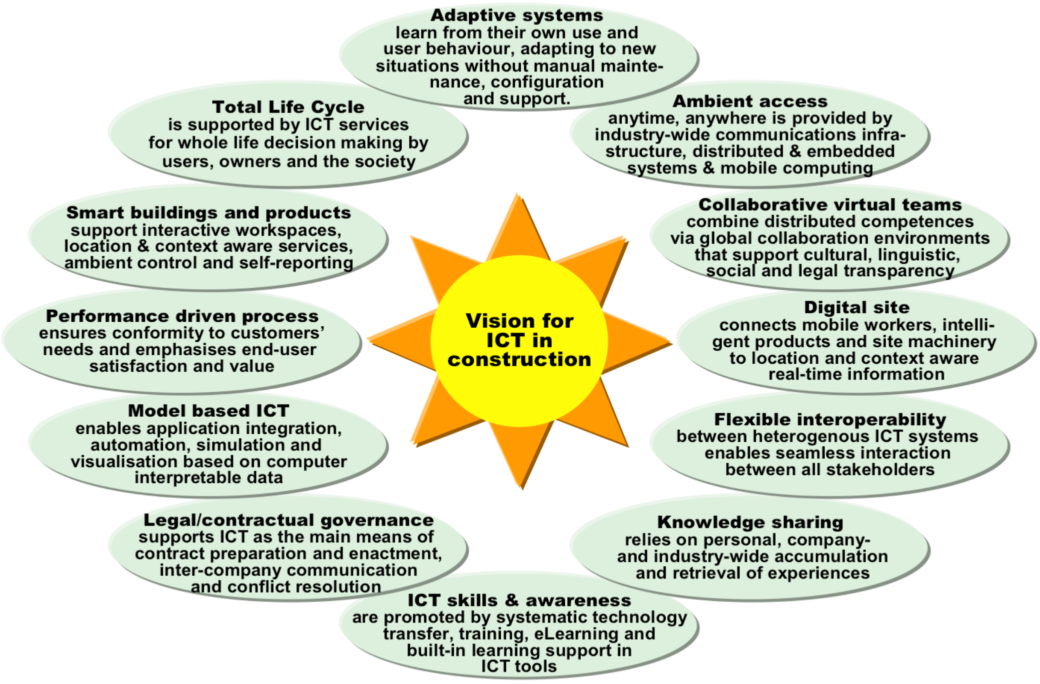


Figure 2.18: ROADCON Vision for construction ICT (Hannus et al, 2003)

Similarly, the European Construction Technology Platform (ECTP) proposed another vision for 2030 for the construction industry, in the year 2008 called the Strategic Research Agenda (SRA). The document addresses 4 key aspects of construction: processes, projects, enterprises and products.

Table 2.8: Key Aspects of Construction

Processes	• Business processes • Production processes
Products	• Digital modelling of products • Intelligent products
Projects	• Interoperability between ICT systems • ICT support for collaborative work between organization
Enterprises	• Capturing project experience into knowledge assets • Exploiting knowledge in new business models.

Source: ECTP (2008)

The SRA vision is quite similar to the ROADCON vision with only slight differences: ROADCON has twelve key drivers; ICT skills and awareness, collaborative virtual teams, adaptive systems, digital site, flexible interoperability, Legal and contractual governance, ambient access, performance driven process, knowledge sharing, Smart buildings and products, Model and object based ICT, and total life support. While SRA has nine drivers, which are; Value-driven business processes, Industrialized production, knowledge sharing, Digital models and ICT, Interoperability, intelligent constructions, Collaboration support, enable business models. Both models are basically the same only that some of the drivers in ROADCON have been collapsed into one theme on the SRA vision. For example, ‘Smart buildings and products, and total life support’ was collapsed to become ‘intelligent constructions’.

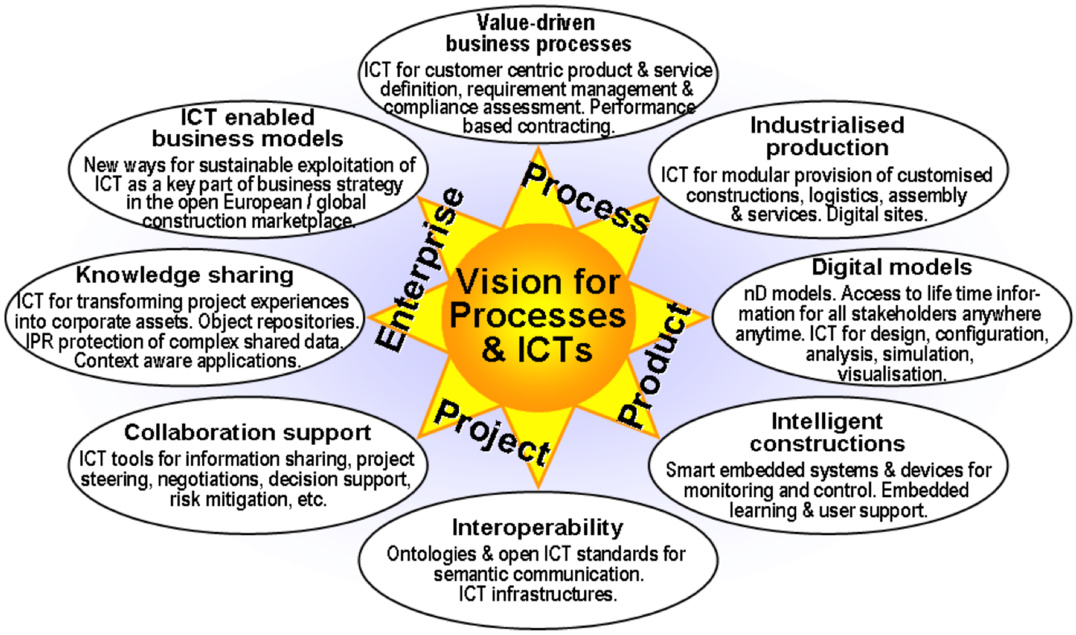


Figure 2.19: SRA 2030 Vision for construction ICT (ECTP, 2008)

North America and Canada, in collaboration, have developed their own future IT vision for the construction industry called the FIATECH: Capital Projects Technology Roadmap Vision. This is the closest research to SRA and ROADCON done outside the European Union (ECTP, 2008). FIATECH aims at defining and executing industry-funded capital projects. It provides a platform for collaborative effort aimed to attract all organizations interested in addressing the critical issues the Roadmap brings forward (www.fiatech.org). According to the ECPT (2008) FIATECH does not address new business models whereas the SRA does.

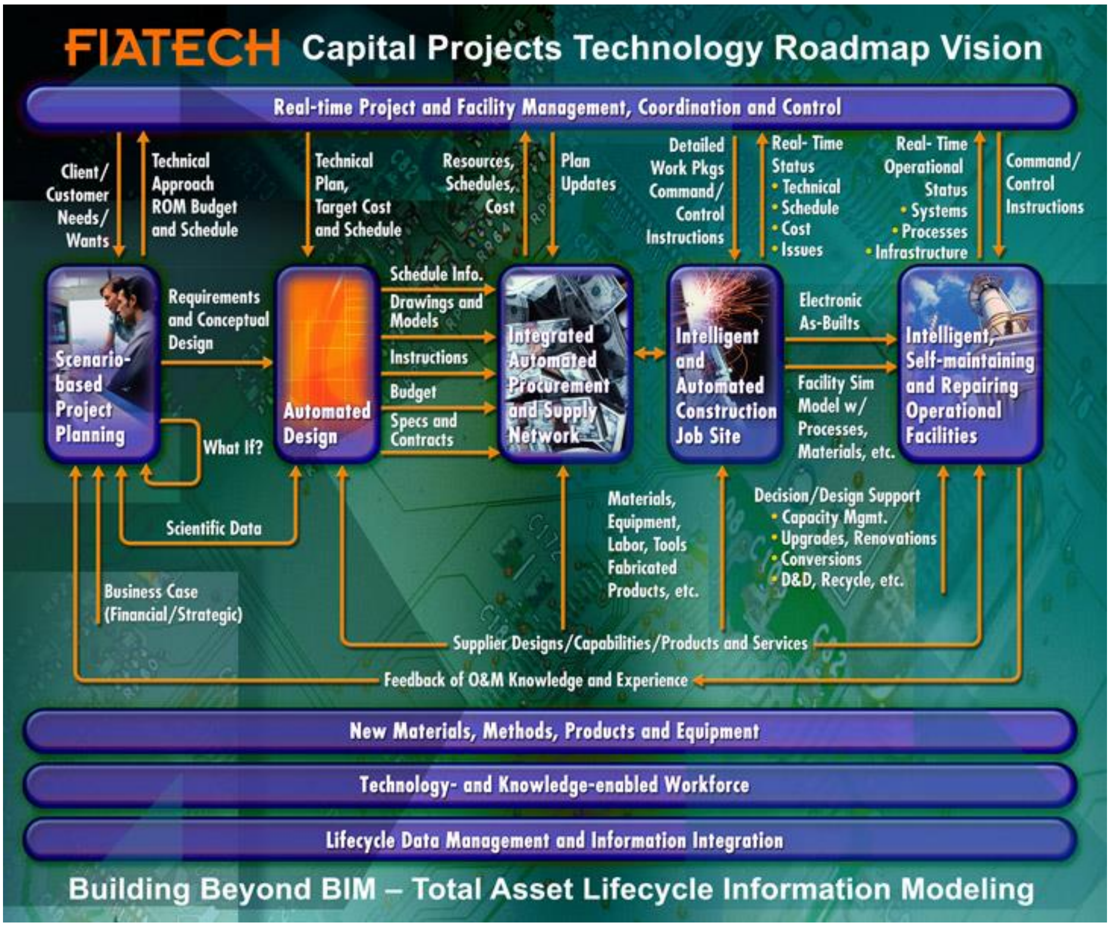


Figure 2.20: FIATECH Roadmap Vision (ECPT, 2008)

2.17 Model driven approach; the Future of IT in Construction

Many have recognized that information technologies (IT) are now a very important part of the construction process and taking steps to create a future vision for their respective organizations. According to Aish (1999), the construction industry is essentially an information HUB with project information streaming among multi-disciplinary teams from different organizations with different cultural backgrounds, processes and IT capabilities. At the dawn of the new millennium, Construct IT's research on the industrial best practice in the UK, created a 5-10 years vision for construction projects and IT process enhancement. Using the work of Auoud et al (1997) who found that communication and networking, integration, visualization, simulation and intelligence are the five most important technologies in the construction industry; as pillars, Construct IT formulated a future vision covering seven themes (Sarshar et al, 2000). The Model driven approach is drastically opposed to the , document driven information management approach for projects. For example, there will be a dramatic change in procurement philosophies, as a result of the Internet, there will be improved communication in all phases of the project life cycle, and so on.

Sarshar et al (2000) argued that the current construction information is captured in documents, which are shared among teams over network connection such as groupware or electronic white boards; that will later be saturated by the increasing volume of documents or become too time consuming by their ever increasing versions. At that point, the systems become ambiguous and confusing. Therefore, a shift to the use of a "model" based approach was advocated. Sarshar et al (2000), state that the model driven approach is one that shares "project information via a 'shared conceptual product/process model' and does not imply a large unique database which controls the whole of the construction project but rather a conceptual model which is implemented on different applications and is shared in different geographical locations." An 'Integrated Data Warehouse' that solves the problem of duplication and double counting, where items of information are inputted once and used multiple times by different users and for different purposes as it relates to them. A model based approach also makes 'life cycle information management conceivable (Kiviniemi, et al., 1999). In 1999, when Kiviniemi and his colleagues stressed that in the future, the construction industry will not only be held accountable for information on design and construction but also on information use and maintenance, now, sixteen years later, that prediction has come true. What better way to ensure the collection and use (effectively and efficiently) of such enormous amount of information but through an integrated data warehouse?

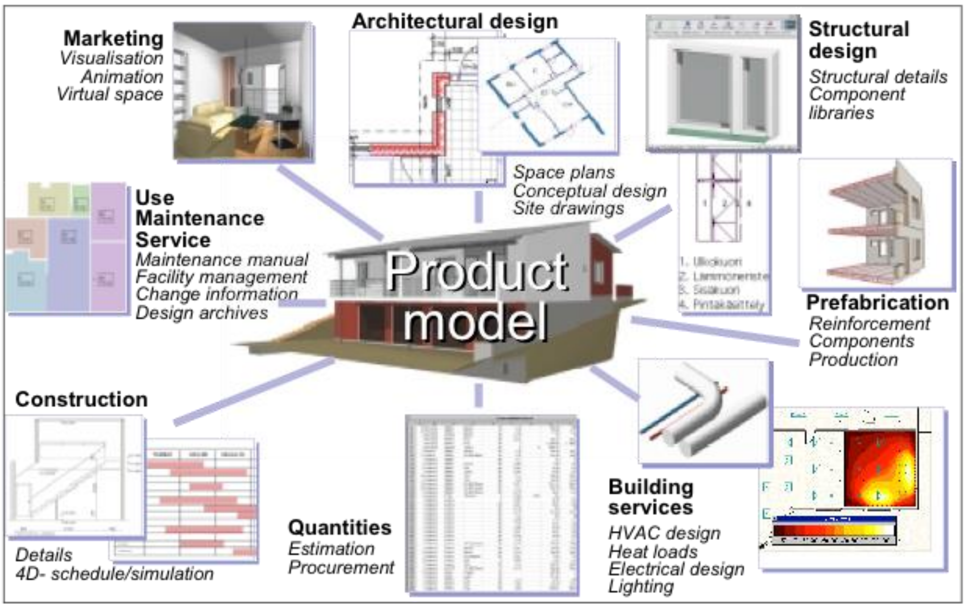


Figure 2.21: Building Model supporting various engineering applications (Hannus et al, 2003)

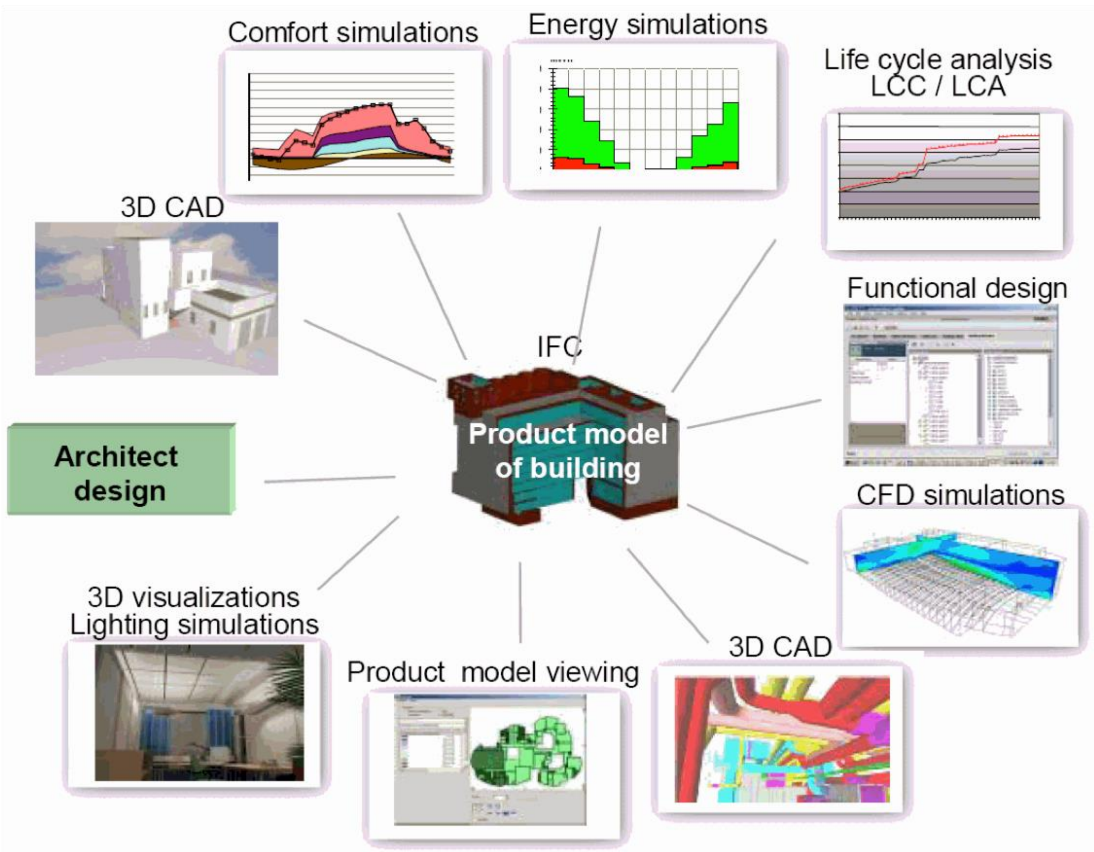


Figure 2.22: Year 2030 Vision of Model-based Information Integration (ECTP, 2008)

Also, according to Sarshar et al, (2000) a conceptual model approach is key for an organization's knowledge management system where information can be stored, retrieved and processed as leverage for future innovation. Hitherto, communication between stakeholders on construction projects relies mainly on drawings and specifications. But with the advent of 3D visualization, the confusions, misinterpretations, and delays that are often associated with 2D drawings are greatly reduced if not eliminated. Visualization as a stand-alone technology will make communications more effective and user friendly (Sarshar et al, 2000).

2.18 Summary

This chapter introduces Information Technology (IT), IT in construction and the future of IT in construction through providing history, benefits, limitations, adoption and adaptability of information technology in the construction industry. It was found that there were several barriers to adopting IT and cost of investment, direct or indirect, monetary or non-monetary, was found to be the major barrier to adopting IT. Other barriers such as training, distrust of IT, and cyber hacks, though significant, were found to be less impede the process of adopting IT. As a result, the construction industry has been slow to adopting new technologies. Literature also revealed multiple IT implementation frameworks in construction. Some of the frameworks are very useful to the industry and have even been adopted by several companies in the industry. However, other frameworks, although thorough, were partly ambiguous and could be simplified.

3 CHAPTER 3| BUILDING INFORMATION MODELLING AND CONSTRUCTION

3.1 Introduction to Building Information Modeling (BIM)

"BIM is not tomorrow's vision; it is today's reality"

Ashcraft (2008)

It is important to note that even though the start of the implementation of BIM on construction was around the mid-2000s, its origin can be traced back to the 1970s and 1980s consequent of the parametric modelling research conducted in the USA and Europe respectively. Now BIM is no more the fad of the day, it is; the norm, the standard, the centrepiece, of AEC technology (Azhar, et al. 2012).

BuildingSMART defined BIM in succinct terms as a 3D object database with rich data and structured information that can be easily visualized. It is also a "process of representing building and infrastructure over its whole life cycle from planning, design, construction, operations, maintenance and recycling." One of the major opportunities and importance of BIM is that it provides a framework for collaboration. It is a "multi-disciplinary environment that brings together all the parties that design, construct and operate a facility, to bring about substantial savings in time, cost and an improvement in quality" (BuildingSMART, 2012).

According to Singh, et al (2010), BIM can also be described, as "an Information Technology (IT)-enabled approach that allows design integrity, virtual prototyping, simulations, distributed access, retrieval and maintenance of the building data." In succinct terms, BIM as defined by Vanlande and Nicolle (2008) is "a tool that enables the storage and reuse of information and domain knowledge throughout the lifecycle of a project" - the utilization of a database infrastructure to encapsulate built facilities with specific viewpoints of stakeholders (Arayici et al, 2012).

Hitherto, a universal definition of BIM has eluded all, professionals and academics alike. According to the Building Information Modeling Task Group (BIMTG), the definition of BIM depends on a person's point of view and/or what the persons intends to achieve from it. To the extent that the Task Group resigned to say that "Sometimes it is easier to say what BIM is not rather than what BIM is: it's not just

3D CAD; it's not just a new technology application; it's not next generation, it's here and now." Arayici and Aouad (2010) gave a rather comprehensive definition of BIM saying what BIM is rather than what it's not. In this definition, BIM is defined as "*the use of ICT technologies to streamline the building lifecycle processes to provide a safer and more productive environment for its owners throughout the building lifecycle."*

However, the BIMTG would not be an institution if they do not "give it a go" at defining BIM. The Task Group defined BIM as *"essentially a value creating collaboration through the entire life-cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them* (BIMTG, 2014). A similar definition is one by the National Building Information Modeling Standards (NBIMS) committee of USA. They defined BIM as *"A shared knowledge of resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract update or modify information in the BIM to support and reflect the roles of that stakeholder"* (NBIMS, 2010).

Campbell (2007) asserts that for a model to be a BIM model it must exhibit the following six key characteristics:

Digital – enabling simulation of design and construction

Spatial – 3D to better represent complex construction conditions that 2D drawings

Measurable – data is quantifiable, dimension-able, and query-able more that visual

Comprehensive – encapsulating and communicating design intent building performance, constructability, and sequential and financial aspects of means and methods

Accessible – data made available to the entire project team through interoperable and intuitive interface, including architects, engineers, contractors, fabricators, owners, facility maintenance and users.

Durable – data that reflects as-built conditions and remains usable through all phases of a facility's life, including design and planning, fabrication and construction, and operations and maintenance

3.2 BIM Adoption across the Globe

The growth of BIM in recent years, as has been predicted by many academic institutions and industry professionals, is not surprising. For example, Stanford University Center for Integrated Facility Engineering reported that BIM use has risen significantly and will continue to rise in the near future (Foster, 2008).

According to research conducted by McGraw Hill Construction (MHC) on BIM adoption around the globe, BIM is reaching maturity among contractors in Europe and North America. The usage of BIM has increased remarkably, owing to the fact that private and government clients want the time saving, increased quality, reduced cost, and overall project certainty that BIM promises. BIM mandates by UK, US and other government entities, has resulted in an unprecedented rise in BIM adoption all over the globe. Results from an investigation of BIM in individual markets (countries) show that BIM adoption in the US has increased dramatically in the last five years, with the UK and other European regions are registering remarkable numbers (MHC, 2014).

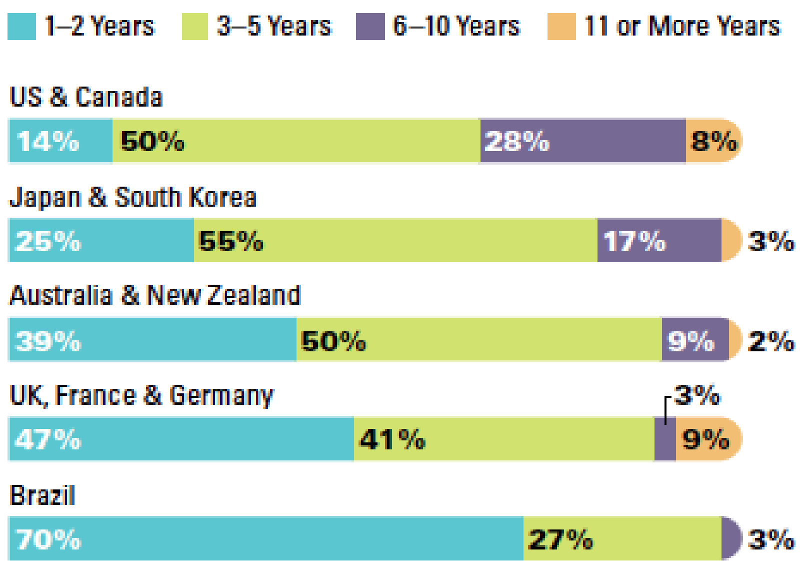


Figure 3.1: Length of Time Contractors have been using BIM by Region (MHC, 2014)

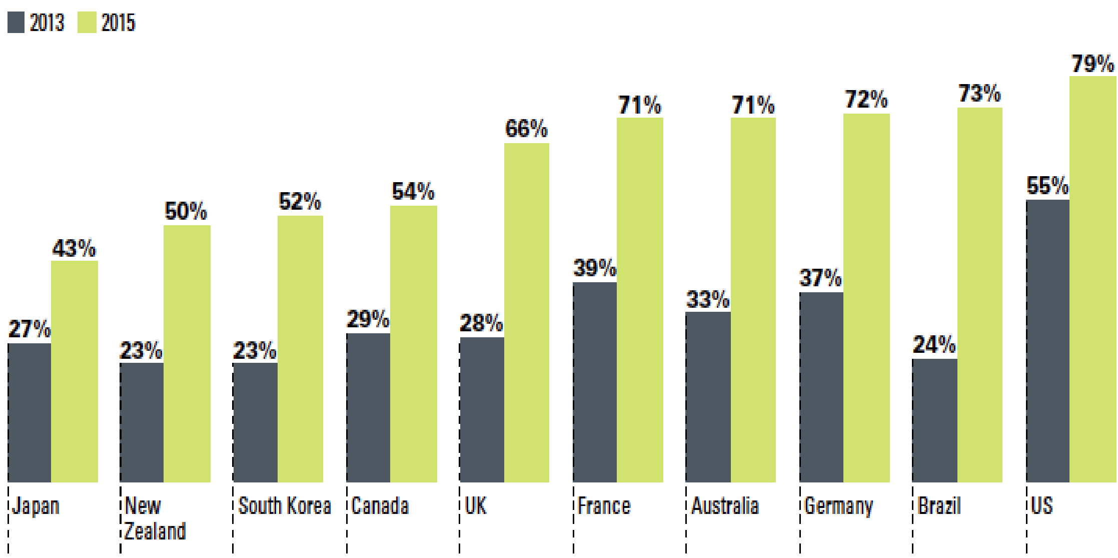


Figure 3.2: Percentage of Contractors at High/Very high BIM Implementation Levels (MHC, 2014)

3.3 UK Implementation of BIM

The implementation of BIM in the UK has been rather aggressive with the UK Government asking for fully collaborative 3D BIM as a minimum by 2016, when procuring public buildings. This minimum standard is also known as the "Level 2" competency – a file-based collaboration and library management comprising of structural, architectural and mechanical, electrical and plumbing [MEP] services 3D models—all within a single environment where structured data can be shared (MHC, 2014). An example of this Level 2 environment is that used by the UK BIM Task

Group called the Construction Operations Building Exchange UK 2012 (COBie UK 2012). The overarching goal of this strategy is that through BIM enabled processes such as early clash detection and building component prefabrication, capital costs can be reduced, and carbon dioxide creation eliminated or significantly reduced (MHC, 2014).

According to the UK Government Construction Strategy report (2013), progress has been made already as:

"A Client BIM Mobilization and Implementation Group to drive the adoption of BIM across government has been established and met for the first time in May 2011, and a staged implementation plan will be published in June."

The UK GCS (2013) asserts that if not for a lack of collaborative and interoperability platform, there would have been a widespread adoption of BIM technology ensuring that all team members are working from the same data.

The UK Cabinet Office strives to co-ordinate with government to develop standards that enable all members of the supply chain to work collaboratively through Building Information Modeling (BIM). BIGPROJECT (2014) report that in June 2011, BuildingSMART ME, BuildingSMART MENA, The Kingdom of Jordan's Ministry of Public Works and Housing (MPWH), BIM Journal, and the Jordan Engineers Association (JEA) all signed an agreement to initiate a BuildingSMART forum to promote BIM in the Jordanian construction industry with an aim to curb waste, improve the construction process, and save cost on projects. In this regard, BuildingSMART took a nation wide survey on BIM awareness and IT use in the Jordan construction industry. They found that only 25% of participants were "familiar" with BIM and only 5% were utilizing IT (BIGPROJECT, 2014).

BuildingSMART has also been working close with the Australian government. In June, of 2012, BuildingSMART recommended four 'action' steps that the Australian Government must use to accelerate the adoption of BIM in Australia and ensure Australian businesses are well placed at an advantage to compete in a growing global construction sector (buildingSMART Australasia, 2012).

These recommendations are adaptable by other governments and with efforts to improve the IT situation in Jordan and in the Jordanian construction industry; these key initiatives, when streamlined, can fit the industry in Jordan.

3.3.1 BIM Maturity Level and Competencies

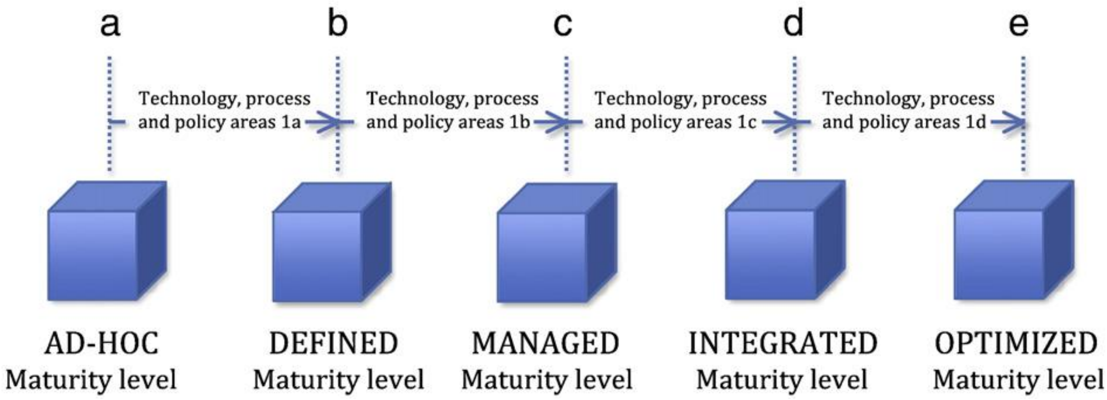


Figure 3.3: BIM Maturity Levels (Azhar et al, 2008)

How a particular organization defines BIM is a true reflection of its "maturity level" (Azhar et al, 2008). A BIM "Maturity Level" is defined as "the quality, repeatability and degree of excellence within a BIM Capability." A "BIM Capability" "is an organization's level of performance or ability within a particular stage, which is measured to determine BIM Maturity according to the five maturity levels; ad-hoc, defined, managed, integrated, and optimized." These BIM Capabilities are in three main categories: network-based integration, model-based collaboration, and object-based modeling (Barlish and Sullivan, 2012). Each of the three categories has within it the five-maturity level.

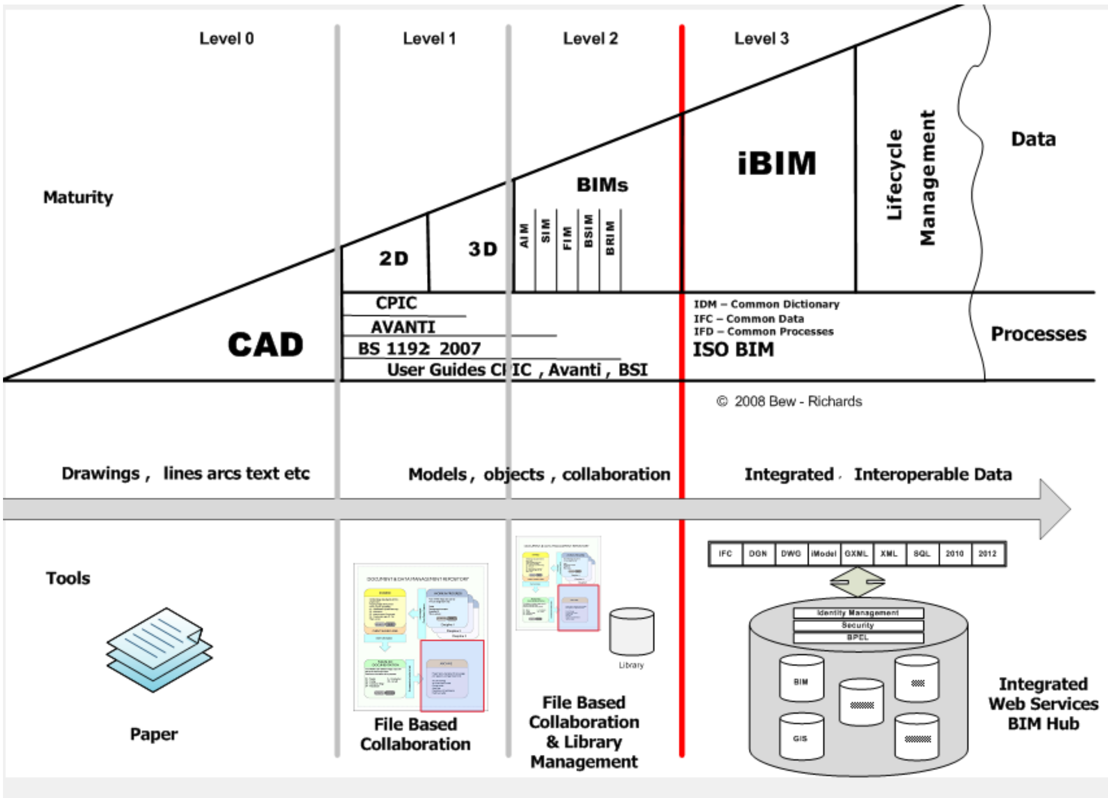


Figure 3.4: BIM Maturity Level (BIMTG, 2014)

3.3.2 BIM Levels Definition by the UK BIM Task Group

1. Level 0: Unmanaged CAD (Computer-aided Design) probably 2D and/or 3D, with paper (or electronic paper) exchange mechanism as the most likely data. That is, design disciplines who are designing, documenting and creating visualizations but who have not yet fully embraced object-oriented modeling and the concept of embedded information and/or appended/linked object information (Gu and London, 2010).
2. Level 1: Modeling – single disciplinary use of object-oriented 3D modeling software within one discipline (Gu and London, 2010). Managed CAD in 2 or 3D format with a collaboration tool providing a common data environment, possibly some standard data structures and formats. Commercial data managed by standalone finance and cost management packages with no integration.
3. Level 2: Collaboration – sharing of object-oriented models between two or more disciplines. Managed 3D environment held in separate discipline "BIM" tools with attached data (Gu and London, 2010). Commercial data managed by an ERP. Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as "pBIM" (proprietary). The approach may utilize 4D programme data and 5D cost elements as well as feed operational systems.
4. Level 3: Full Integration – integration of several multidisciplinary models using BIM model servers with the ultimate aim of moving from local servers to a web based environment (Gu and London, 2010). Fully open process and data integration enabled by "web services" compliant with the emerging IFC / IFD standards, managed by a collaborative model server. Could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes.

According to the BIM Task Group (2011), the maturity model has been devised to ensure clear articulation of the levels of an organization's competence with BIM. The development of the model was birth out of the recognition that differing construction clients and their supply organizations are currently at different level of experience or competence of BIM. Therefore, a model to determine the exact level of a client's BIM competence will enable the said client to move towards acquiring higher level of competence, the BIM Maturity model, then, serving as a structured learning progression calibrator over a period of time.

It is imperative to note that BIM is not only software; it is both process and software (Azhar, et al. 2012). BIM is the latest tool that can effective and most efficiently play the "main role of coordinating and integrating the exchange of information and knowledge between different disciplines and phases within the project life cycle" (Azhar, et al. 2012). BIM workflow process aims to achieve the concept of Integrated Project Delivery (IPD), which is a novel project delivery approach (the future of IT in construction) that integrates people, systems, business structures and practices (Azhar, et al, 2012; Glick and Guggemos, 2009).

However, the pace of adoption is off the mark due to issues and difficulties in putting technologies into practical use within the construction sector (Sun et al, 2000). Backed with and derived from this discussion, the general research inquiry is then defined and articulated as a need to develop an implementation methodology that is used to approach and understand the construction special context in order to identify possible means for introducing and implementing new advanced technologies such as BIM in the Jordanian construction industry.

"The foundations of BIM are laid on two pillars, *IT collaboration* and *communication."*

Azhar et al, (2012)

3.3.3 Understanding BIM as Technology and Process

For some, BIM is a software application; for others it is a process for designing and documenting building information (Aranda-Mena et al, 2008; Balish and Sullivan, 2012). Azhar et al (2012) made this dichotomy to emphasize and therefore facilitate a greater understanding of BIM as technology and also as a process. According to them, BIM as Technology can be seen as "project simulation consisting of 'parametric' 3D models of the project components with links to all the required information connected with the project planning, design, construction or operation." This is different from the "non-parametric" traditional 3D CAD where dimension changes in one view, such as plan, elevation, or section, is not automatically reflected in the other views. All the other views would have to be followed-through and changes effected to make the drawings homogeneous, which then yields high probability of error and defective work. BIM is made up of smart building components that carry individual information such as specification, operation and maintenance procedures and supplier, flow rates and clearance requirements, etc. On the other hand, BIM is also a "process" (from conception to post-completion) which can be viewed virtually and contains information consistent to the building (Gu and London, 2010), allowing all stakeholders to collaborate to the execution of the structure in a way more efficient than the traditional alternative could provide (NBIMS, 2007; Lindblad, 2013). BIM comes into play at the schematic design stage. Here, all the stakeholders, the client, engineers, architect, quantity surveyors, contractors, subcontractors and suppliers, start creating, refining, and adjusting their portions of the model according to project specifications. And work does not start on site until the model is as accurate as possible.

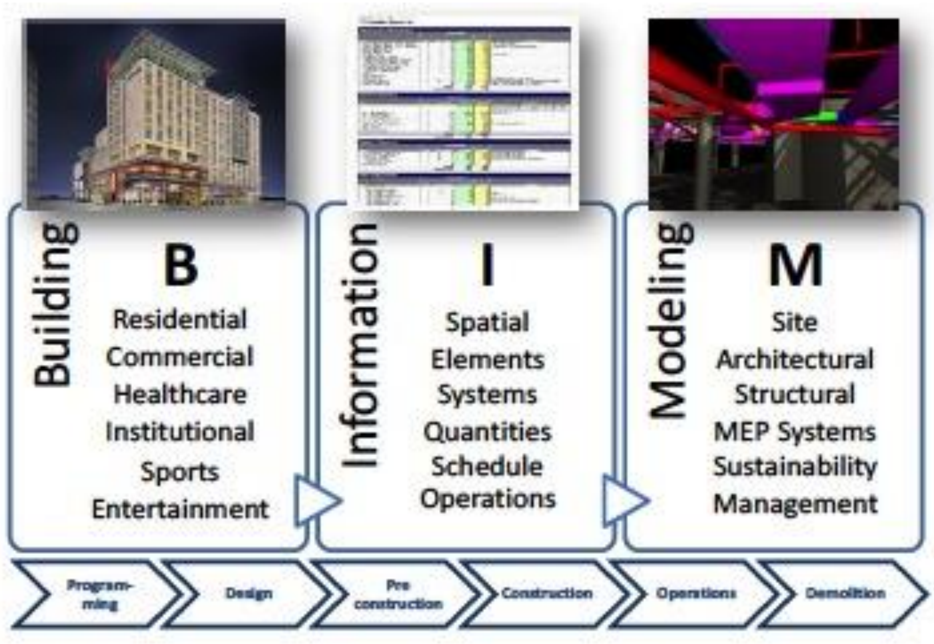


Figure 3.5: Visual Representation of BIM concept through the lifecycle of a project (Azhar et al, 2012)

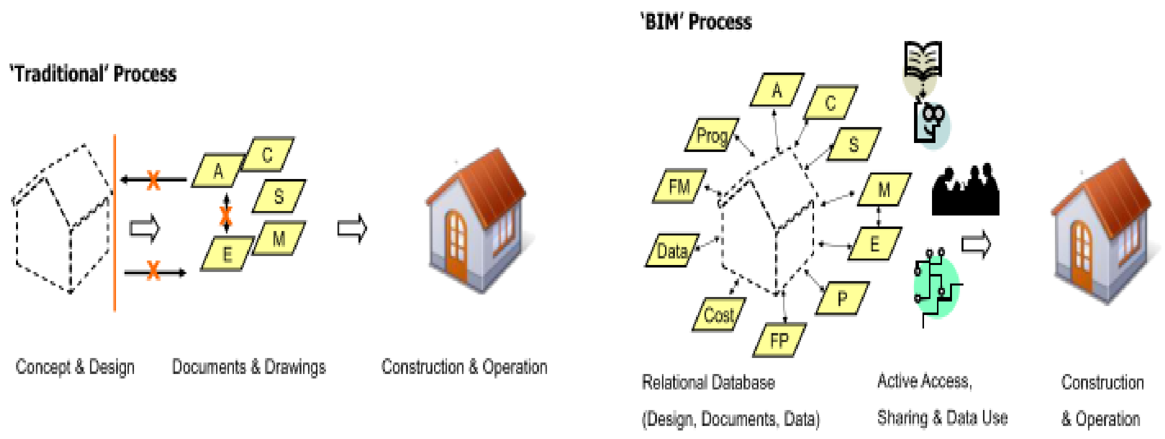


Figure 3.6: The difference between Traditional process and BIM process (Azhar et al, 2012)

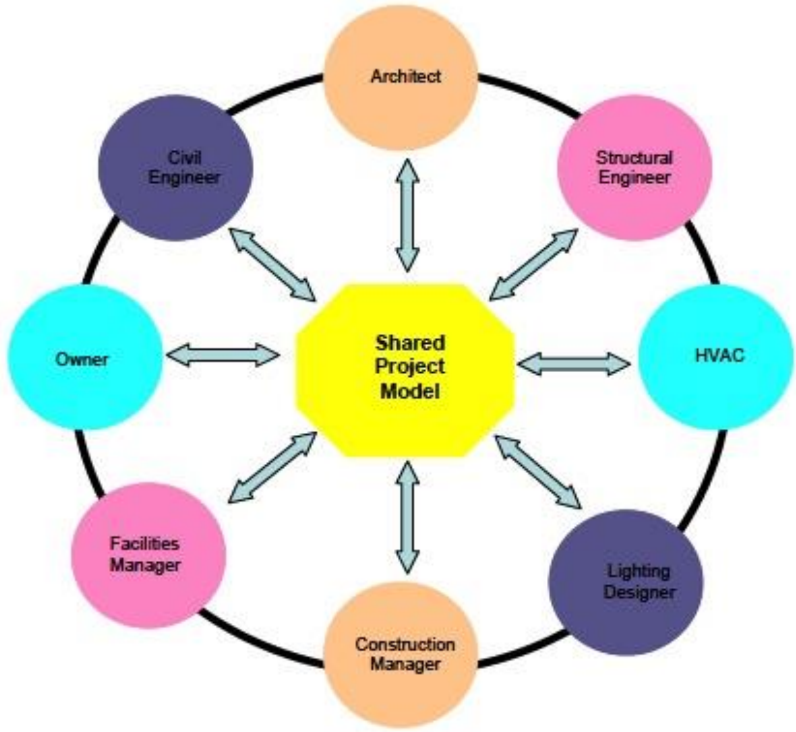


Figure 3.7: BIM Process - a shared project model concept (Foster, 2008)

3.4 BIM and Project lifecycle

According to Azhar et al, (2012), BIM through the lifecycle of a project; from design, project programming, construction, preconstruction and post-construction phases presents a unique opportunity of time savings, cost saving, improved quality increased efficiency. At the project programming stage, the project team is able to analyze suitable sites for the project using hybrid software between BIM and GIS. Engineers and architects can take advantage of BIM applications at the design stage to produce the right and accurate design, while at the same time, through the help of quantity surveyors, and value engineering, the right structure can be produced. Accurate estimating, general site coordination, and constructability analysis are the main activities of the preconstruction phase. And these activities can be done more efficiently using BIM models. At the construction phase design is assumed to be complete, BIM can be used for 4D scheduling and monitoring, and 5D costing, RFI integration and trade coordination meetings. Since BIM contains all information regarding, location, specification, manufacturer, supplier, operation and maintenance procedures, commissioning information, performance data, flow rates and clearance requirements, etc., it therefore means that facilities managers can harness this information at the post-construction phase thereby making operations and maintenance of a facility more efficient.

3.4.1 How is BIM different?

Technical	I. There are identifiable objects that persist in different contexts II. The 3D object is the central representation III. 3D allows extraction of useful information (schedules, quantities, drawings, etc.) IV. Alternative representations are linked (drawings, schedules, budgets) V. Information aggregates VI. Integration of ALL spatial information VII. Integration of geometry with reports VIII. 2D and Schedules • Information is re-purposeable and inter-related • Data is used for construction • Data can be used for owner asset tracking and management
Procedural	• We work in 3D • 2D and other documents are reports from the 3D model • We spend less time "red lining" • We spend more time "getting the model right" • More localized implications are resolved, less is left to "intent" • There is a change in where we put our hours • Less is spent in "production" • More is spent in "design"
Contractual	1. BIM data is operative beyond the context in which it was created 2. BIM supports – perhaps requires – a more collaborative way of working

Source: Ashcraft and Sheldon (2014)

3.5 Benefits of BIM

According to Azhar et al (2008), “the key benefit of BIM is its accurate geometrical representation of the parts of a building in an integrated data environment.” He also mentions the following benefits of BIM – “faster and more effective processes, better design, controlled whole-life costs and environmental data, automated assembly, better customer service and lifecycle data.” The benefits of BIM are numerous and some specific to given stakeholders (Balish and Sullivan, 2008). In construction, there are four distinct stakeholders; The Client/Owner (who may or may not be the ‘User’), Project Consultants, Contractors, and Facilities Managers. Based on the works of Eastman et al. (2011) and Reddy (2011), Azhar et al, (2012) outlined a number of benefits that are enjoyed by the different stakeholders on a construction project. They are the following:

Table 3.1: BIM benefits according to Project Stakeholders

Client(s)	
	Early design assessment to ensure project requirements are met
	Operations simulation to evaluate building performance and maintainability
	Low financial risk because of reliable cost estimates and reduced number of change orders
	Better marketing of project by making effective use of 3D renderings and walk-though animations
	Complete information about building and its systems in a single file
Project Consultants	
	Better design by rigorously analyzing digital models and visual simulations and receiving more valuable input from project owners
	Early incorporation of sustainability features in building design to predicts its environmental performance
	Better code compliance via visual and analytical checks
	Early forensic analysis to graphically assess potential failures, leaks, evacuation plans and so forth
	Quick production of shop or fabrication drawings
Contractors	
	Quantity takeoff and cost estimation
	Early identification of design errors through clash detections
	Construction planning and constructability analysis
	Onsite verification, guidance and tracking of construction activities
	Offsite prefabrication and modularization
	Site safety planning
	Value engineering and implementation of lean construction concepts
	Better communication with project owner, designer, subcontractors and workers on site
	High profitability
	Better customer service
	Cost and schedule compression
	Better production quality
	More informed decision making
	Better safety planning and management

Source: Azhar et al, (2012)

3.6 BIM Application

The construction industry is constantly under pressure to provide value for money, which has become an impetus to the Building Information Modeling movement that has transformed the construction industry from 2D based drawing information systems to 3D object based information systems (Arayici et al, 2010). There is no doubt to the benefits BIM provides for the construction professional and the project as a whole. However, we must not make the mistake of thinking that the advent of BIM is the end of the many problems in the AEC industry. Foster (2008) and Ashcraft (2008) have both assert that "the uses of BIM will inevitably change the ways projects are conceived, designed, communicated and constructed but the core responsibilities of the members of the project team will not change."

Foster (2008) reminds us that whether design is in 2D or 3D, or both, the responsibilities of the members of the project team remain unchanged. BIM aids "coordination" of the project and injects efficiency into the process. It improves communication, decrease construction time and cost, and ultimately reduce risk.

BIM Application	Owners	Designers	Constructors	Facility Managers
Visualization	x	x	x	x
Options analysis	x	x	x	
Sustainability analyses	x	x		
Quantity Survey		x	x	
Cost Estimation	x	x	x	
Site Logistics	x		x	
Phasing and 4D scheduling		x	x	
Constructability analysis		x	x	
Building performance analysis	x	x	x	x
Building management	x			x

Figure 3.8: BIM application by project stakeholders (Azhar et al, 2012)

BIM is aimed at reducing waste in the AEC industry. The Associated General Contractors of America (2006) listed a number of BIM applications which it called 'benefits'. In most cases BIM application is synonymous to BIM benefits. The list, is as follows: visualization, partial trade coordination, option analysis scope clarification, collision detection/avoidance, construction sequencing planning/phasing plans/site logistics, design validation, virtual mock-ups, marketing presentations, (value engineering analysis), sight line, studies and walk-through and fly-throughs.

Table 3.2: More Applications of BIM

Design and Engineering	**Risk Assessment**
Project Definition Design (Conceptual, Architectural, Engineering) Document production Document Quality Control	Metrics & Impact Scheduling Conflict Identification / Problem Identification Resource Assessment Visualization Scenario Analysis (Feasability & ROI)
Construction Planning	**Integrated Project Delivery**
Shop drawing and Fabrication Surveying/Scanning Field positioning RFI Management	Decision/Knowledge/Data aggregation Accelerated decision making Impact exposure Accountability & auditability
Collaboration	**Project Assurance**
Information integration Information distribution Document management	Quality control Predictability Delivery optimization Visibility Cost & Risk avoidance Information control
Project Management	**Bidding and Construction Management**
4D Modeling (Scheduling) Value engineering	Quantity surveying Scope definition
Capital Allocation Planning	**Project, Contract & Financial Controls**
Calibrating funding with execution	
Claims Analysis	

Source: Ashcraft and Sheldon (2014)

3.6.1 Visualization

Design visualization is one of few effective methods of simulating the project so that all inaccuracies can be corrected thereby mitigating against what would likely be costly mistakes in actuality (Foster, 2008). 3D renderings can be easily generated in-house with little additional effort (Azhar et al, 2008). Designers and contractors communicate design intentions to other parties on the project using BIM.

3.6.2 Design Assistance and Constructability review

An anonymous critic of designers once said "designers sometimes get carried away with their work and may design something that is practically and structurally impossible to build (Azhar, 2011). When this happens, BIM enables the contractor to provide constructability review to the designers. This would involve various buildability tests and analysis of alternative methods to ensure design can be built in the field to meet a target schedule and cost (Eadie et al, 2013).

3.6.3 Site planning and site utilization

BIM can be used to study known and anticipated site conditions including but not limited to the following elements; site logistics, site access and safety, underground utilities, excavation, shoring, crane placements, temporary parking and storage areas (Foster, 2008; Azhar, 2011).

3.6.4 4D Scheduling and Sequencing

The realistic sequencing and costing of construction works, saves significant money and time through reduced rework and delays to programme (Eadie et al, 2013; Azhar, 2011). A combination of the 3D model and the CPM schedule creates the "4D" model with time as the fourth dimension (Foster, 2008). With this, 'phase optimization' can be achieved and communicated clearly to the entire project team as to what and when it will happen on the construction site (Azhar et al, 2008).

3.6.5 5D Cost Estimating

We have discussed this in an earlier section. This is when a 'cost' element is added to the 4D model to generate the 5D model of BIM, hence the fifth dimension. Quantity Surveyors are the pioneers of this type of model as it enables the surveyor to produce cost related documents in real time as building designs are modified. Matchell is one of many construction professionals advocating for the adoption of all the 5 'D's in the industry in order to shape the standard practice for the future. The construction industry has embraced 3D and recently, BIM, which is encouraging but very little development has happened in the fields of 4D and 5D (Azhar et al, 2008).

3.6.6 Integration of Subcontractor and supplier models

In BIM approach, all subcontractors and suppliers submit their respective models (which in most cases are produced using different design packages) and the model manager provides one platform upon which all the models are combined into one file to be viewed as one composite model (Foster, 2008). It is at this stage that most design errors or design conflicts are detected.

3.6.7 System coordination

The 3D model of BIM allows for building systems to be coordinated and before they are fabricated and installed on site. Conflict, interference (Eadie et al, 2013), collision or clash detection tools are used to check all electrical, plumbing, mechanical, structural, architectural systems and fire protection and to discover and resolve all conflicts before installation (Azhar et al, 2008). Foster (2008) asserted that some projects have reported up to 80% reduction in site-related questions and conflicts due to the use of BIM.

3.6.8 Layout and fieldwork

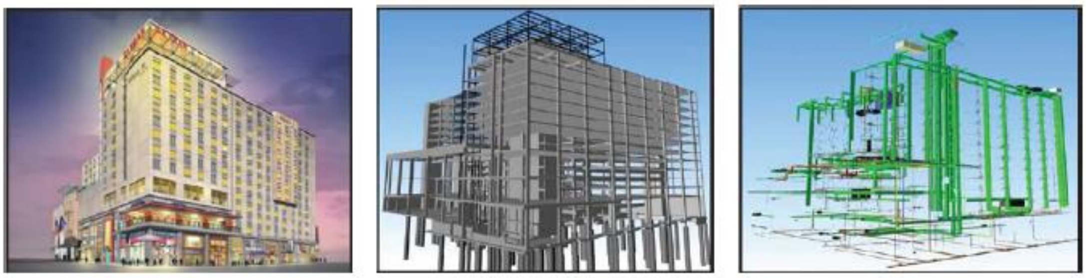
Here, 2D plans are produced; elevations and sections, which are then integrated with pertinent safety and quality information that assist in the layout of systems and materials on site (Foster, 2008; Azhar, 2011).

3.6.9 Prefabrication and Preassembly

BIM is one the most effective tools in the prefabrication business as the majority of the building components are built under a controlled environment. It is easy to generate shop drawings for various building systems (Azhar, et al, 2008)This enables faster assembly of building, reduces labour (skilled and unskilled), and reduces congestion and inventory on site; hence improving health and safety.

3.6.10 Operations and maintenance

Facilities management departments can use BIM for renovations, maintenance operations and space planning (Azhar et al, 2008). When BIM is used on a project, post-construction duties of maintenance become a breeze. The BIM model is a true "as built" record of the building's condition (Foster, 2008). Thus, facilities managers can quickly and easily locate, and repair a blocked pipe for example. Also, since each element of the building contains information such as, specifications, supplier and/or manufacturer, it will be easy to find and replace any damaged or worn-out elements of the building (Eadie et al, 2013).



(a) Architectural Model (b) Structural Model (c) Plumbing Model

Figure 3.9: Examples of BIM applications (Azhar et al, 2008)

Table 3.3: BIM software applications

Design/Engineering	Integration
Bentley Triforma Graphisoft ArchiCAD AutoDesk Revit AutoDesk Architectural Desktop Digital Project Nemetchek All Plan Rhinocerous	Navisworks Innovaya Digital Project Rhinocerous
Engineering	**4D Modeling/Construction Management**
Tekla Engineer FEA (SAP, Stead…)	Vicon Constructor Navisworks
Facilities Management	**Shop Drawing**
Onuma systems	Tekla Structures SDS-2

Source: Ashcraft and Sheldon (2014)

3.7 Criticism/Barriers to BIM

Although, there are numerous benefits of BIM, there are risk and barriers to its implementation. BIM adoption requires changes to four key interrelated domains. They are; resourcing, work processes, initiation, scope/ project and tool mapping (Gu and London, 2010). Furthermore, Ashcraft (2006) points to the construction industry's dilemma of using BIM, that is, the struggle to reconcile the adversarial nature of the industry where duties and responsibilities are traditionally defined; and the promotion of collaboration and complete reliance on the project model for information. This dilemma poses a number of barriers. The works of Ku and Taiebat (2011), and BuildingSMART (2012) found that the challenges or barriers to BIM implementation are; legal, procurement and insurance issues, adoption of common BIM Guidelines and Information Exchange, the learning curve and the lack of skilled personnel, the high cost to implementation, Product information and BIM libraries, Business process change, the reluctance of other stakeholders (e.g. architect, engineer, contractor), the lack of collaborative work processes and modeling standards, interoperability, and the lack of Compliance and Certification. Similarly, Arayici et al 2009 found that the challenges to BIM implementation in the United Kingdom's construction practice are:

- Overcoming the resistance to change, and getting people to understand the potential and the value of BIM over 2D drafting
- Adapting existing workflows to lean oriented processes
- Training people in BIM, or finding employees who understand BIM
- The understanding of the required high-end hardware resources and networking facilities to run BIM applications and tools efficiently
- The required collaboration, integration and interoperability between the structural and the MEP designers/engineers
- Clear understanding of the responsibilities of different stakeholders in the new process by construction lawyers and insurers

Further more, Azhar et al. (2012) divided these barriers into two categories: Technology related risks and Process related risks. However, Ashcraft (2006) classified barriers into: commercial, legal, and technical issues. Azhar et al's (2012) list of barriers dissolves within Ashcraft's (2006) list, which will be discussed in more detail below.

3.7.1 Commercial issues

This is the question of who is prime beneficiary of BIM adoption. Foster asserts that *"design professionals are currently experiencing asymmetrical rewards for BIM (excessive risk with no reward)."* In earlier sections, we documented a number of benefits an owner enjoys from BIM. However, the design professionals do not enjoy much of these benefits. In fact, it is not economically viable for the design professionals to adopt BIM given the designers have to adopt this new technology, champion the use of BIM in their respective design discipline and train their employees with no guarantee of additional fees. According to Foster (2008), the designers have little incentive to fully adopt BIM processes since BIM increases the designer's potential liability.

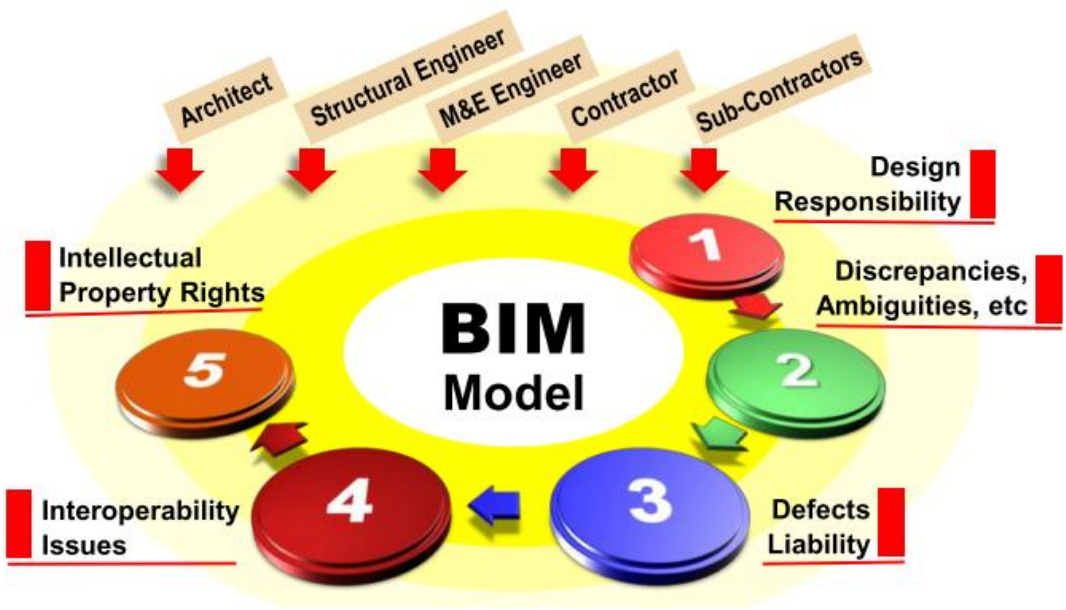


Figure 3.10: Conceptual Challenges of BIM adoption (Lip, 2012)

3.7.1.1 Absence of standard BIM contract documents

According to Azhar et al, (2012), another major barrier to adopting BIM is the lack of industry standard BIM protocols for management and integration of models from the project's multidisciplinary teams. As there are no industry standard protocols, firms, adopt their own methods, which in the end may lead to inaccuracies and inconsistencies in the BIM model. This will require the person responsible for the model to check for such inconsistencies in the models submitted by the different project teams and make or ask for corrections (Wickersham, 2009). This costs time and money. Furthermore, Ashcraft (2006) asserts that the absence of this document ultimately hinders the development of BIM in the construction industry. He went on to add that a standard BIM implementation contract document would provide; a framework for practice, establish consensus for the allocation of risks and dispute resolution, and make clear roles and lines of responsibilities of the parties on the project.

At the moment, the industry's contractual documents seems to conflict with the collaborative environment BIM seeks to achieve. This is because contractual agreements have clearly defined, and allocated roles and responsibilities under design and construction as separate entities. On the other hand, BIM fosters an environment of shared responsibility and integrates design and construction. According to Foster (2008), as integrated practice evolves, contracts will also need to evolve. Such contracts will be able to assign shared responsibility for design information, justify the reliance on the information, assign criteria for choosing a model manager and outline his/her duties, and provide practical compensation guide for the services, risks, efficiencies and savings created on the project.

Generally, contractors and construction managers have to coordinate the project in a manner that encourages ease of assimilation into BIM processes. Appropriate contract documents will guide open sharing of information between the project team, contractors and subcontractors alike. Every party on the project is however still responsibility for conveying their design intent to the design team, coordinate with other parties by sharing electronic information generated in formats accessible, readable and incorporable with the work of others.

3.7.1.2 Insurance

The issues of insurance arise when it comes to collaborative systems such as BIM contracts that have blurred lines of responsibility and hence blurred lines of liability. Insurance companies tracks legal liability, and therefore needs clear separation of responsibilities which the traditional contract documents provide. According to Ashcraft (2006), a collaborative system presents legal ambiguities that make insurance companies reluctant to assume such imprecise exposures (Foster, 2008). According to Ashcraft (2007), a professional liability policy most certainly covers much of designer's use of BIM owing that BIM is a part of professional practice. The contractor also needs to take on a commercial general liability policy to protect him/her from economic losses e.g. loss of modeling information.

3.7.1.3 Inertia

BIM has been around in the industry for over two decades now. However, its adoption by construction professionals has been rather slow. According to Foster (2008), unless a collaborative system such as BIM is made a contractual obligation, it is unlikely to see full collaboration from project team members. If this doesn't happen, much of the time and cost savings promised by BIM will be lost. Perhaps, that is why most governments are starting to make BIM compulsory on all public projects. According to Foster (2008), the goal can only be achieved if each member accepts this new technology and faithfully works together in a collaborative manner.

3.7.1.4 Need for a New Business Model

There are few business models, such as Partnering and IPD, have to become the order of the day in the construction industry today. These models are collaborative and hence are supported by a BIM system. The adversarial nature and the yet slow uptake of the collaborative approach are the major barriers of BIM adoption. Partnering in construction allows for better business relationship as it allows for shared risk and promotes reward and recognition on better performance. Foster (2008) asserts that firms can only achieve such collaborative approaches when they have similar economic interests, and business values.

3.7.2 Legal Concerns

3.7.2.1 Risk allocation

As already mentioned, the use of BIM changes the relationships between parties and blurs traditional roles and responsibilities (Wickersham, 2009). However, the legal framework of the construction industries assumes a less collaborative environment as it has clearly defined roles and responsibilities for all parties involved. Foster (2008) asserts that the future of BIM on projects will require a rational allocation of responsibilities based on amount of risk assumed, and the benefits enjoyed by parties. BIM contracts should state that participation does not make the architect responsible for construction means, safety programs and methods, neither does it make the contractor responsible for project design (unless the contract documents says otherwise) (Wickersham, 2009). The three major processes of BIM risk management in construction are: risk analysis, risk identification and risk response planning and control.

3.7.2.2 Standard of care, Privity and Third-party reliance

Standard of care has the characteristics of two sides of a coin. On the one hand, BIM raises a number of technological and design issues that require careful considerable by the user. These issues could prove costly for the designer, monetary and otherwise if not given careful attention, which raise the question whether BIM should be used at all (Wickersham, 2009). On the other hand, not using BIM if BIM can readily solve design issues, constitute negligence, and therefore, acting below the required standard of care (Ashcraft, 2007). Construction professionals are weary of BIM because economic losses caused by the BIM software itself, is not realistically recoverable by the injured party. Ashcraft (2008) points out, however, that there is a gap between the the software vendor's limited warranty and the designer's responsibility to produce plans or other deliverables in accordance with the standard of care.

In construction contracts, the 'standard of care' clause exists to protect the owner or the holder of the contract from faults. In this case design produced using BIM. The clause is commonly known as "design liability". With BIM system, where multiple models and drafted by different project groups and then incorporated into one, a 'standard of care' needs to be exercised by the different groups in providing up to standard designs because project group members are dependent on each other. Now, even if roles and responsibilities were still clearly defined, and liability was easily traceable, the 'standard of care' clause would still exist. In reality, since complete reliance by one party on the ability of others to protect its interest does not really exist, project groups use a number of risk transfer tools such as limitations of liability and/or indemnity agreements. An example of a 'design liability' is:

"The Contractor acknowledges that it has exercised and will continue to exercise in the design of the Works all reasonable skill and care as may be expected of a properly qualified designer of the appropriate discipline(s) for such design, experienced in carrying out works of a similar scope, nature, timescale and complexity and on a similar site or at a similar location to the Works."

Risks and liability are likely to be enhanced due to the integrated nature of BIM, which, to a certain extent, blurs levels of responsibility. A similar clause provided by *JCT Design and Build Contract, 2011 edition* (DB11) for example, clause 2.17.1 states:

"*The Contractor shall in respect of any inadequacy in such design have the like liability to the Employer… as would an architect or, as the case may be, other appropriate professional designer… who… has supplied such design for or in connection with works to be carried out and completed by a building contractor who is not the supplier of the design."*

The model designer must keep in mind that other parties to the contract are going to be relying on the accuracy of his/her model, and therefore, will be liable if any negligence is proven. Hence, any party to the contract can use the model will likely be able to bring an action against the designer for damages caused by negligent errors (Foster, 2008). This is why waivers are given as a pre-condition to limit consequential damages arising due to errors. However, according to Foster (2008), the idea of obtaining waivers or limitations of liability to control allegations of detrimental reliance is counter to the BIM process because they inherently look at electronic data as inferior to hard copies. Furthermore, the BIM system is a platform that encourages free exchange of data and this exchange comes with an unspoken 'standard of care' requirement, which makes 'disclaimers' redundant since reliance is implicit.

3.7.2.3 Economic Loss Doctrine

In traditional contract process, 'economic doctrine' states; "purely economic losses cannot be recovered through a negligence cause of action" (Foster, 2008). Here, contractors can claim and recoup economic losses on professional negligence. This doctrine, most commonly known as the "Spearin Doctrine" in the United States states that; "the one who provides the plans and specification for a construction warrants that those plans and specifications are free from defect". This therefore makes the owner (not the designers) liable if any errors or omissions are found. Hence, forcing many owners to cross-claim against the designers to protect against inconsistent verdicts. In the same respect, the owner is protected from claim relating to performance specifications where the owner has not dictated how the work will be performed. This means that the contractor must also be careful to perform his duties according to the specification and must not introduce his own design or ideas because when things go wrong, he/she may be unable to claim under spearin doctrine.

However, with BIM; a collaborative platform, where the contractor has his/her inputs in the design, it becomes difficult to establish the designer's economic loss (Ashcraft, 2007).

3.7.2.4 Distributed Design (professional responsibility).

Who is responsible for any inaccuracies? And takes control of the entry of data into the model? These are the questions that come when contemplating the adoption of BIM. As yet, there is no requirement mandating the appointment of a licensed BIM manager who is responsible for the entry and modification of the data that forms a digital model. Due to the fact that a BIM project entails sharing and exchange of volumes of electronic model-based data, by multiple parties, there needs to be appointed a gatekeeper for the model. This person is commonly known as the "Model Manager" (Foster, 2008). This responsibility has both a legal, and a cost implication. Ashcraft (2007) showed that, under the law, the use of software by an unlicensed individual constituted "unauthorized practice". Therefore, it is necessary, from the legal perspective that the composite model is in the "responsible charge" of a licensed professional or under his or her supervision. "*the gap between statutory requirements and good professional practice is widening"* (Ashcraft, 2007). The blurring of lines of responsibility that BIM inherently has, makes it difficult to separate work performed by the design professional and/or unlicensed professionals, to work performed by the software. These are changes or work which the design professional cannot take credit for because he/she neither developed the code nor understand how it works. However, the licensed model manager is responsible for changes to be in line with the design objectives. Therefore, the statutory definition of "responsible charge" has to be modified under BIM to support collaboration while preserving public safety and confidence.

From the cost point of view, the time taking in reviewing and inputting data could be costly. The construction manager is mostly likely to be the "model manger" on most projects because the role of the construction manager appears to be most in line with that of the model manager. Some duties and responsibilities that the model manager is likely to perform are not uniformly established and agreed upon across the AEC industry as every project is unique and BIM software varies. However, here, we will outline a few:

- Maintaining file transfer and access, compilation, correction (if necessary) and dissemination in a useful form of smaller models of other projects members to all project stakeholders. According to Foster, (2008), this role is likely to carry some liability exposure. Therefore some BIM users may request for indemnities, which can be handled earlier in the project by offering limited warranties and disclaimers (Azhar et al. 2012).
- In some more sophisticated projects, a model manager may be required to have some BIM technical skill as cases may arise that he may be called upon to render a professional service. He may be required to be a licensed professional, someone capable of monitoring and guiding design to align with the true intent of the contract requirements (Foster, 2008).

3.7.2.5 Intellectual property and ownership

This is concerned with determination of BIM data ownership and the need to protect it through copyright laws and other legal channels (Azhar et al, 2008). This is yet to be addressed in the BIM process. The nature of BIM, promotes sharing of information and collaboration among project team members who all contribute to the final project model, blurs out copyright bright lines. This ultimately may lead to disputes over who owns the copyright to a design should there be an attempt to use any of the design elements on future projects (Azhar et al, 2008). Licensing issues could arise. Designs submitted by parties who require copyright protection must be restricted beyond the project. In other words, the license owner must be protected. If project teams are not assured copyright protection, they may be reluctant to share and fully be open. Thus, defeating the integration purpose of BIM. As Azhar et al. (2012) state clearly, that the goal is to avoid inhibitions or dissentions that discourage participants from fully realizing the model's potential. According to Ashcraft (2007) the solution to intellectual property, is embedded in a well-drafted contract document that predetermine who will own specific parts of the model and which parts will be licensed for use.

3.7.3 Technical Issues

3.7.3.1 Universal Model or Multiple Models

"Significant effort is being made to tighten the integration between BIM software and to support interoperability, but the single model and perfect interoperability is still a dream not reality".

Foster (2008)

This raises the issue that even with the adoption of BIM on a project, there are yet multiple models produced by the parties to a project making the 'one universal model' theory elusive. In reality, project teams work on different BIM software, produce multiple models, and may not even utilize an interoperability software such as Navisworks even when provided. In theory, there needs to be one "composite model" upon which changes to design, whether electrical, architectural, mechanical, structural, etc.; can be done simultaneously, and instantaneously.

3.7.3.2 Interoperability and Data adequacy

This is one of the most sited problems of BIM software also known as 'data translation' (Ashcraft, 2007). It is the notion that data exchange between BIM software applications should allow for multiple uses and automation and avoid data re-entry. This is the ability to effectively and efficiently manage and communicate project data among collaborating firms. This reduces waste in the design process. It is inaccurate, that a single BIM "model" will be created by the project team, it is rather more accurate to think of a federated set of inter- related BIM models, created by different members of the project team, but with the ability to exchange information between their differing software platforms (Wickersham, 2009). According to Ashcraft (2007), it is imperative that the chosen BIM products and analysis tools allow for 'round tripping' i.e. the ability to transfer information accurately from one program to another, and be accurately returned (if needed) to the originating program after it has been enhanced elsewhere.

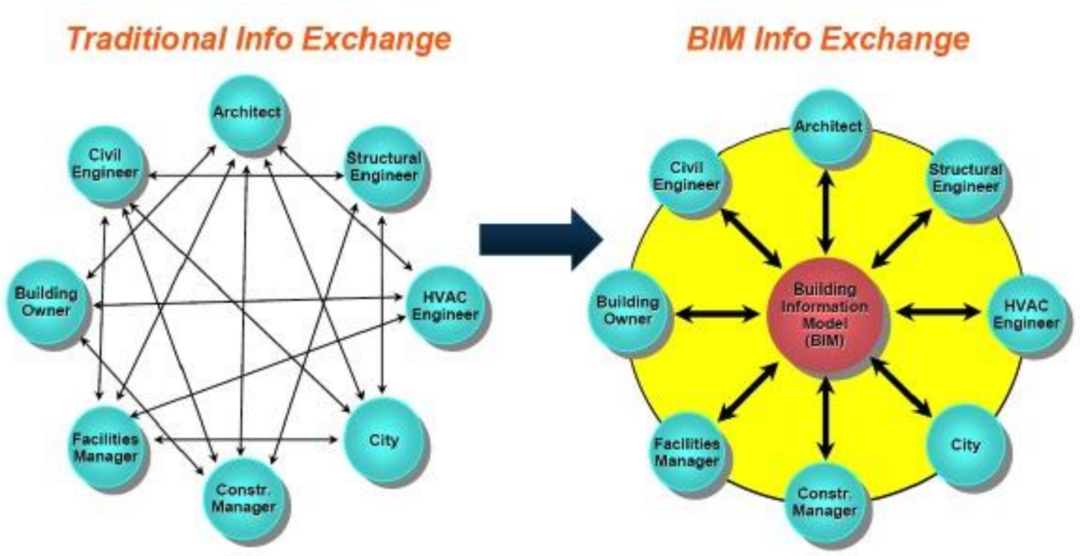


Figure 3.11: BIM Interoperability and Integrated Processes (Foster, 2008)

On the one hand, interoperability has been achieved evidently in the current ease of transfer of geometric information from one program to another. On the other hand, it has not been achieved as additional data describing attributes of design elements may or may not be successfully transported. This is typical of design tools with dissimilar features. A transfer of information between the two will see only the common features translated. Thus, rendering some information lost. For example when two parties to the contract use the same software by different models e.g. AutoCAD 6 and AutoCAD 7, data transferred from AutoCAD 6 will be translated in its entirety in AutoCAD 7 but not the other way around. Data translated from CAD 7 to CAD 6 will be in part because there are new programming upgrades that CAD 7 has that CAD 6 doesn't have but CAD 7 would have all the programming of CAD 6. Even if the data is translated accurately, the adequacy of the data translated is also very important. Therefore, it is important for persons transmitting and receiving data to understand and agree on acceptable tolerances and currency (Ashcraft, 2007).

Ashcraft (2007), asserts that interoperability is a critical factor in transitioning to Integrated Project Delivery (IPD). Interoperability is the backbone of IPD without which the integrative and cooperative model envisioned would not be realized. Revit BIM system is one of few software developed to facilitate interoperability between related models. According to Steel et al (2012), when making a decision to adopt BIM, the project team should consider four different categories of interoperability proposed by “buildingSMART alliance” under the Industry Foundation Classes (IFC). They are: File level interoperability, Visualization level interoperability, Syntax level interoperability and Sematic level interoperability.

3.7.3.3 Model hosting and archiving

This issue arises with the question “who will host the model?” The host may be an internal of an external vendor. During construction and post-construction activities, the host has the responsibility for model use access, record keeping, archiving, warranty, protection of the model and preserving the model for use in later litigation (Foster, 2008). it must be mentioned that all the risk associated with information technology; system crash, computer viruses, hackers, etc. must be taken into consideration at this stage.

3.7.3.4 Training

The lack of technical knowhow and consequently obtaining training is one of the steepest barriers of adopting BIM. Design firms have to put this into consideration before changing their systems to BIM systems. Foster (2008) outlines a number of important issues for design firms to consider before making the leap. They are as follows:

Table 3.4: Key Issues to consider before adopting BIM

Issues	Description
Steep learning curve	These software packages are complicated and require a great deal of time to master. It is best to train small groups of employees at a time, rather than to attempt to convert an entire company at once.
Few advanced users	Most advanced users appear to be younger architects that lack extensive design experience, while older architects have extensive design experience, but lack the required technological ability to use BIM software. A solution may be to establish a mentor program where an advanced BIM user is paired with a senior designer lacking software experience, creating a two-way learning experience.
Duplication of content	If a component has been accidentally duplicated (i.e., a window on top of a window) and this is not corrected before the job is sent out to bid, this can affect the contractor's price.
Details done in 2D	Details must still be done in 2D and are not necessarily linked to the virtual model.

Source Foster (2008).

3.8 Legal Impact of BIM

One major issue that impedes the adoption of BIM is the legal fog that comes with it. Contract Law in constructions can only thrive on clear lines of responsibilities. BIM blurs these lines due to its collaborative nature. Conflicts on a construction project are a regular occurrence but when it becomes impossible to identify who is responsible for design errors and allocate responsibility, then contracting parties do not feel safe. Now, the absence of this safe, this protection, or comfort, is what hinders a lot of construction firms from adopting BIM.

For example, in the United States, the Spearin doctrine is the go to case that exonerates contractors from owners' claim of defective and non-conforming work. It holds that a contractor is not liable to any functional faults arising from the completed works based on strict conformity to the owner's design plans and specifications (Foster, 2008). Here responsibility of defects arising from the owner's plans and specifications are quickly shifted onto the owner's architects and engineers. Now, BIM does make this rather difficult as a result of its collaborative nature.

3.9 BIM Adoption and Implementation

According to Arayici et al (2012) "BIM implementation increase productivity, efficiency, quality; reduce costs, lead times and duplications, collaboration and communication of stakeholders within remote construction projects. Unlike many other construction practices, there is no single BIM document providing instruction on its application and use" (Azhar et al., 2012).

The effective Implementation of BIM not only requires significant changes in the way construction business works but also, requires learning new software applications, reinventing the workflow, training of staff and assigning responsibility (Arayici et al, 2010). In the absence of any BIM implementation guideline, thorough planning and commitment is needed in order to make adoption successful. According to Ashcraft (2007), a number of questions will have to be considered. They are:

1. How will the model(s) be used?
2. Who will own and/or license the model(s)?
3. What is the model's contractual status?
4. How will modeling requirements be specified?
5. How will the model be administered?

How will the models be used?

According to Ashcraft (2007), participants to BIM contract should have an understanding of how they should create and manage their data on the system.

Who will holds license to the model(s)?

Ownership of model has been discussed in previous sections within this chapter. Here, we discuss the three primary options of ownership in a BIM contract.

Owner owns modeling information

This is also known as 'owner owns' approach. Institutional and public owners will typically subscribe to this ownership approach as most information are created for them. e.g. contract document (Ashcraft, 2007). Here, all participants to the project must be licensed to use the modeling information for project purposes. However, in the case where design professionals develop their own standard library of elements and/or custom elements, for use on the owner's design model, designers should reserve the ownership of their standard library elements for use on future projects. Also, designer's indemnity against liability arising from later modification and reuse of model elements must be insured.

Designer owns modeling information

Where designs are seen as the architect's instruments of service, all other parties to the contract, owner, contractor, etc. will need licensing from the architect to use the information. However, since the owner's license allows for limited reuse and modification, the designer must be indemnified against liability arising from such modifications and reuse.

Everybody owns what he or she creates

There is also the approach that all parties own whatever they create which requires cross licensing between all parties and individual insurance.

What is the model's contractual status?

According to Ashcraft (2007), before the advent of BIM, only hardcopy drawings printed from a model could form part of the contract document. The 3D model itself could not be accepted due to the fragility and risks associated with information technology. Therefore, BIM it was denied contractual status. However, in recent years, the three-dimensional model is now being considered as part of the contract documents.

How will modeling requirements be specified?

There are two standards here; the performance specification standard and the hybrid specification standard. The former states the goal of BIM use without specifying how it will be accomplished while the latter, details the types of allowable software, depth of interoperability requirements for modeling (Ashcraft, 2007).

How will the model be administered?

There are three distinctive aspects of BIM administration. This is because there are three different tasks that need to be performed.

1. The first task is the information technology task – the model needs to hosted and securely and reliably.
2. The second task is the administrative task – rights to access specific project areas need to be granted, audited, and enforced.
3. The third task is the professional task – competent professionals are responsible for model content.

BIM contract most specify who will handle all these individual tasks and also specify who will control and coordinate contents.

3.10 Strategies for Adopting BIM

The introduction of BIM in the design and construction process promises improvements in communication, capital savings, reduced delivery times, mitigation against disputes, and reduced waste in the delivery process. However, this requires a commitment to develop new workflows and competencies (Arayici et al, 2010; Ashcraft, 2007). An action research conducted by Arayici et al (2012) on an Architectural firm suggested 'four' stages to BIM implementation. The stages can be seen in Figure 3.12 and further expanded in Table 3.5.

A set of guidelines outlining an effective strategy and methodology of implementing BIM at an organizational level has been proposed by Arayici et al (2010) to include three 'cycles' or phases. Although this implementation strategy was proposed for a case study, a study and an understanding of the intricacies therein may be useful for this research.

Cycle one

Cycle one has the main focus of finding out which BIM tool is the most appropriate for the firm based on the firm's specific features and prioritized needs. The first step is the Exploration of BIM tools and efficiency gains identification: It involves an exploration of BIM tools, identification of firm's efficiency gains, development of test cases from past projects, piloting the BIM tools on the past projects, and making comparative analysis of the BIM tools, before making a decision. When diagnosing for the best tool that fits the firm's needs, it is imperative to identify prioritized needs and Key Performance Indicators (KPIs) that are to be achieved through the adoption of BIM. These can be done by evaluating the firm's processes against lean principles, and by analyzing current practices of the firm and areas of wastes and possible value generations via SWOT analysis (Arayici et al, 2010). The second step involves the development of test cases from past projects specific favored BIM tools chosen after diagnoses stage. These tests are to be experimental studies or trial versions of all the considered BIM tools. Firm's staffs are given the opportunity to try the software and select the ones they are most comfortable with and provide proper justification. It is important to note that some members of staff may view certain tools favorably than others. Therefore, the need for legitimate justification is needed as against some abstract unquantifiable feeling. The next step involves piloting the BIM tools on past projects – an assessment of the test performances of the considered BIM tool. The main aim is to test the flexibility of the tools. An exercise that is critical to understanding how a BIM tool aligns itself to specific company requirement. After applying the BIM tool on past project, the performance must be kept against the test checklist of forty criteria. Following the beta test, a quantitative analysis is to be carried out. This could be done through a matrix analysis where each criterion in the checklist is given a score between 1 and 5 signifying the extent to which the BIM tool meet the corresponding criterion by each tester. The results of the quantitative analysis should reveal the BIM tool that is most favored by the firm's staff (Arayici et al, 2010).

Cycle two

Arayici et al (2010)'s second cycle involves diagnosis towards lean design processes and in order to do that the first step is to access the impact of the new technology on the firm's processes and overall productivity. The next is the implementation of the selected BIM tool on different current project. This stage will not only show how much efficiency can be achieved via the BIM tool but also provide an opportunity to train the staff and increase their skills to proficiency levels. After implementation the BIM tool, the next step is the piloting and development of project support information

(PSI). This aids an understanding of what is required to construct BIM models to then achieve lean efficiency gains and leaner design practices.

Cycle three

By this time, the firm has learnt much about the BIM tool and its fit with the system. Here, the firm needs to reinforce the efficiency gains by identifying further needs for further improvement via automation. This can be achieved by establishing standards to BIM modeling; developing BIM object library and catalogues based on the BIM tool. However, the object library must comply with relevant building regulations. The benefits of this library will then be evident in improvement in the overall process with regards to time, cost, quality and skill. After the development of the BIM object library, a documentation of process and procedures should be carried out. This could be done in the form of a guidance manual so the library can be successfully tested on future projects. At the end, an evaluation of the impact of the BIM adoption on the company's process and practices can be obtained.

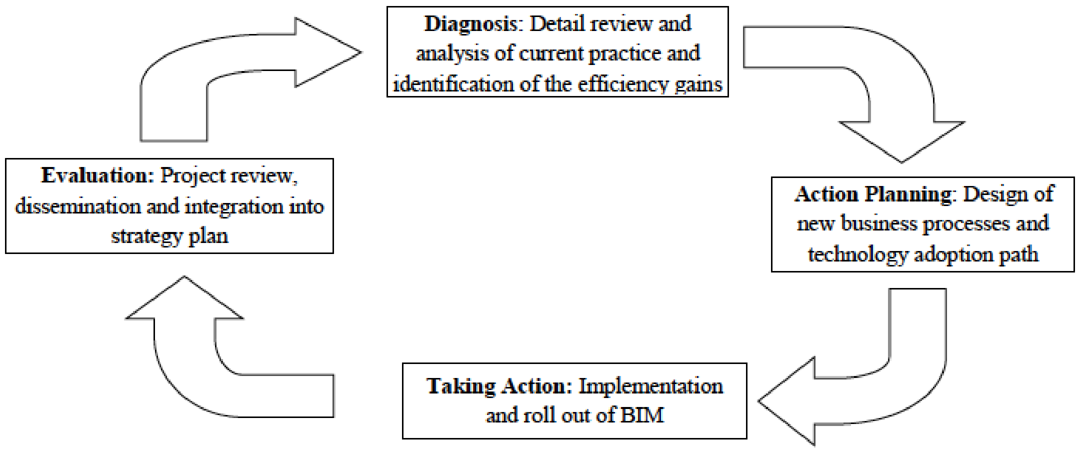


Figure 3.12: BIM Implementation Approach (Arayici et al, 2012)

Table 3.5: Activity within the BIM Implementation Stages

Stages	Activities	Implementation Strategies
Stage 1: Detail Review and Analysis of Current Practice and Identification of Efficiency gains from BIM implementation	Production of Current Process Flowcharts Review of overall ICT systems in the company Stakeholder Review and Analysis Identification of competitive advantages from BIM implementation Review of BIM tools for the company Efficiency gains from BIM adoption	Soft System Methodology Process Innovation
Stage 2: Design of new business processes and technology adoption path	Production of detail strategies Documentation of Lean Process and Procedures Development of the Knowledge Management system Documentation of BIM implementation plan	Soft System Methodology Process Innovation Information Engineering
Stage 3: Implementation & roll- out of BIM	Piloting BIM on three different projects (past, current, and future) Training the staff and stakeholders Devising and improving companywide capabilities Documentation and integration of process and procedures	Soft System Methodology Process Innovation
Stage 4: Project review, dissemination and integration into strategy plan	Sustaining new products and processing offerings Evaluation and dissemination of the project	Process Innovation

Source: Arayici et al, (2010)

Similarly, Foster (2008) proposes a strategy for adopting BIM that will achieve a commercial, collaborative and a legal environment most sustainable to the broad adoption and growth of BIM technology. According to Foster (2008) there are four steps that must be done when developing BIM as a new project delivery system. They are as follows; Develop appropriate business model, Develop BIM contract and specification language, Implement integrated project delivery tools, and Purchase appropriate insurance. Now, let us look at Foster's 2008 BIM Implementation approach.

3.10.1 Develop appropriate business model

This entails developing a business model that incorporates proper "compensation" and "risk allocation and reliance". According to Foster (2008), firms invest significant portions of their resources in order to implement BIM for the enhancement of their procedures and services. However, it appears that there have been little financial benefits provided to the design professionals. Foster, recommends that project owners must absorb the responsibility of providing designers with a portion of benefits related to increased efficiency and lower project costs by adjusting existing design fee structures. Performance-based bonuses are a solution to this problem. On of the only ways of knowing the application of BIM on a project has actually accrued benefits promised, is through the 'actual construction cost' and not on the budgeted cost. Now, what the Foster proposes is that there must be shared benefits for the project participants based on project success. Only then can the industry see a real and wide spread adoption of BIM.

We have reiterated on a number of occasions the risks and reliance issues of adopting BIM. BIM collaboration definitely blurs out lines of responsibility and hence, requires appointment of the model that controls and coordinates the flow of information in the model. There is also the question of reliance – that is, to what extent should parties to a contract rely on design information submitted by other parties? Both this issues must be addressed early on in the project contract document. The project 'agreement' must show early on that design and construction services are priced to reflect the exposure retained by each project participant. It must also contain information that addresses liability limitations, liquidation, indemnity and consequential damages due to errors in the model.

3.10.2 Develop BIM contract and specification language

When adopting BIM, traditional lines of responsibilities still apply. They only need to be expressly defined to fit in the context of BIM. These defined roles and responsibilities must be understood and accepted by all parties. Only then, can appropriate allocation of risks be achieved. Each contracting party needs to have control over its own model and makes the designs available of for comments and criticism, conflict-checking, and problem solving without changes or updates being made by other parties (Foster, 2008). The model host is the sole director of the 'composite model'. He maintains the availability, security, and version control of the data. Foster (2008) advocates the use of a list of questions developed by Larson and Golden (2008) when adopting BIM. Although, he states that these questions are not exhaustive but must only be seen as a guide. These questions, he says must be expressly addressed in the BIM contract agreements.

3.10.3 Implement integrated project delivery tools

At the moment, there is not a formal standard form agreement governing the implementation of BIM system on a project. In the United States however, two independent bodies; ConsensusDOCS group and the American Institute of Architects (AIA); produced two documents; the ‘ConsensusDOCS 301: BIM Addendum’ and the “Integrated Project Delivery; A Guide to help define the concept of integrated or rational contracting for project delivery”, respectively, to help facilitate the transition from traditional 2D contract to today’s 3D world. These standard documents mark significant steps toward utilizing BIM as a collaborative tool (Foster, 2008).

3.10.4 Purchase appropriate insurance.

The complicated environment that BIM and its integrated processes provide requires insurance of both general and professional liability. According to Foster (2008), BIM accelerates the already fading lines separating professional services and contractor’s means and method. It is imperative to get coverage against general and professional liability. Implications Of BIM Adoption Frameworks In Construction

Based on current problems of the AEC industry’s lack of experience in BIM Gu and London (2010) produced a collaborative BIM decision framework to make BIM adoption easy for industry professionals by relating said professional’s likely BIM adoption with experience of same on existing collaboration tools from other projects. By implication, this framework is not for professionals with zero BIM knowledge. But aimed at those professionals who are BIM “ready” or actively implementing BIM particularly those with Level 1 and above proficiency under the BIM Maturity Level chart by the UK BIM Task Group.

Table 3.6: Scoping activities, purpose and phase matrix - non-technical requirements

Scoping activities	Purpose	Project initiation	Concept design	Developed design	Bid documentation	Tendering	Construct	Commission	Occupation	Refurbishment
8 Non-technical strategic steps 1. Identify purpose(s), extent of BIM and map to project phases 2. Define model ownership, funding source, owner requirements, management structure, and boundaries of responsibilities for model and/or submodels for all project phases including: Contractual roles Obligations and protocols for model management Interrelationships between collaborators 3. Develop business plan for BIM integration including financial and time constraints and appropriate resourcing for training and support 4. Integrate design consultants model developers with document management systems managers 5. Undertake scoping analysis of collaborator competencies according to capability Levels 0–3 6. Conduct BIM adoption workshops for selected senior executive and project level participants towards developing a collaborative culture and creating a BIM communication strategy to raise awareness and identify conflicts 7. Develop BIM technical support levels for collaborators: Level 1: start up training for inexperienced collaborators Level 2: tool and model server support for collaborators Level 3: long term education related to knowledge management strategy 8. Develop knowledge management strategy for capturing learning for future BIM integration projects	Community marketing	■	■		■	■	■		■	■
	Client presentations	■	■	■					■	■
	Discipline design sub-models		■	■				■		■
	Interdisciplinary design collaboration		■	■				■		■
	Multidisciplinary design collaboration		■	■				■		■
	Design review		■	■	■	■	■			■
	Design analysis		■	■	■	■	■			■
	Subcontractor tendering				■	■	■			■
	Construction information management				■	■	■	■		■
	Facilities management operations	■						■	■	■
	Facilities management maintenance	■						■	■	■

Source: (Gu and London, 2010)

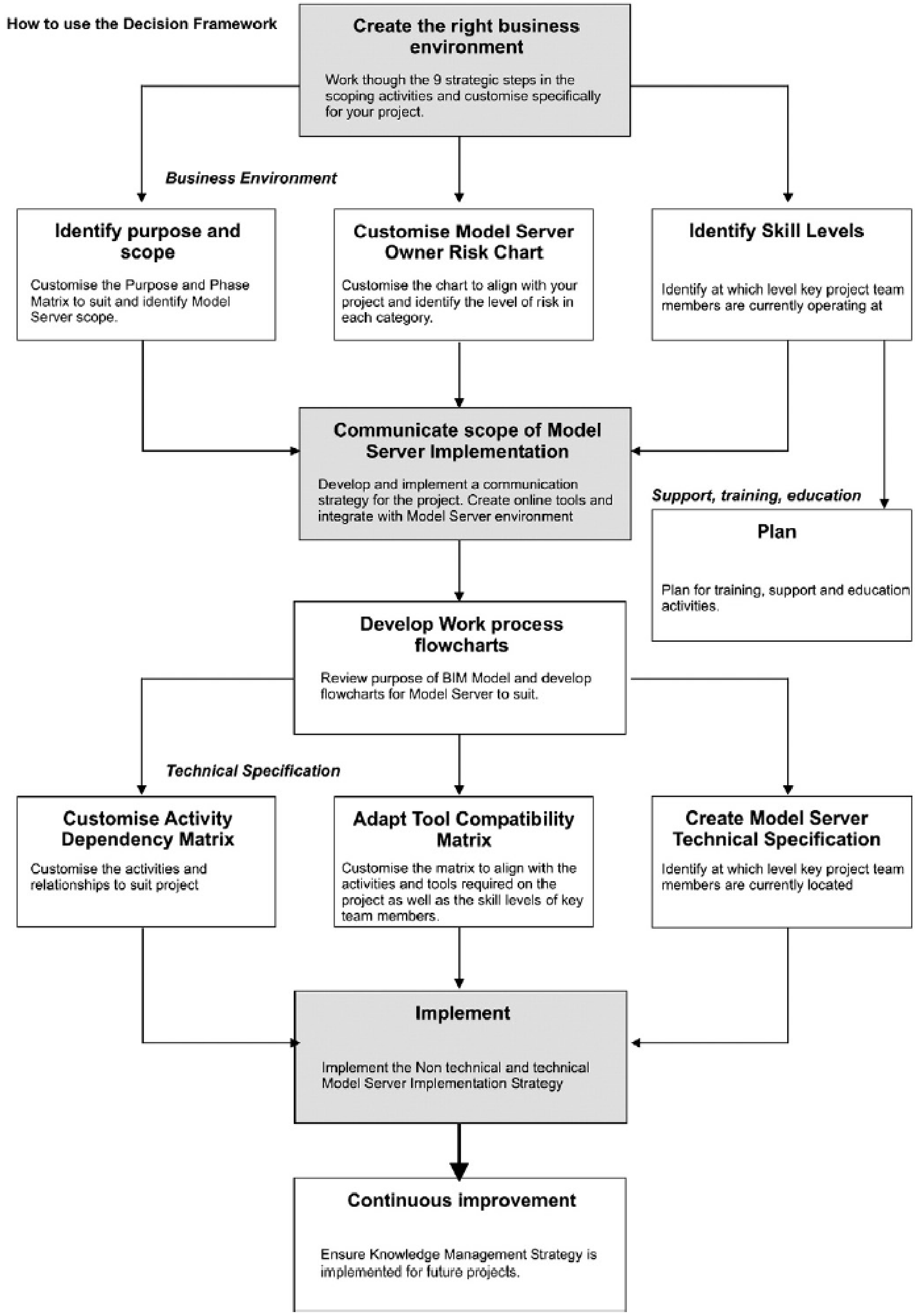


Figure 3.13: BIM Model server implementation using the decision framework (Gu and London, 2010)

3.11 Drivers for BIM Adoption

There are several drivers for BIM adoption. Many of which are the benefits of using BIM. Based on a research conducted by Eadie et al, (2013) it was found that users of BIM ranked "*Clash detection, government pressure, competitive pressure, accurate construction sequencing, and cost savings through reduced re-work,* as the top five drivers of BIM." The drivers are listed below in order of user rank.

3.11.1 Clash Detection

BIM has been proving to show clashes in structures, services and fabrics as its 3D visual representations and animated simulations of the building enables the detection of clashes between different elements of the building to be seen and corrected before physical works begin. Azhar et al (2008) found a 10% cost savings on contract value and up to 7% reduced project duration through BIM clash detection. Traditionally, this corrections would have been during the construction phase of the project resulting and rework, and more often than not, incur high un-recoupable costs (Eadie et al 2013; Azhar et al, 2008).

3.11.2 Government Pressure

In most countries, the government is usually the biggest client for the construction industry. The UK government, the Australian government, the United States government, Europe, Middle East, and many other governments around the world are using their large share in the construction industries' annual turnover to introduce on a nationwide scale measures that will ensure sustainability for the future of the industry (Eadie et al, 2013). At this time, both the UK government and the Australian government have made 2016 the threshold from which no public sector funded project will be awarded without the contractor showing a satisfactory level of competence in BIM. In the case of the UK, "Level 2" is that minimum satisfactory level (Efficiency and Reform Group, 2011; buildingSMART Australasia, 2012). Government policies have started changing to reflect the government's vested interest, as number one client, for better value for money, sustainable design and construction through BIM adoption (Arayici, et al, 2011).

3.11.3 Competitive pressure

Eadie et al (2013) found that 'competitive pressures' was third in the main drivers for BIM adoption in the construction industry. Given that 2016 is the deadline for contractors to start showing satisfactory BIM capabilities before they are considered for government contracts, it makes sense that contractors would be prepping their design departments to become 'BIM experts' in order to have a competitive edge in the market. Private clients are not behind in the demand for better services; pretty soon, this will be the new norm in the whole construction market.

3.11.4 Accurate construction sequencing

Construction delays, time and cost over-runs can be mitigated against with accurate construction sequencing. Time over-runs could prove to be very costly. Within the BIM software, is 4-D BIM, which is a detailed scheduling tools (Eadie et al, 2013).

3.11.5 Cost savings through reduced re-work

One of the major causes of delay in construction is the submission of "RFIs" – Request for Information and/or "AI" – Architect's Instruction (Dickinson, 2010). With regards to the former, the time it takes to respond to this requests causes delays leading to project overruns; while the latter, more often than not, has to do with variations in design, and hence, a change in the work executions. Both may lead to significant project cost overrun detrimental to the success of the project. BIM has proved to reduce RFIs and AI significantly (Eadie et al, 2013). Other drivers of BIM are: Client pressure, Improve Built Output Quality, Time Savings, and all the benefits of BIM serve to motivate adoption of BIM.

3.12 Measuring the Benefits of BIM

According to Barlish and Sullivan (2012), a relevant and accepted calculation of BIM's benefits has not yet been established. Therefore, there is a bit of confusion on how to measure project outcomes for companies trying to determine if BIM has or will benefit them, Barlish and Sullivan (2012) proposed a framework for benefits measurement based on Return metrics and Investment metrics. For any major capital investment in BIM to make sense, the benefits and cost savings must outweigh its up-front cost and risk of rework, whether in the short term or long term. On the other hand, ‘Return on Investment (ROI)’ matric for BIM can be used to measure such benefits (MHC, 2014). MHC (2014) affirmed Barlish and Sullivan (2012) statement by stating that there is no single widely accepted method for calculating a company’s return on its investments (ROI) in BIM. Instead, BIM benefits is measured based on users’ perception of the value they are receiving for the time, money and effort expended on their BIM program. A research by McGraw Hill Construction (2014) on ROI for BIM in several regions in the world found that most firms’ ROI on the BIM investments were between 10% and 25%.

3.13 Integrated Project Delivery

The push for efficiency in the construction industry by clients/owners has increased interest in exploring alternative methods of project delivery, including construction manager-at-risk, fast tracking, and contractual clauses that fall within the umbrella of “Integrated Project Delivery” (IPD) (Wickersham, 2009). The American Institute of Architects California Counsel (AIACC) defined Integrated Project Delivery (IPD) as “a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction”. IPD and BIM are not the same concepts but the technology of BIM is intertwined with the process of IPD (Ashcraft, 2007). Although the two can be and are mutually exclusive, the synergy of the two produces far greater results. BIM augments IPD because it provides that platform for collaboration from inception to completion by combining design, erection instructions, fabrication information and project management logistics in one database.

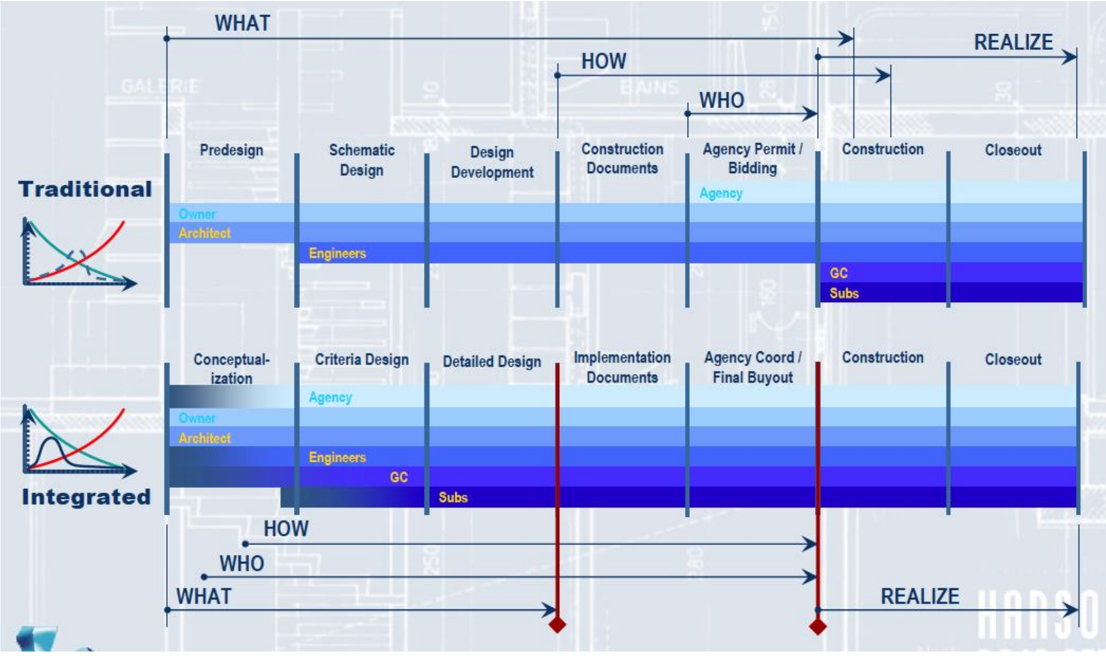


Figure 3.14: Integrated Project Delivery Process (Ashcraft, 2014)

3.13.1 The Implication of Integrated Project Delivery

Wickersham, (2009) descrides two elements to IPD: collaborative design process and sharing of financial risks/rewards. This has given rise to the development of a number of new contract forms such as; "Tri-Party Agreement for Collaborative Project Delivery" issued by ConsensusDocs in 2007 (Form 300); relational 3-party contract issued by the Lean Construction Institute; "Transitional", and the "Single purpose entity (SPE)" documents. Wickersham (2009), asserts that, the difficulty in getting the construction industry to embrace new technology and processes calls for a gradual, incremental approach – "*an evolution, not revolution*" of IPD. According to Ashcraft (2007) there are three main implications of IPD most of which are legal issues. They are:

1. An increase in process cost
2. A shift to allocation based on project outcome rather than from fault based liability allocation
3. A change in work and cash flow

An increase in process cost

The initial preparation of setting up teams and process design phases that is required in IPD takes a lot of time because it is a period where the project participants are interact and build bond thereby revealing if the team can work together or not. IPD is only worth it on projects of sufficient size. The payoff of IPD can be realized through greater project efficiency.

A move from fault based liability allocation to allocation based on project outcome

In IPD, project risk sharing is reflected by liability waivers, which limits or reduces traditional industry claims. This greatly reduces the parties' risks. Instead, project outcome risks are allocated through compensation incentives provided the risk is mitigated. However, if risk occurs, then the responsible party's reward/compensation/profit is reduced accordingly. Though risks are allocated in the contract document, this method of compensation under IPD makes it less likely for claims such as economic loss doctrine, third party reliance, privacy, and warranties to be effective and the parties have to rely on individual insurance to project them against risk.

A change in work and cash flow

In IPD design is expected to be finished in totality at the earlier phase of the project. This requirement shifts the timing of design cost and puts emphasis on greater detailed design to be performed by designers, contractors, and all parties to the contract. IPD work process requires reinventing the workflow, and training staff and assigning responsibilities. This needs some getting used.

It is also imperative to point out that many of the legal issues relating to BIM also apply to IPD, but more intensely (Ashcraft, 2007). Legal issues such as; design ownership, professional responsibility and liability, insurance, intellectual property, etc. These issues can be dealt with adequately by clarifying roles and responsibilities in the contract document.

3.14 Summary

Chapter three introduced the concept of Building Information Modeling (BIM), definitions, benefits and criticisms, the adoption of BIM, challenges of adopting BIM, drivers, barriers, implementation of BIM in the AEC industry, and the future of BIM and Integrated Project Systems (IPS). It was revealed that BIM is widely used around the globe with US, Brazil, Germany, Australia, France, and the UK leading the way, respectively, in the percentage of contractors with high BIM implementation levels in the world. It was also revealed that by 2016, contractors willing to bid on UK government projects must attain a fully collaborative 3D BIM as a minimum, which is also known as “Level 2 Competency.” Literature also revealed a number of BIM implementation frameworks, some for western and others for Middle Eastern countries. These frameworks will serve to guide this research in its quest to developing a framework for the uptake of IT and BIM by SMEs in the Jordanian construction industry.

4 CHAPTER 4| RESEARCH METHODOLOGY

4.1 Introduction

Selecting an appropriate research method that best answers the research question is essential to the concreteness and validity of the research. It is imperative to state how the research intends to achieve its objectives. In this section, the research discusses how it intends to achieve its aims and objectives, and will begin with an overview of the selected research philosophy, followed by the process and the structure for this research. The research philosophy will be followed by a discussion about the research methodology used. The discussion about the research method includes an overview of quantitative and qualitative research methods, and selection criteria, and the research strategy. A detailed justification of the data collection method will be provided by looking at access to the field and interview schedule, interview style and questions, ethical considerations and selection of the companies, followed by a description of the data analysis method used.

4.2 Research Philosophy

Saunders et al., (2009) describes research philosophy as that which is concerned with the development of knowledge and the nature of that knowledge. Saunders et al (2009) classified research philosophy into three schools of thought - ontology, epistemology and axiology. They also point out that it would be misleading to think that one philosophy is “better” than the other as they are “better” at doing different things.

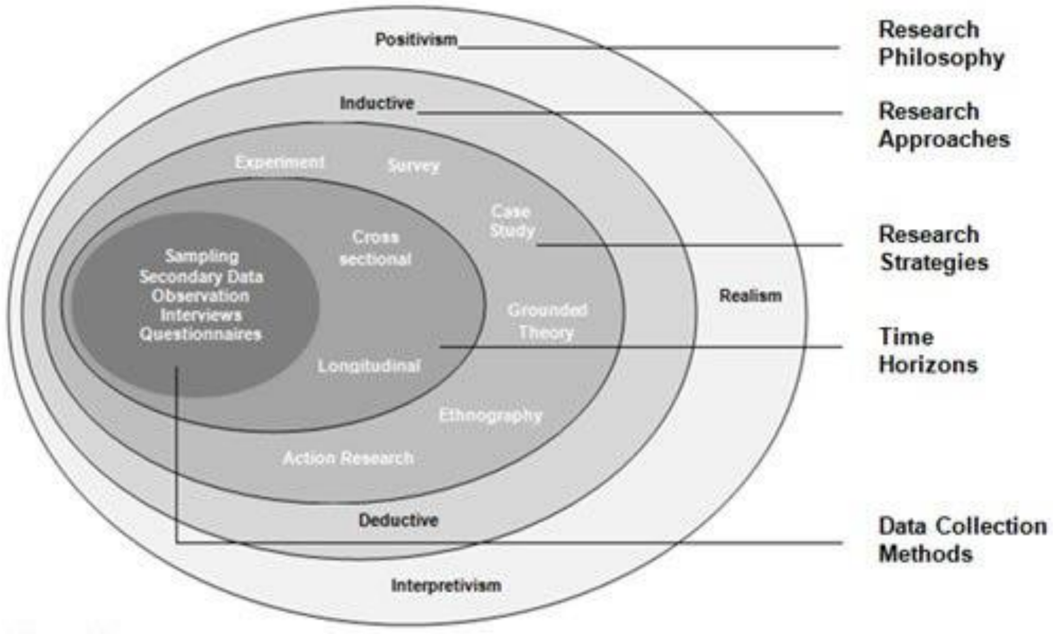


Figure 4.1: The Research Onion (Saunders et al., 2009)

4.2.1 Ontology

Ontology studies the nature of reality and the assumptions that govern the way the world works. There are two characteristics of ontology; objectivism and subjectivism. Objectivism assumes that social entities are independent of social actor, (in other words), the actions of social actors are as a response to the social entities in their environment. Whereas, the subjectivist school of thought holds that social phenomena are created from the perceptions, interpretation and consequent actions of social actors (Saunders et al., 2009).

4.2.2 Epistemology

Epistemology explores what is considered to be acceptable knowledge in a particular field of study (Saunders et al., 2009). Epistemology is a general set of assumptions that guides how we perceive the nature of the world (Easterby-Smith et al. (2002). There are different titles attributed to philosophical stance within epistemology but typically, they have similar meanings. Saunders et al., (2009) classifies epistemology into positivism, realism and interpretevism.

4.2.2.1 Positivism

According to Saunders, a research using a positivism philosophy is likely to represent a natural scientific approach where only observable phenomena can lead to credible data. Similarly, Remenyi (1998) furthers on this, stating that, *"working within a positivism philosophy implies that the researcher is working with an observable social reality and that the end product of such research can be the derivation of laws or law-like generalization similar to those produced by the physical and natural scientist."* A researcher adopting a positivism approach will be concerned with facts rather than impressions and undertake the research in a value-free way (Saunders et al., 2009).

4.2.2.2 Realism

This is similar to positivism with the difference being that in this case the realist research assumes that objects exist independent of our knowledge of their existence (Saunders et al., 2009). There is direct and critical realism. Direct realism says what we experience through our senses portrays the world accurately, while Critical realism advocates to the notion that our sense deceive us sometimes and that what we see may not be the actual reality. An example, from Saunders et al (2009) explains this perfectly using the umpire/referee in a game of rugby or football. The direct realist referee would defend his decision by saying "I gave it as it is" while the critical realist would defend his by saying "I gave it as I saw it".

4.2.2.3 Interpretivism

The interpretivism approach is concerned with the understanding of the differences that exist between people as social actors (Saunders et al., 2009). A researcher adopting the interpretivism approach would need to enter the social world of the research subjects and understand their world from their point of view (Saunders et al., 2009). Usually, the researcher is open-minded as to allow the research to flow and take new direction as new findings erupt.

4.2.3 Axiology

This is the third perspective in research philosophy. Axiology is a branch of philosophy that studies judgment about values (Saunders et al., 2009). It tries to understand or weigh the extent to which our values play a part in our judgment, impact on the choice of methodology, or even the topic of research. There are two sides to axiology; value-laden and non-value-laden. Researchers from the natural sciences claim that they are less influenced by their values. In fact, it cannot change the outcome. For example, the test if a liquid is acid of base. The litmus paper will either turn blue or red. So, their value has no impact on the results. However, Saundres et al., (2009) claims that for the researcher to choose to do that research, he or she has, in-fact been influenced by their values.

4.3 Philosophical stance of this study

Within the context of the research philosophy, the aim of this research is the development of a framework for the adoption of BIM by the SMEs in the Jordanian construction industry. The ontological stance of this research falls into the subjectivism continuum as this process involves different stakeholders and the fact that their "subjective" perceptions and decisions collectively, and "socially construct" what is seen as the BIM "phenomena". In addition, this research includes special emphasis on the adoption of BIM by the construction industry SMEs. Different perceptions and experiences of various construction companies who have currently adopted IT in their processes will be analyzed. Accordingly, this research recognizes and values such differences and has therefore utilized in-depth interviews with a number of construction companies and experts to understand their different perceptions. From that point of view, the epistemological stance of this research will lie in the interpretivism approach. Furthermore, the data collection process includes interviews with different sources. The researcher believes that personal interaction with the interviewees is of high importance in order to obtain a good insight into the interviewees' perceptions and to understand the context of the phenomena being discussed. Hence, from the axiological stance, this research will be value-laden in nature.

4.4 Research Approach

According to Saunders et al., (2009), the research approach relates to theory development. There are two types of approaches to research, deductive and inductive (Research Onion).

4.4.1 Deductive Approach

Within this deductive approach, the researcher develops theory and hypothesis (or hypotheses), expresses the hypotheses in operational terms, thus explaining the relationship between variables, and tests these hypotheses before examining the results, and (if required) modifies the theory according to the findings (Robson, 2002 cited in Saunders et al., 2009). It is interested in establishing causal relationship between variables and the researcher is relatively independent of what being observed in order to satisfy the principle of scientific rigour (Saunders et al., 2009).

4.4.2 Inductive Approach

In the inductive approach, no theory is developed before data is collected. Rather than creating a cause and effect link independently as in the deductive approach, the research using the inductive approach believes that an insight into the way in which humans interpret and perceive their social world is critical and is particularly concerned with the context in which such events take place (Saunders et al., 2009).

This research is mainly a combination of exploratory and explanatory. The principle objectives of this research are to understand the reasons behind the slow pace integration of advanced IT such as BIM by the Jordanian construction SMEs. The research involved in this study is deductive approach.

4.5 Research Strategy

There are two research strategies namely ‘quantitative research’ and qualitative research’. According to Naoum (2007), deciding which strategy to follow depends on the purpose and type of the study and the availability of the information, which is required. This is where the decision is made as to whether qualitative or quantitative data is used (both can also be used). Saunders et al., (2009) points out that both quantitative and qualitative techniques and procedures can be used in the same research. They categorized research choices into two main categories; mono method which refers to using a single data collection technique and its corresponding data analysis procedures; and multiple methods which, uses more than one data collection method (Saunders et al., 2009). Multiple methods can be divided into multi-method and mixed-methods study. Multi-method is where more than one method is used, either quantitatively or qualitatively, and the results are analyzed in accordance with their relevant procedures, whereas, mixed-method is defined as "using both quantitative and qualitative data collection techniques and analysis procedures in one research design" (Saunders et al., 2009).

As said in earlier sections, not much has been written on the adoption of BIM by construction SMEs in Jordan. Due to the nature of the research, and the limitation in the amount of knowledge this research will be exploratory in nature. It also implies that a qualitative approach will be adopted in order to explore the impact (benefits and cost) of adopting BIM by construction firms in Jordan. The aim is to diagnose the situation and to discover new ideas and not to test or verify existing theories (Naoum, 2007).

Table 4.1: Difference between quantitative and qualitative research

Topic	Quantitative research	Qualitative research
Research enquiry	**Exploratory, descriptive and explanatory**	**Exploratory, descriptive and explanatory**
Nature of questions and responses	Who, what, when, where, why, how many Relatively superficial and rational responses Measurement, testing and validation	What, when, where, why Below the surface and emotional responses Exploration, understanding, and idea generation
Sampling approach	Probability and non-probability methods	Non-probability methods
Sample size	Relatively large	Relatively small
Data collection	Not very flexible Interviews and observation Standardized Structured More closed questions	Flexible Interviews and observation Less standardized Less structured More open-ended and non-directive questions
Data	Numbers, percentages, means Less detail or depth Context poor High reliability, low validity Statistical inference possible	Words, pictures, diagrams Detailed and in-depth Context rich High validity, low reliability Statistical inference not possible
Cost	Relatively low cost per respondent Relatively high project cost	Relatively high cost per respondent Relatively low project cost

Source: Yin (2003)

According to Saunders et al. (2009), the choice of an appropriate research strategy for a study is based on; the research questions and objectives, the extent of existing knowledge, the amount of time and resources available and the philosophical underpinnings. According to Yin (2003), research strategies are divided into experiment, survey, archival analysis, history, case study, action research, grounded theory and ethnography. No research strategy is perfect, each has its own advantages and disadvantages, however, they can be used for all three-research purposes; exploratory, descriptive or explanatory.

For the purpose of identifying a research strategy, we must understand the following questions the "who", "what", "where", "how", and "why" type of questions (Yin, 2003).

4.6 Research Methods

There are numerous research methods found in literature. These methodologies include: surveys, experiments, quasi-experiments and single-case research, case studies, correlational research and action research, grounded theory, ethnography, and archival research.

Experiment: This is the most common research strategy in science laboratory-based research. It is considered value free. The essence of experimentation is the ability to maneuver variables – to manipulate one variable, usually called the independent variable and recording to effect on the other variables known as the dependent variables. Experiments are used mainly to for testing and for proving theories.

Quasi-experiments: this method is like normal experiments only that the samples are not randomly selected.

Single-case research: this method is another form of experimentation that is characterized by an assessment of a certain phenomena and recording the findings over a certain period of time. Variables are also manipulated and the effect on other variables recorded. This is used in the field of clinical psychology, and medicine.

Survey: a research strategy that operates on the basis of statistical sampling. It is used to answer, what, where, how much and how many questions (Sounders, 2009). It is also a method for comparing existing conditions to standard ones and for building relationship between events at specific points in time. There are a number of survey methods but there is two main survey methods: the descriptive survey which deals with census-type data and analytical survey which deals analyzing causality. Surveys are used to gather data about people; thoughts, actions, and beliefs (Martin and Guerin, 2006). Within survey, there are numerous instruments used for data collection. The following are survey data collection instruments.

1. Questionnaires – self-completion or postal questionnaires
2. Interviews – structured and semi-structured interviews
3. Standardized tests of attainment or performance
4. Attitude scales

Case study: is an in-depth analysis of a phenomenon (Yin, 2003). The case study approach is designed to answer the "how" and "why" questions. According to Yin (2003) there are two case study research strategy types; single case study and multiple case studies. Single case studies are used for in-depth studies regarding extreme or unique events, whereas multiple case studies focus on identifying a number of occurrences of an event and then generalizing from the findings. According to Yin (2003) case studies are used to:

1. Describe causes of intervention within a certain context
2. Explain causalities in real life
3. Illustrate particular topics within a study
4. Explore situations where interventions occur
5. Evaluate studies

There are two approaches to case studies research

- Single case study – studying a single case
- Multiple case studies – studying multiple cases to draw similarities, differences or reinforcement of findings.

In general, the case study approach is linked with the qualitative method and it is an approach used for investigating and understanding the disclosure of the facts surrounding a particular phenomenon, which will help to achieve development of theory and contribution to the knowledge (Yin, 1994). Case studies are designed to bring out the details from the viewpoint of the participants within the context of the phenomenon. Tellis, (1997) criticism of case study research method is the issue of generalization of the research findings i.e. the results may not be widely applicable in real life. Yin (2009) also noted that the generalizability of a single case study could be achieved by using multiple cases. He further stated that case study like experiments are generalizable to theoretical propositions and not to populations or universe. Another criticism is that case studies are too long and researchers are usually swamped with too much data to analyze in which much has to be omitted (Hodkinson and Hodkinson, 2001; Yin, 2009). However, this can be overcome by using conventional ways of writing case studies as proposed by Yin (2009). There is also the criticism that often, the credibility of the findings of case studies are paralyzed by the sloppiness of the researcher in allowing equivocal evidence or bias views to influence the direction of the findings and conclusions. Just like in most quantitative research, to overcome bias, the researcher must demonstrate self-discipline in following systematic procedures to report all evidence fairly.

Correlational Research: as the name implies, this method is used to detect if, and explore why, a relationship exist between two or more variables or data sets. This is mostly used in social sciences and educational research (Cohen et al, 2000).

Action research: requiring active participation by the researcher throughout the process of the study, in order to highlight problems and provide potential solutions. Action research has been defined as "a form of collective, self-reflective inquiry that participants in social situations undertake to improve: the rationality and justice of their own social or educational practices; and the participants' understanding of these practices and the situations in which they carry out these practices" (Kemmis and McTaggart, 1988). Participants of action research must have a common ground and common interest.

Grounded theory initiated with data collection which theory is developed from and tested for validity.

Ethnography: the researcher becomes part of the group, and observes the participants behavior as they interact with their social world (Fellow and Liu, 1997).

Archival research makes use of administrative records and documents as principal sources of data (Sounders et al, 2009).

According to Naoum (2007), in order to answer the research question, we have to understand the context of the problem, which explores the question ‘how IT is currently applied by construction firms?’ The aim is to understand the current situation, identify the problems, and propose some changes to improve the use of IT by these firms. The latter approach is called the Problem-solving approach. Therefore, this research adopts two methods of data collection; the survey approach as there is limited amount of knowledge in the research area and the Problem-Solving approach as it seeks to bring corrective changes to improve the implementation of Building Information Method in the Jordanian construction industry.

In addition, the survey method was adopted because the research seeks to answer the question “how” construction firms Jordan are behind in adopting BIM systems (Naoum, 2007 p.45) on their projects by exploring the benefits and costs of the BIM systems with respect to the industry in Jordan. The lessons to be learnt from this study are intended to expand and generalize theories (qualitative) for use on future construction projects.

4.7 Choosing the Research Methodology

This investigation would involve the opinions, experiences, and perceptions of contractors and industry professionals on Building Information Modeling within the context of Jordanian SMEs. In order to achieve the research aim, the researcher has chosen the survey method as the most suitable. As a result of the nature of the data required, this research is a mixed method, that is, both qualitative and quantitative in nature, since the research will be seeking people’s perceptions and opinions, whilst, using quantitative approaches to establish frequencies. It is important to note that the quantitative approach will help in establishing qualitative outcomes (Marsland et al, 2000). As a result statistical tables and charts will form parts of the analyses.

Bearing in mind the nature of all the different research methods – their pros and cons, the survey method was seen as the best method of achieving the desired result. The limitation in the generalizability of Case Study and Action Research approach made it impossible to select this method. The purpose of this survey study is partly exploratory, i.e. to find out and understand "what" barriers exist in implementing BIM by SME contractors in Jordan. This is reflected in the "how" type of research questions developed for this study, which includes how IT influences the Jordanian construction industry. The remaining questions of this study include "why" type question. Therefore, in addition to finding out what actually happens in the Jordanian construction industry through addressing some "what" and "how" questions, this study is also intended to enhance the understanding of "why" such singularities occurred and therefore establishing causal-links between the observed phenomena through interviews with key contractors. This study will provide an insight into the decision making process as well as into the process of finding and creating solutions for challenges and obstacles experienced in the project delivery.

4.8 Criteria for The Selection Of The Survey Study

The selected companies are private construction companies in Jordan. The selection criteria will be based on several factors related to the sector, size, projects, investments, locations and experience in terms of IT usage and implementation. The sizes of the selected companies are small and medium enterprises. The companies selected are a mixture of new and experienced firms. Their experience in using and implementing IT was a key element for selection, to gain the best understanding of the implemented IT systems within the companies and a clear picture about the situation. The selected sample for this research study was based on a purposive sampling which allows the researcher to select respondents related to implement IT systems within the company.

4.9 Data collection techniques

Clarifying the research problem and background is the key element to deciding what the most appropriate research methods for data collection are. Several methods for data collection can be used separately or together to gain data and information. However, identifying the research limitations and understanding the applied techniques and methods are essential to achieving the benefit of the designed research strategy. There are a number of techniques for data collection in a survey approach. However, this research will utilize only three, literature, interviews, and questionnaires.

After choosing the research methodology and the data collection technique, it is important to determine whether the method and techniques will collect the data necessary to answer the research questions, and whether it will stand the test of reliability, validity, and representation (McNeill and Chapman, 2005).

1. *Reliability:* A method is considered reliable whenever other researchers use it or the same researcher used it again, and the obtained results turn out to be the same. When using participant observation, for example, the risks are always high that this technique is considered unreliable, as it cannot be repeated.

2. *Validity:* Whenever the collected data reflects truly what is being studied, then this data is considered valid. People respond to questions within a study, but their answers might not actually reflect the truth about them.

3. *Representativeness:* If the results achieved relevant to the group of people or the situation under study are also relevant to other people outside the group, then representativeness is achieved. Hence, one should then be able to generalize from the sample under study.

4.9.1 Literature

In order to achieve the aim of this research, a document review, interview and questionnaire was used as data collection techniques. In the initial stages, however, literature and document review is extremely critical and necessary to provide the basis of the inquiry, especially in terms of developing the initial conceptual framework. It is hoped that the literature review will result in triangulate data.

4.9.2 Interviews

The purpose of this research is to collect realistic information as well as thoughts of contraction firms on how IT and BIM systems are implemented. Therefore, it was felt that the most suitable method of data collection technique would be 'interviews'. Face-face interviews will be held with both senior managers of the construction company; procurement managers, site managers, project managers, program, scheduling managers as well as their respective supply chains in order to get their experience with BIM.

The research will use 'open-ended' questions in order to discover as much as possible about the issues of adoption of BIM in Jordanian construction companies. The interview will focus on the respondents' experience regarding the situation. Semi-structured interviews will be used throughout the survey study to collect the primary data, in order to gain further understanding of the views and opinions of the respondents. A semi-structured and in-depth interview provides the opportunity to further investigate the responses given. Participants may use words or ideas in different ways, therefore the opportunity to better understand these meanings will add depth and appreciation to the data obtained. This method may result to greater insight where interviewees lead discussions into areas not previously considered by the researcher but are significant to the research. The result should be that the researcher is able to collect a rich and detailed set of data. However, Saunders (2009) warns that the researcher needs to be aware that the manner of interaction with the interviewees will impact on the data collected.

4.9.3 Questionnaire

Questionnaires were also used in this study as a way of triangulating the data received and providing conclusions. Standardized questions were created and distributed (through either a paper-based or electronic-based interface) to a wide range of stakeholders and experts who are relevant to this study. Triangulation can be described as a process that involves the use of multiple research methods, for example, qualitative and quantitative, for checking the reliability of a research method and the validity of gathered data (McNeill and Chapman, 2005).

4.10 Research Process

Table 4.2: Research Process

Process	Research Theme	Tool and Method
Stage 1: Best practice in advanced IT and BIM in construction	Research problem identification	Literature review
Current construction practice and theory of advanced IT and BIM in the Jordanian construction SMEs	Develop research questions	Literature review and interviews
Investigate the factors impacting the adoption of BIM among SMEs in the Jordanian construction industry	Data collection	Semi-structured Interviews, and questionnaires
Develop methodological framework	Conceptualize the framework initial review	Data analysis and literature review
Validate framework	Conclusions and recommendations	Benchmarking analysis and literature review

4.11 Structure of the Interviews and questionnaire

A similar research, conducted by Alsahli (2011) on “construction organizations in Saudi Arabia”, identified six areas necessary for examination and investigation, which has suitably covered all aspects of IT, adoption and implementation in construction companies in the Saudi Arabia. Therefore this research is going to use these six areas to structure its investigative questions. The areas are:

- *The company history of using and implementing IT*: This is aimed at investigating and examining the process followed and the problems faced during the implementation of the applied IT system within each company.
- *The implementation process and IT roles within the company*: this is to identify if there are key performance indicators set to measure the performance of the IT system applied.
- *The organization's resources*: Many executives are not aware of resources' ability to improve organizational performance and contribute in developing competitive advantage. Studies have shown that the integration of the necessary resources and other organizational elements will lead to success or failure in IT implementation. To gain in-depth information, questions were designed to help understand the company's plans toward allocating and selecting the required resources for IT

implementation. In addition, the questions were aimed at identifying the difficulties faced in planning for the resources before and during the implementation process.

- *Change management*: Taking change management into account is essential to support the organizations' adjust to the new systems. But the fact is that the aspect of change management and its impact on IT implementation may not be well recognized by the organizations' top management, which could influence the implementation process. Research also clearly shows that reaping the benefits IT depends on the successful implementation of change management within the organization. The survey study questions focused on identifying the companies' actions toward change management.
- *IT alignment with business*: Planning for the implementation of an IT system should consider the alignment between the system and the organization as high priority otherwise the new system can just lead to the failure of the entire company. The survey study questions focused on identifying the alignment process followed, and the issues and problems faced by Saudi construction organizations.
- *IT implementation strategy*: The lack of a planned IT implementation strategy is a major barrier to IT effectiveness. Developing an IT implementation strategy is important because the organization needs to identify the steps required to achieve successful implementation and how to drive the investments. The research will take into consideration the IT strategies required to achieve successful IT implementation.

4.12 Sampling

The defined sample frame for this research covers three groups: construction firms (both civil and general construction), design firms, and facilities management firms in Jordan. This sample frame was chosen in order to narrow down the research population into a homogeneous set. Homogeneity in the sample population is important because it increases the chances of collecting data that is generalizable. This means that the greater the amount of shared experiences and common practices among participants of the research, the better the data set, and the more likely to get a representative conclusion.

4.12.1 Sampling techniques

These are the techniques used to draw out a sample out of a larger population. Oppenheim (1992) outlines a number of sampling techniques. They are:

4.12.1.1 Probability sampling

"This method deals with distributions and proportions of samples in relation to the target population. Using this method, the sample members are chosen randomly using random numbers/tables from a defined list, register, etc. of all members of the population. This results in what is called the simple random sample. If the population happens to be larger than a few thousands, generating a simple random sample and carrying out data collection becomes much more expensive. An alternative to simple sampling could therefore be used, cluster sampling that is. Cluster sampling applies random selection on a population's subdivisions created based on various characteristics. This provides the benefit of having sample members grouped geographically making it easier to collect data."

4.12.1.2 Quota sampling

"This method also deals with distributions and proportions of samples in relation to the target population. Using this method, research participants are not selected based on lists but based on certain quota instead. The "quota" used in this method represents a common socio-demographic characteristic between both the sample and the actual population. The sample would then contain the same proportions of characteristics as found in the target population."

4.12.1.3 Snowballing and judgment sampling

"These two methods are used when none of the population characteristics is actually known. The borderline around the target population cannot be drawn and consequently, it becomes impossible to come up with a sampling frame. In this case, the population is either inaccurately or partially represented by samples produced using those two methods."

In this research, small and medium-sized; construction firms (both civil and general construction), design firms, and facilities management firms; were chosen purposely because these are the firms that are likely to be using BIM systems. The reason for this choice is to gather information from firms, which have the most knowledge in design software and current market trend in the same. These are usually the target groups even for BIM software manufacturers. The companies to be interviewed were randomly selected within the sample population of small and medium-sized enterprises in the construction industry in Jordan. Simple random sampling technique was used; that is, choosing firms randomly using random numbers/tables from a defined list or register. The Jordanian Construction Contractors Association was kind enough to supply the research with a list of small and medium sized construction companies, from which the sample was randomly drawn. This sample of firms is expected to be reliable, valid and representative of the sample population

4.13 Data analysis

Data analysis procedures consist of examining, categorizing, tabulating, testing or combining both quantitative and qualitative results to address the original proposals of a study (Yin, 2003). Yin stressed that developing a general strategy for data analysis is essential as it may reduce potential analytic difficulties. Therefore, the research has adopted Carney's (1990) "Ladder for Analytical Abstraction". The ladder allows for large chunks of information from the interview tapes with respondents to be coded into some themes and trends for ease of analysis.

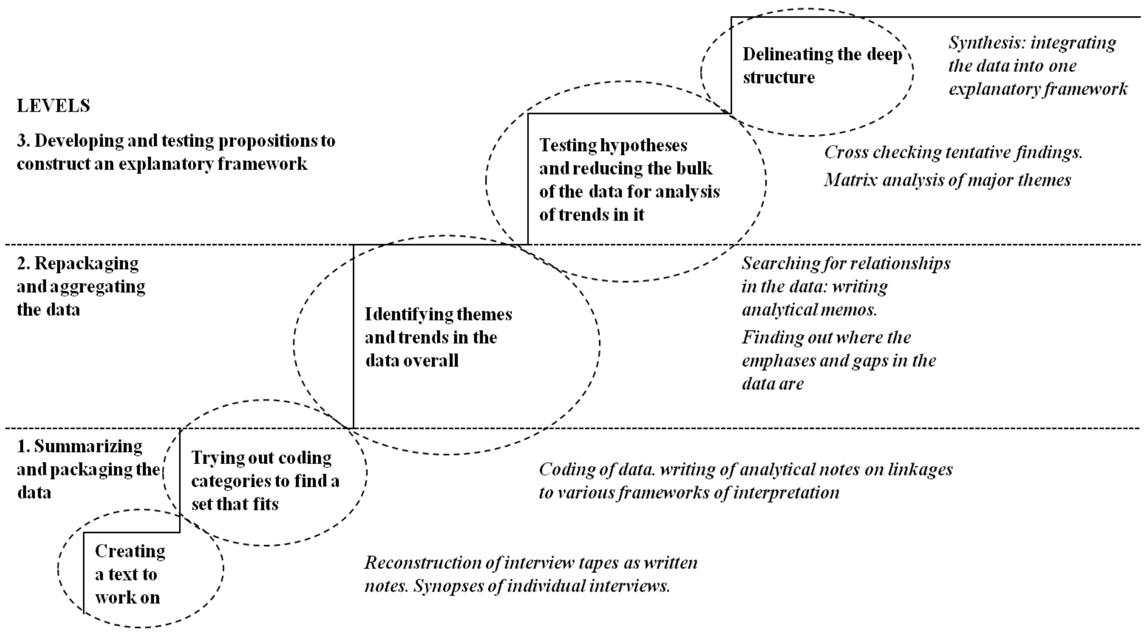


Figure 4.2: The Ladder for Analytical Abstraction (Source Carney's, 1990).

Before making an analysis, data collected from non-written evidence; such as interviews were transcribed into written accounts. The coded data was analyzed qualitatively but may lead to quantification of the qualitative data. The results of the quantitative data collected from questionnaires were also analyzed. This, therefore, emphasizes the mixed method research strategy adopted by this research.

4.14 Time horizons

There are two types of time horizons in the research planning; cross-sectional and longitudinal studies. The cross-sectional studies refer to a "snapshot" of the practical phenomena at a particular time. In contrast, longitudinal studies are a "diary" perspective or record of change of the occurrences over a period of time (Saunders et al, 2009). This research will be cross-sectional in nature as it seeks to take a snapshot of the impact of the advancements in BIM within the Jordanian construction SMEs.

5 CHAPTER 5| DIAGNOSIS OF SMEs FOR IT USE AND BIM ADOPTION IN JORDAN

5.1 Diagnosis of IT Use in the Jordanian Construction Industry

"Construction industry in Jordan and in other developing countries would be able to maximize the Return on Investment (ROI) in IT by going beyond basic applications such as word processing and spreadsheets toward more technical business applications like e-business, electronic data management and teleworking"

Attar and Sweis, (2010)

The construction industry in Jordan is an important sector of the economic activities of the country. It has become the largest in recent years. Like any construction industry in any economy, the Jordanian construction industry has had its ups and downs but has almost always enjoyed a high dynamic nature of demand. The construction industry in Jordan is presently requiring advanced technical and economic innovative management practices (Al-momani, 1995). The above quote is an abstract from the comprehensive research article on the relationship between IT adoption and job satisfaction within Jordanian contracting companies. It showed that more investment in technology would increase employee job satisfaction. This inevitably would transpire into increased productivity from the workforce, cohesiveness within the employees, improved communication and many other benefits relating to human capital. Furthermore, this study reveals that IT use in the Jordanian construction is basic, and that there is evidence of the benefit Jordan could harness from the use advanced IT. No doubt the industry would benefit from advanced IT such as BIM, e-business, management information systems (MIS) etc.

Table 5.1: Background of Participants

Company Size	Type of company	Participants' Role	Participants' age	Years of experience
Small	Civil Engineering	Engineer	55	35
		Contractor	39	17
	General Contracting	Engineer	49	26
		Quantity Surveyor	36	14
		Architect	48	28
	Civil Engineering	Owner/Engineer	41	15
	Civil Engineering	Owner/Engineer	46	23
	General Contracting	Owner Contractor	67	45
	Architectural firm	Architect	28	7
		Structural Engineer	31	11
	House Builder	Owner Contractor	46	24
	General Contracting	Quantity Surveyor	25	4
		Civil Engineer	53	30
		Architect/Owner	45	20
Medium	House Builder	Architect	47	17
	Civil Engineering	Civil Engineer	42	22
		Owner Contractor	58	31
	Civil Engineering	Engineer	40	19
	Architectural Firm	Architect	42	20
		Architect	51	27
	General Contracting	Owner Contractor	62	34
		Civil Engineer	38	10
	General Contacting	Engineer	39	15
		Owner Contractor	64	42

Goh (2005) had four things to say to companies considering the adoption of IT in their businesses:

Firstly, he warns against the *"technology for the sake of technology"* trap. This is where companies over-invest or adopt IT with no clear thought of the objectives or how it would complement its strategy – *Technoholism,* as Goh puts it. This is based on the delusion that an organizational problem can be solved by the application of the state-of-art technology. The right application of technology in a business yields great results. However, an inappropriate use can result in devastating results to the demise of the company. Processes might take longer than planned, costs might escalate, users might be left with less autonomy than they had before, there's also the risk of abrupt or slow spiraling down of company performance. Hence, the attempt to empower the people ends up crippling them because technology was deployed for the sake of technology's sake or for the sake of some future promise rather than for current business needs. This is also called the "empowerment myth" (Kanungo, 1999). A number of the contractors interviewed had similar views. When a lady civil engineer was asked to state why in her point of view, many contractors and engineers do not use BIM or haven't even heard of it yet, she stated:

"I think the first reason is ignorance, the second it has not become fashion in Jordan yet."

So to some extent, people have a feeling that adopting new technology is fashionable. Perhaps it shows that the company is ahead of its competition. The comment below touches on the ignorant bit of the comment above.

"Until now they are fixing the primitive methods they are using for long time. In general, for many companies there is no development... for them why to use BIM if AutoCAD is doing the same job?"

Secondly, Goh (2005) emphasized the *development of standards, integrated databases and interactive applications*. BIM adoption would require a change in existing work practice (Gu and London, 2010). Goh (2005) stated that Standards are critical for building integrated databases and interactive applications that are web-enabled which further play an even greater role in cultures of business, technology and knowledge. And, since IT is intended for better and more efficient information management and exchange, and a common language is required for machines to communicate, then, companies must also take advantage of the Internet to interoperate. A BIM system provides an avenue for collaboration and communication across disciplines where multiple parties contribute to a single shared model. Many participants expressed similar views. One of the participants was particularly emphasizing on coordination and pointed to one of the advantages of BIM, which is; a change in one model by the model manager effects changes across the board on all models belonging to other parties to the project. Therefore, everyone has the same information at the same time. Other advantages of this function are ease of communication and coordination. In the words of a participant interviewed on this study:

"There is always mis-coordination problems and pointing of fingers between engineers, contractors, civil engineers, mechanical, and electrical. But unfortunately there is no one (that) *works on BIM."*

"I do not know too much about BIM. But from the information I have about it, I think by using BIM if there is any editing or updating all the departments as mechanic or electric etc will get it and there will not be any problems. One of the biggest problems we face is that when there is editing or new revision to the project and one did not write it or edit it, a problem happens and delays occur as a result. I think BIM might resolve this problem (the coordination between departments)"

Thirdly, he emphasized that an investment in IT systems, must *support existing business strategy* in order to maximize business and/or operational potentials. Otherwise, the losses could be great and there will be no future justification for further investment in IT. Participants brought up different facets to this area. There is the aspect of size of business and the project that they can undertake. There is also the aspect of changing existing work practices to support BIM or new technology where benefits would only be seen in years to come.

"If I use BIM the work will be faster, but at the beginning it will be slower until they learn it, later on it would be easier coordination, and monitoring"

"The cost for using a new programme, the cost for training the employees, and the time spent on the training, and changing from one programme to another will reflect on the profit and the competition in the market."

Here, the participant was trying to say that not adopting BIM or new technology, is not so much about not having the desire to adopt the technology, but the fact that he feels it will affect the company's short term goals and growth.

Lastly, he states that the adoption of *IT must focus on people* and their needs – the ability to manage change. Problems always arise when there is a dogmatic top-down approach to leadership where management wants to force down changes on employees without adequate study: of their employees' needs, knowledge, and attitudes; the choice of proper channels of communication; and enabling systems for learning. Information Technology must focus on the people and their needs. IT is supposed to support the user and augment the process (Gu and London, 2010). Management plays a major role in the change and must work to motivate personnel to align with the new technology through training. Boddy et al (2002) states that, "understanding the power and interests of stakeholders vital in sustaining their commitment to industry programmes because essentially they have the power to help or hinder the change." Much of IT infrastructure and certainly BIM infrastructure development projects require long-term participation from stakeholders. Therefore, the process of managing relations with all involved to gain support or contain their opposition is continuous. Hence management has to understand its staff, to know how they will think about the change, to be able to predict reactions and corrective and alternative measures (Goh, 2005).

So while most of the participants acknowledge that BIM will be of benefits to their day-to-day activities and projects, most remain unsure how they can introduce it to their company staff given the nature of the people. The interview analysis indicates that there are several non-technical issues that need consideration in BIM adoption. There were numerous barriers mentioned that affect BIM adoption such as the age of the staff, years of experience on particular way of doing work (habit), language, and so on. Let's look at a few comments below.

Table 5.2: Participants' comments on barriers of adopting BIM in Jordan

Factors	Comments
Age	*"We are still extremely underdeveloped as a construction sector or system in the country, we have not reached a technical level and technology in construction as in Europe, we are still primitive and traditional at the same time. We have engineers 70 years old retirement age, if you ask them to log on computer, they will tell you 'sorry I do not know.' This is a problem, because there is no will to learn, research, or doing courses that might be expensive in their point of view.*
Experience and Habit	*"most of the employees are old and have 30 or 35 years of experience, so when you tell him about programmes immediately he refuse the idea. Of course 100% he will refuse, age plays a great role, because he will say "I thinks its like this" "I have been working 30 years and now you are trying to convince me that this programme will do what I was doing all these years!! " he wouldn't understand or get the idea. The age and experience play essential role."*
Attitude to learning	*"The nature of the people play a role, there are people who do not like to use something new so that they do not spend time*

	learning about it, so its easier for them to stick to the old system." *"the nature of the employees, their primitive methods and refusing developing, (they have no faith in new IT). And the nature of the customers, they prefer dealing with contractors on the old system to save money "why would I pay more for a design"*
Language	*"And one of the main problems that all the technology is in English. The language is a barrier for too many engineers, because our main language in Jordan is Arabic, so in order to learn English programme we have to learn the language first. Too many engineers do not have time to learn the language in order to take this programme, the language is a big barrier."*

With much of the participants completely oblivious of the application and benefits of BIM, the question of who is responsible for driving the awareness of BIM arises. From the researcher's interaction with the research participants it seems they are looking to either the Construction Industry Associations in Jordan or the Jordanian government to drive the BIM initiative. It is also evident that there is confusion on where to start. There is the need for guidance on where to start, what to do, whose help to employ, what the available tools and the right fits are, and of course, how to work through the procurement, legal and cultural challenges. Therefore the proposed BIM adoption framework for SMEs in the Jordanian construction industry will incorporate the needs of the industry. All these different components will be discussed in greater detail in later sections.

5.2 Corporate Culture

Culture is a significant factor in any organization and must be taking into consideration when attempting to make a change in the organization. Organizational culture or corporate culture is simply defined as a set of beliefs and values on which members of an organization share in common. However, a more in-depth definition is that by Mitchell & Larson (1987) refer to Schein (1985) who defined organizational culture as "a pattern of norms and values that is shared by the entire organization, not just by an isolated group." While, Johnson et al. (2008) refer to Schein (1991) defined same as "basic assumptions and beliefs that are shared by members of an organization, that operate unconsciously and defined in a basic taken-for-granted fashion an organization's view of itself and its environment."

Johnson et al. (2008) suggested four layers of organizational cultures that are prevalent. They are: Values, Beliefs, Behaviors, and Paradigm (taken-for-granted). It is important to note that more often than not, organizational strategies yield from the set of assumption and behaviors in an organization.

- *Values*: The values of organization commonly exist in written form as mission statement about the organization.
- *Beliefs*: Beliefs discern in how people collectively talk about issues the organization faces.
- *Behavior*: It is the way in which organization operates day to day and can be seen by people inside and outside the organization.
- *Paradigm*: It is a set of assumptions held relatively in common and taken for granted in an organization and are the collective experience applied to a situation to make sense of it and inform a likely course of action.

5.2.1 Corporate Culture and Jordan

Jordan is a country with deeply held cultural values and orientations. While Jordan is an Arab country that shares basic cultural values with the rest of the Arab World, particularly the Arab Gulf States, unlike the Gulf States, Jordan's economy is not oil-based, and the country does not rely greatly on external workers, because it has a relatively skilled domestic work force. Ali and Sabri (2001) found that the prevailing organizational culture in Jordanian organizations is "power" (personal power rather than organizational power) and that the most desired culture is "achievement". Top executives demand complete submission from their employees, and employees in return do not take initiatives that may not be sanctioned by top managers. This is also the culture found in construction companies. Top executives make all decisions and are unlikely to delegate because of the need to centralize power. Power culture, strengthens personal power at the top but marginalizes the power of the middle and lower-level managers and employees. In fact, Ali and Sabri (2001) found that top managers in Jordan, like most Gulf States, utilize rules not to minimize subjectivity but to glorify their position as the "all-knowing" and "supreme authority" within the organization. Al-Hegelan & Palmer (1985) found that "Arab managers avoid responsibility and risk-taking; prefer a stable life style over rewarding but challenging work; are highly concerned with job security; are reluctant to delegate authority; believe that centralization builds respect, and, finally, they give priority to friendships and personal considerations over organizational goals and performance." In Jordan and in many parts of the Arab World, a combination of the power culture and high levels of unemployment has resulted in individuals at work showing remarkable loyalty to their organizations. This loyalty is enhanced through careful cultivation of trust and employment security. Furthermore, these individuals normally show a high respect for managers who share information with them and give them opportunities to be involved in daily affairs. This reinforces their commitment and loyalty to the organization. It is obvious that there will be a lot of personal politics, lobbying, and nepotism going on in the work place.

Ali and Sabri (2001) recommended that Jordanian companies "should make sure that recruited senior managers are oriented toward organizational rather than personal power. These selected managers must encourage creativity, tolerate ambiguity and differences, and not be inclined toward arbitrary use of power. That is, companies should make sure that senior managers show concern for both human dignity and productivity." Organizational culture is hard to change. Never the less, certain aspects can be easily changed. This is because Islamic principles and some of the tribal traditions are not in conflict with ideal consultative and participative approaches. The planned educational programs should incorporate the elements of the Islamic instructions that condone responsibility and participation. Attar and Sweiss (2010) found that job satisfaction in Jordanian construction companies increased with increased investment in IT.

5.2.2 Connecting BIM with Company culture

BIM is more than just a change in technology. It is an answer to the many inefficiencies of the construction industry – the solution to the interoperability problems and fragmented nature of the industry. The inefficiencies of the construction industry are far greater than that of other industries, say, manufacturing. Many a people are required in order to finish a construction project and hence the need for collaboration. BIMTG (2014) defined BIM as “essentially a value creating collaboration through the entire life-cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them.” BIM’s interoperability and collaborative platforms seek to eliminate these problems by enabling better exchange of information within the project team and throughout the building lifecycle (Lindblad, 2013). It is important to note that the issues of industry fragmentation and poor collaboration are deep-rooted and arguably within the fabrics of the construction industry, and installing a better information sharing system will not, in one day, eliminate the problem. BIM adoption provides an avenue where all parties to a project can, together address these problems by enabling new work processes, which in turn, improves collaboration and increase productivity. The exchange of information between the various professionals will add more impetus to the efficient completion of complex structures. However, this efficiency level hoped for is quite hard to achieve in construction. In real life, people are difficult. Not only that, the large number of people and multiple information networks makes is easy for mistakes to happen. The adversarial nature of the industry means that people are generally not collaborative. Sharing of information is not very much in the culture of the industry, which, typically conflicts with the collaborative work processes associated with BIM. All individuals involved in the BIM adoption process will need to comply with the new collaborative work processes otherwise, much value will be lost. They also must be individuals with the interest and knowledge to make the change possible.

Needless to say, it will be difficult to introduce a system like BIM in a firm with a solid culture and deep-rooted values. The company staff members must be made to understand why it is that they are changing. The people considering BIM adoption must first understand what BIM is and the advantages that come with the system. The company should be willing to take advantage of that. According to Lindblad (2013) more efficient transfer of information will in itself not make projects better, but rather enable new and more efficient work methods. Therefore, BIM should not be the goal in itself but rather a tool to achieve the goals that BIM adoption promises. The people in the company must shift their attention to the goals they want to achieve with BIM rather than the technology itself. This mindset will definitely change the way BIM is used and culture changes, though hard, will be easier to accommodate.

5.3 Data Analysis of the Interviews Conducted With SMEs in Jordan

BIM has existed for more than two decades, and in the first world it has made its way into law. But in the third world, it is as though BIM is non-existent. It is time for the third world, and with respect to this research, The Kingdom of Jordan to start considering the impact of new digital technologies such as BIM. This research provides intriguing insights into the current and future direction of Information Technology, in particular BIM and SMEs in the Jordanian construction industry.

The positive side of it is, progress continues to be made in information technology adoption amongst construction SMEs in Jordan. The survey shows that the percentage of participants who use IT 'very much' in their day-to-day activity is a good 63%, for those who 'moderately use' IT is 25%, while those who 'do not use' IT at all is 4%. With this result we can dare to suggest that 88% of the construction SMEs in Jordan are aware and using information technology in their everyday activities. This is a positive statistic and the construction industry in Jordan can be sure to enjoy the many advantages of information technology and expand its doors to new and better technology coming into the market place.

Hence, the progress on the adoption BIM can only get better since the interview survey shows the percentage of the survey sample actually using BIM is 0%. However, the percentage of the survey sample that is 'Aware' of BIM is a good 62% while that of participants 'neither aware nor using' is 38%. Whilst these figures are good for the prospect of BIM adoption amongst SMEs in Jordan, many remain confused by the subject and, inferring from their attitudes, we suspect a lack of trust in the claims of what BIM can deliver. Many participants thought that BIM is just another 3D CAD software and did not see the need to explore it. To them, "why waste time and money switching to BIM when AutoCAD can do the same thing?" what we've tried to make them understand is that BIM is not just another 3D CAD but also a vehicle for the delivery of standardized and consistent construction information regarding quality, specification, vendors, facilities management, live cost analysis, scheduling, and so on.

Within the study, the participants have shown much interest in knowing about BIM but neither has shown any dedication to taking the plunge to adoption even in the next couple of years. The survey shows 59% ‘willing to adopt’ BIM but neither of them has shown any commitment. All of the participants who said they where willing to adopt BIM, maintained that they would do it sometime in the future. This emphasizes that more needs to be done on aware campaigns. BuildingSMART has started, but much has to be done. The government needs to get involved if adoption is to be expedited.

This research believes that if BIM can be demonstrated to be an effective information management tool that will lead to business efficiency and profitability, whilst debunking the idea that BIM is just another 3D CAD software, we will see great progress to BIM adoption among construction SMEs in Jordan.

5.3.1 Interviews Process

More than fifty construction professionals from construction firms (both civil and general construction), design firms, and facilities management firms in Jordanian were solicited for an interview to support this research reach its goals. These people were significant players and associates that cover all major areas of the construction small and medium enterprises in Jordan. The goal of the study was to find out and analyze the current situation of IT and BIM adoption amongst construction SMEs in Jordan. Only 24 responded to the invitation. This is close to a 50% response rate. Amongst these respondents are; business owners, civil engineers, architects and quantity surveyors. While civil engineers remain the largest group of participants, making up over 50% of participants, the other groups were very much significant to the research and of course, contributed immensely to the success of this research.

Previous studies have suggested that the various reasons for the varying adoption rate of IT and BIM in the construction industry is not limited to technological reasons alone, but include factors such as work practice, building new management systems, organizational structure, business interest, shift in existing legal and contractual measures, user training, culture and so on (Gu and London, 2010). Therefore, the research was familiar with some issues that could be mentioned by participants regarding the adoption of BIM in their firms. Over the course of the research journey, the study kept a core of questions that was used to ask every participant. This allows the research to track any changes and/or trends in the information given by participants and hence, industry.

Some of the interviews were recorded on tapes and somewhere accompanied with note taking lasting up to 30 minutes each. The data was first transcribed and the analyzed firstly using a content analysis to identify the main themes. After the main themes were identified a coding system was developed and applied to the data for detailed analysis. Through the analysis from the interviews the study was able to identify some industry need, concerns and expectations specific to the Jordanian construction SMEs regarding IT and BIM adoption. The coding scheme used for the data analysis was developed based on the dominant themes identified within the first content analysis and from literature review. These dominant themes were categorized under the following categories: Use of IT, Knowledge of BIM, Perceived benefits of BIM, Openness to adopting BIM, Challenges/Barriers to adopting BIM, and Drivers of BIM adoption. Within, these categories, sub-themes were also identified and analyzed. These sub-themes were in the form of keywords such as design, culture, knowledge or skill, communication, training, time, and so on. These keywords allows the identification of key and/or common factors across the different categories and hence participants, for which their priorities can be obtained by evaluating the frequency of their data occurrence. A detailed analysis of the data advises that most concerns about BIM adoption are on Lack of awareness and skill.

These categories were used in order to firstly; understand the present level of knowledge, awareness and interest of, first Information Technology and then, BIM amongst construction SMEs in Jordan. And secondly, to identify the priority issues across with regards to IT and BIM in the Jordanian construction industry. The interviews revealed the level of BIM awareness and knowledge of, and interest in Information Technology and Building Information Modeling across construction SMEs in Jordan. This research must emphasize that while the findings in the study are significant, it must only be taking as indicative rather than definitive of the construction SMEs in Jordan. At this point, let’s look at some of the limitations of the study.

5.4 Limitations of the study

1. The interviews were semi-structured in nature because the researcher needed to allow the participants to talk about anything they felt was related to their companies IT adoption experience – to share and clarify their views on various IT and BIM adoption issues such as requirements, hurdles, benefits and expectations of IT and BIM. This method of data collection enables the collection of more in-depth data on advanced IT adoption. It is important to note that the information received from this method of data collection is possibly influenced by the subjective opinions of the participants.
2. Also, the method of data collection obviously limits the number of participants compared to quantitative methods like questionnaires. Twenty-four interviews were conducted on construction professionals all of whom play important roles to the delivery of projects in Jordan.
3. The interviewees' roles ranged from; owners, directors, engineers, architects, quantity surveyors and site foremen. These participants have great experience, some of which have been involved in building projects of different scales in Jordan and overseas especially, the Gulf States and Africa. Nevertheless, it is also important to state that, as the interviews were conducted within Jordan, with most participants being based in Amman, Jordan.

Now, lets examine the data and see what clear trends have emerged from the study.

Table 5.3: Characteristics of participants

Company size	Number of companies	Number of Interviews	Average years of experience
Medium	6	10	23.7
Small	8	14	21.4

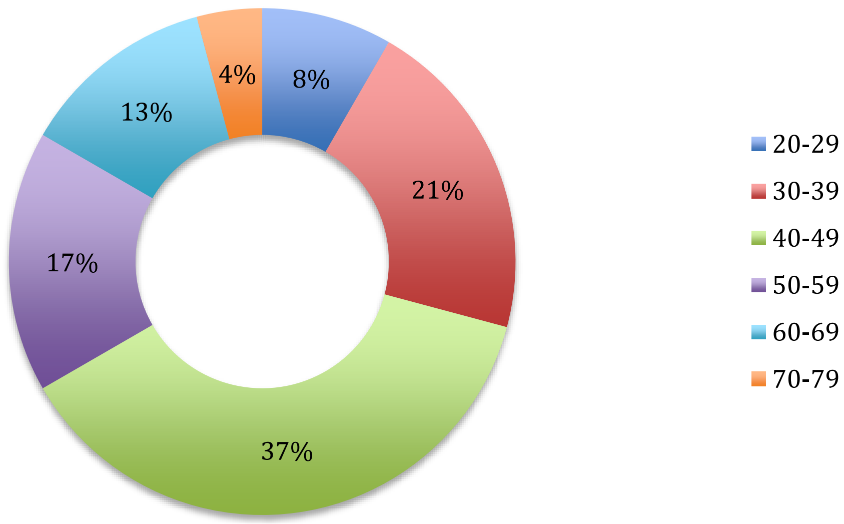


Figure 5.1: Age of Participants

5.5 Use of IT/BIM

This research was undertaken to propose a framework for BIM adoption amongst construction SMEs in Jordan. To achieve this, it was also imperative to find out the level of IT maturity in the same sector of the industry. This finding will not only assist the researcher to assess the degree to which BIM can be introduced and adopted successfully but also position the BIM as a value-added system that can help the company place itself at the high-end knowledge-based terrain of the sector – as a beacon of innovation amongst its pairs.

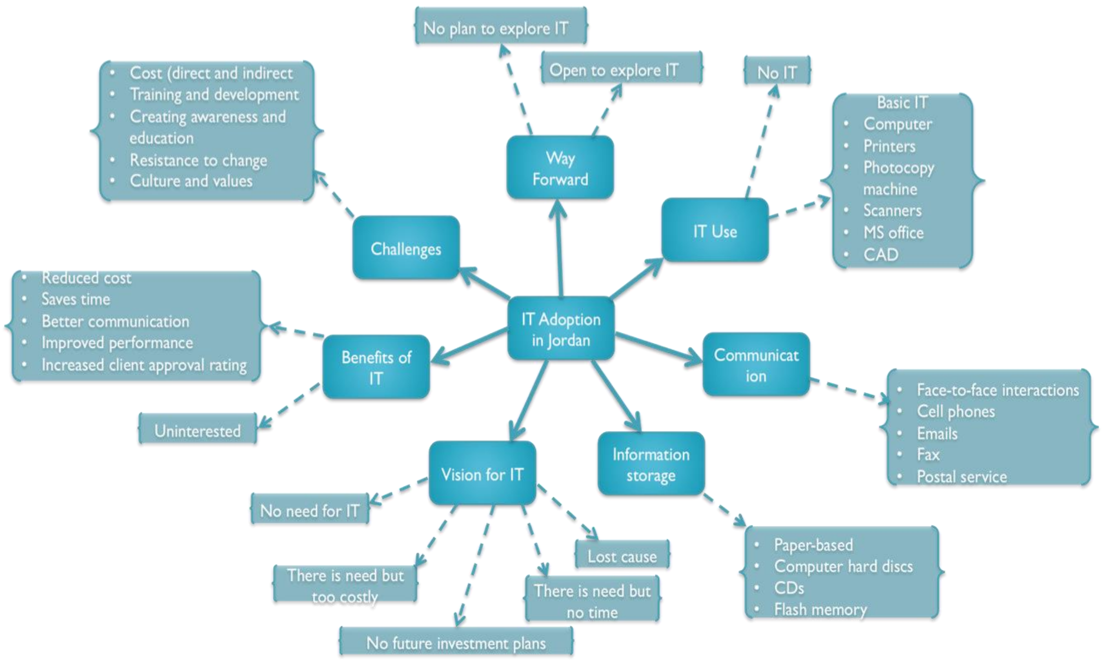


Figure 5.2: Particpants' comments on IT adoption in Jordan

5.5.1 Communication

The researcher asked two questions regarding communication; how are stakeholders' (clients, subcontractors, consultants etc.) inputs collected and recorded through the project life cycle? And, How is information shared? What's the dominant structure of information exchange? The answers received for the two questions were quite similar. Therefore it was deemed fit to put them together here. Majority of the participants, both small and medium contractors said they prefer face-face interaction or phone calls with clients and subcontractors. However, for legal purposes, most document exchange is paper based. Emails are also used to support communication. Others also said they use flash memory and Compact Discs (CDs) which are sent by post. Some slightly sophisticated information technology tools such as conference calls and intranet also not utilized. One of the participants eluded to cost as the main reason for not doing so given the size of the business and the size of the projects undertaken.

The interview participants were asked how what IT is used in their company to support their business? The participants from the medium companies said they use computers, internet networks for communication, printers, photocopy machine etc. the software are basic; MS Office and CAD for drawings. Two of the smalls companies said they have all the basic IT (as mentioned above) that supports day-to-day activity.

While another two do not use IT all. One of the participants said the only IT he has is a cell phone.

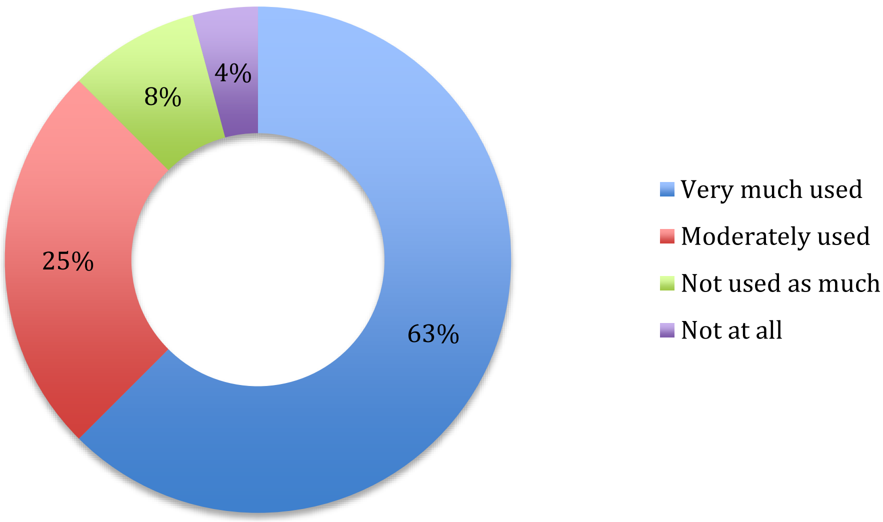


Figure 5.3: Participants' Degree of IT Use

96% of the research participants said they use IT in one form or another and to differing degrees. Of the 96% that use IT in some form, 25% said they moderately use IT and 8% said they do not use IT as much. Though, it is hard to believe 4% said that they do not use IT at all. Stating paper-based drawings as their conventional method of design and communication. At this point, it was important to point out to the participants some of the inherent inefficiencies of solely using paper-based designs such are disparities in design quality, duplications, lack of continuity in the supply chain, lack of effective design management and communication, and so on. To which one responded:

"I prefer papers, because if there is any error in the design I correct it with the engineer immediately… According to my work as a contractor we do our best to stay far away from IT but not too much. And the reason why we cant use computers because most of our work is in the desert… if there is a mistake we take a picture and we send it to the engineer by Watsapp"

21% of the participants stated that they use both 2D and 3D CAD in their activities and AutoCAD seems to be the popular software for design. 71% use only 2D CAD function of AutoCAD. They do not explore the 3D function because of the lack of know-how. Granted, it is not easy and will be a big culture-shift to move from traditional 2D workflow to a 3D BIM workflow, but it can be done, starting by training staff on the use of 3D software before making the shift. Some contractors eluded to thinking 3D AutoCAD drawings was equal to BIM. What they do not know and need to know is that the capabilities of CAD software – along with software independent formats and standards for information exchange – are a vital part of the BIM toolbox (NBS, National BIM report 2013) but there is so much more – the coordination and interoperability alone is a function that eliminates a ton of problems on the construction processes.

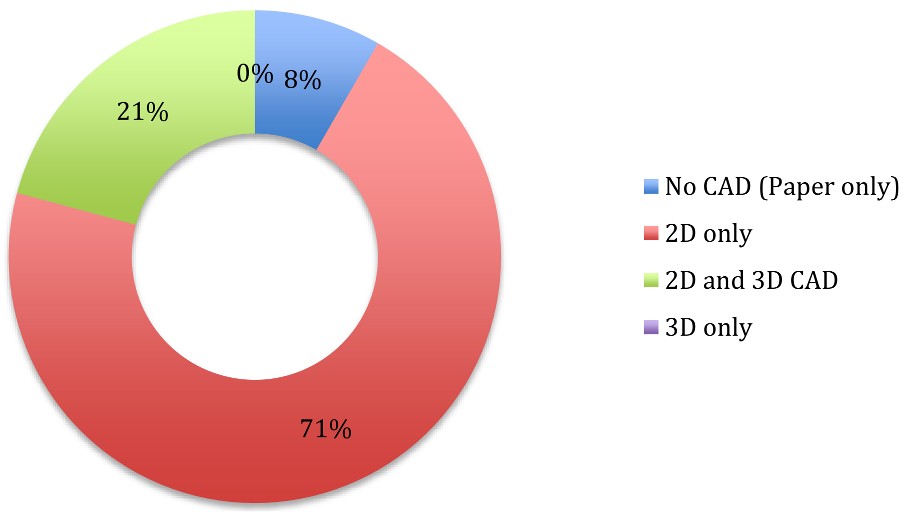


Figure 5.4: Participants Design Current Platforms

The participants were also asked how has their company used IT to monitor and improve performance (time and cost efficiency)? The participants from the medium companies said, their IT has help increase their efficiency, save cost and time. The participants shown some light on his point by referring to a recent project that required travel but with the Internet connection within the company, passage of information was swift: through watsapp, emails and fax, travel costs and risks were reduced, information was received quickly and effected.

"Jordan Whatsapp becomes a very important tool to send pictures in the project, or for the problems they are facing immediately. Before that, we have to send fax and wait for the reply back, so it was taking long time. Now it becomes faster and this is one kind of using IT for example."

While there is a small size of the sample population who do not employ IT in their day-to-day activities, a large size of the sample population believe that IT brings with it a lot of advantages and will continue to revolutionize the Jordanian construction industry.

"IT revolution helps them so much in the achievement and in improving plans. I think that in the future using IT will be wider and better and it has to deliver to everybody. But it will take longer time for employees than engineers because of the educational attainment."

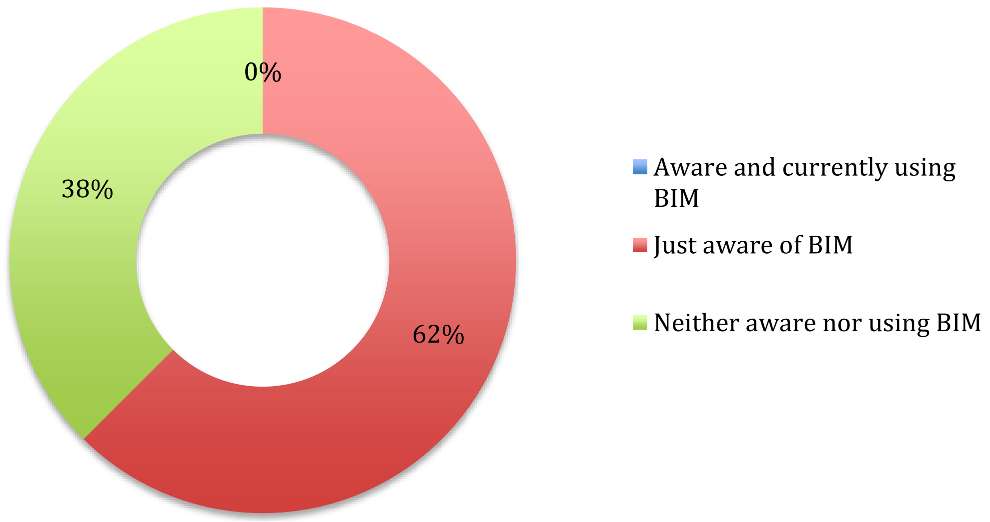


Figure 5.5: Participants Awareness of BIM

The participants were also asked their awareness of Building Information Modeling (BIM) systems. There was a zero response for he 'aware and currently using BIM'. On the bright side, 62% are aware of BIM. A handful is quite abreast with functions and benefits of BIM but majority have just heard of it by word of mouth or some other means. 38% however, do not know of the existence of BIM systems and therefore the researcher had to give them a quick rundown of BIM, its functions and its benefits to the construction processes and projects. When asked how is it they have never heard of BIM, the participants stated that course are not done about BIM and there are no journals permanently dedicated to talking about recent developments both locally and internationally. It was also interesting to see a chart showing the relationship between Awareness of BIM and Age of participants. A previous study by Attar and Sweiss, (2010) found that demographic data of employees in the construction industry such as Middle-aged employees had higher level of IT use than in older employees and that IT usage was higher for employees working in large companies. Similarly, this study revealed that those participants who were aware of BIM were between the ages of 30-49. The younger generations who haven't had much travel of exposure do not have much awareness of BIM since Jordan, is only starting to promote BIM. The older generation is somewhat an issue of interest as there is lack of interest to learn new technology and frankly, some just want to continue with what they are used to.

One of the participants, a civil engineer, was asked if he had heard of Building Information Modeling (BIM)? He said 'no' but then said he had taken a 3D training course ten years ago in the gulf. After explaining what BIM was, the participant said they used something similar while working in the gulf – very simple software, but could not remember the name of the programme. He was later asked what were the main problems he faces with contractors or owners on the job? He responded quickly by saying; *"Not using technology. Some of them understand and accept it, others do not, depending on their educational knowledge."* Furthermore, he was used if he thinks contractors using IT will make a positive impact? *"Yes of course, they will give you the precise answer without confusing you. As engineers we are willing to adopt"* Many other barriers to adopting BIM in Jordan were mentioned including, lack of awareness, distrust of IT, lack of interest to learn, and so on. These will be discussed in greater detail in later sections.

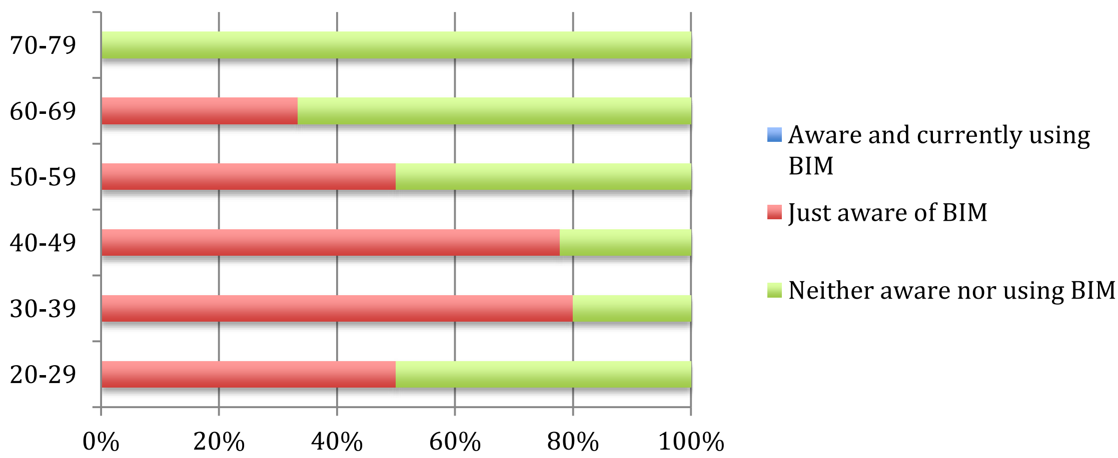


Figure 5.6: Relationship between Awareness of BIM and Age of participants

5.6 Benefits of current IT

Participants to the research seem to know enough about the benefits of information technology in construction. They were asked to list some of the benefits that they have enjoyed since adopting IT in their processes. The medium sized companies who have applied IT in their work processes answered this question quite similarly – Reduced cost, time, and improved performance, reduces working hours, clients are easily convinced with visual presentation of achieved projects to support planned projects. The small companies with basic IT use said that they couldn't say what benefits they've enjoyed. Although, they have enjoyed better communications as compared to their counterparts who do not have IT. These company's employees have smartphones and are able to take pictures of defects on site and instantly send it the engineers to alert them of the issue. Our findings marched up with the findings of Attar and Sweiss (2010) who found that the benefits that best contributed to IT adoption in the Jordanian construction industry were faster access to information, time and cost savings, and better communication.

"The most thing we use in technology, if there is a mistake we take a picture and we send it to the engineer by Watsapp."

The other two with no IT systems are simply not bothered because, in one's case, the nature of their business clients does not allow the adoption of IT, and in the other's case, the owner's traditional approach to doing work.

5.7 Perceived benefits of BIM

The researcher wanted to find out what participants' perception of what BIM could do for them after being told some of the benefits of the technology. The aim was to assess their attitude towards the technology. You can see from the findings in the chart below 67% are positive that BIM will improve their business, 29% are on the fence and quite unsure whether or not BIM will improve their business. One participant was kind enough to oblige us in this exercise by stating a number of advantages his firm could enjoy if they were to adopt BIM.

"Speed, punctuality, cost saving. If you use the programme you will save cost in long term for all parties of the contract. For example if the project takes a year, by using the programme you can finish it in Six months. In the end it saves the overhead cost for everyone, and finishes the project in the right time, and makes better profit than the traditional method we use nowadays."

One participant shared his understanding of BIM adoption to his business. We have to say his feelings were not unfounded.

"If I use BIM the work will be faster, but at the beginning it will be slower until they learn it, later on it would be easier coordination, monitoring follow of for construction based on number data without surveys (cutting time)."

However, 4% of interviewed participants did not feel that BIM would improve their business. Some participants shared their negative feelings about Information Technology and their fixation on traditions and how they like to work. These are some of the comments;

"I am a traditional man like working with papers"

"I prefer papers… they (employees) *all prefer paper… According to my work as a contractor we do our best to stay far away from IT but not too much. And the reason why we cant use computer is because most of our work is in the desert."*

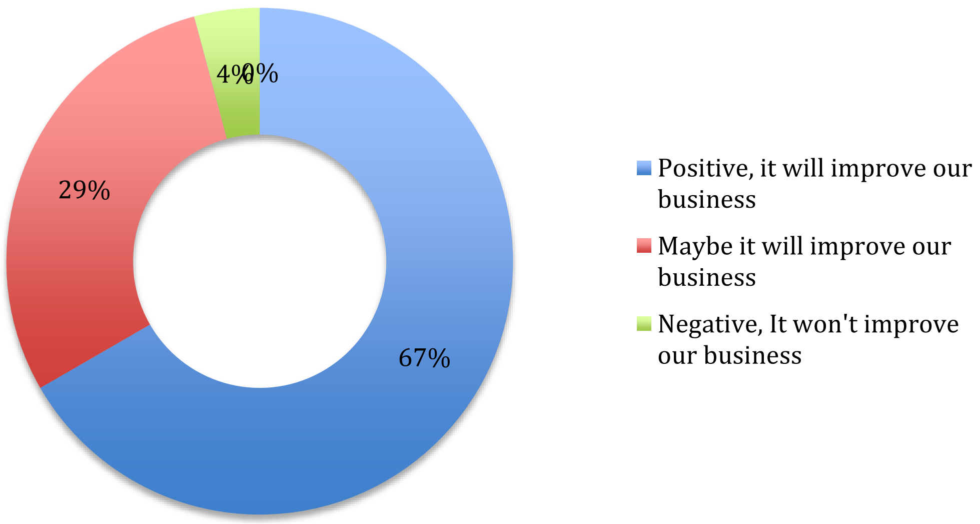


Figure 5.7: Participants' Perceived Benefits of BIM

5.8 Openness to adopting BIM

Within the study, the participants have shown much interest in knowing about BIM but neither has shown any dedication to taking the plunge to adopting BIM even in the next couple of years. The survey shows 59% are 'willing to adopt' BIM but neither of them has shown any commitment. All of the participants, who said they were willing to adopt BIM, maintained that they would do so sometime in the future, which suggests that more has to be done on aware campaigns. Quite a few were enthusiastic about the technology taking roots in Jordan. One states; *"BIM is perfect, we must use it in Jordan, new technology must be used to enjoy the advantages of it, to improve our work, save time and cost."*

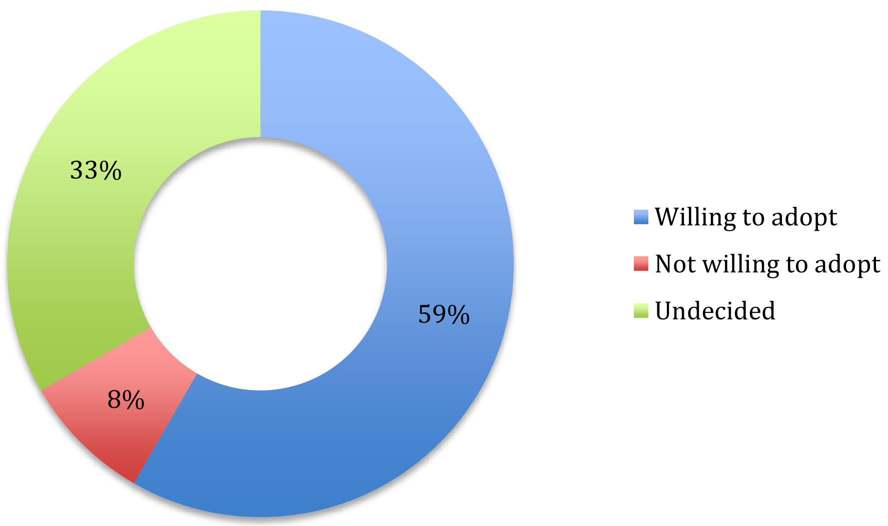


Figure 5.8: Participants' Willingness to adopt BIM

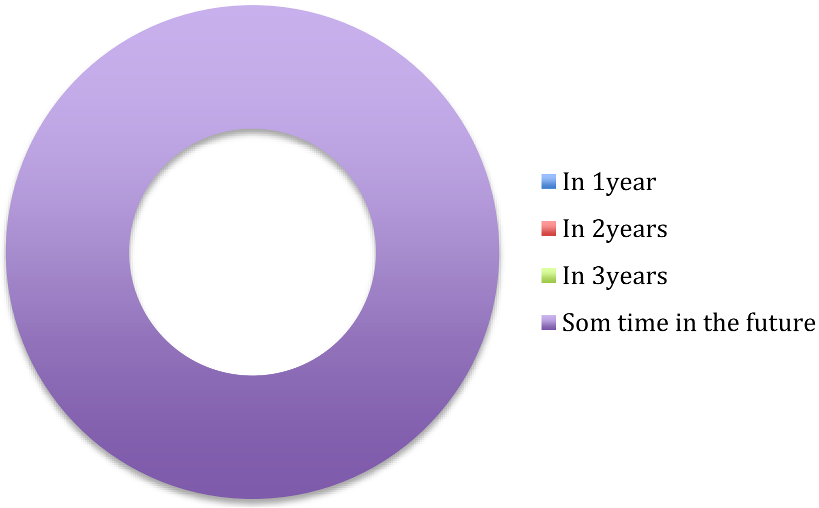


Figure 5.9: Participants' commitment to adopting BIM

Lastly, the researcher asked the participants what was the way forward for their companies regarding BIM adoption? All the companies had a similar approach to the way forward for their companies, which is to investigate further on, possible BIM and IT systems that could be of great benefits to them. For example the company that said they would love to improve on their systems but do not have the time to investigate further, stated they would appoint an IT manager who would be responsible for the investigation. Those that were 'undecided' on whether or not their companies will adopt BIM believe that BIM is useful but do not think it will fit their business, considering the size of their company, the size of their projects, their aged employees, and their established cultures and traditions. It was also clear that the better-to-do medium firms were more positive about the adoption of BIM than the very small ones. One medium sized contractor said, *"sooner or later it will be a must that we learn about BIM."*

The findings of National BIM report (2013) provide the participants of this research some form of encouragement. National BIM report (2013) compared the experience of the companies who have adopted BIM and the expectations of those companies who were aware of BIM but who had not yet adopted its use. They found that, in every measure, those who have adopted BIM are warmer to it than those who have yet to. In other words, they felt that BIM exceeded their pre-BIM adoption expectations. This is good news for those contractors in Jordan who desire to adopt

BIM sometime in the future. We end this section with a quote from National BIM report (2013) *"Those who are looking to BIM see its advantages, but tend to understate them. Those who have adopted BIM tell us that there are real benefits to be had, and they're greater than expectations. The anticipation of future adoption remains high. Delaying BIM implementation may reduce expenditure – but the risk is an even greater reduction in future income."*

5.9 Challenges to adopting BIM

There are many challenges that arise when contemplating the adoption of BIM in the construction industry. The findings have shown that there is zero adoption of BIM amongst construction SMEs in Jordan. The reason for this cannot be drawn to one single issue. The participants were asked to shed some light on the challenges SME contractors in Jordan are facing or are likely to face with regards to adoption new technology especially the likes BIM. Previous study showed that continual request to upgrade and greater know-how required were the main challenges facing contracting companies in Jordan (Attar and Sweiss, 2010). The participants mentioned quite a number of barriers to the adoption of BIM in the construction industry in Jordan. Gu and London (2010) put BIM implementation barriers in the following the main three categories: people, process and product.

5.9.1 In terms of product

In terms of product, these are issues limiting the adoption of BIM in the construction industry in Jordan that is related to the performance or understanding to the BIM tool. The technical issues of BIM implementation such as; interoperability, cost savings, scheduling and so on; are not accessible to this research as non of the companies in the study adopted BIM. Therefore, the barriers listed below are more socioeconomic in nature.

5.9.1.1 Lack of awareness of professionals and firms

Lack of awareness seems to be the overarching factor impeding IT adoption in Jordan especially for the adoption of BIM. 75% of the participants seem to stress the fact that there are no competent BIM professionals in Jordan; no awareness of BIM on the part of the engineers; no journals or books released on BIM, no workshops done about

BIM, there is a lack of interest on the part of government and construction associations to promote BIM, and so on. There is also the issue of both the professionals and the firms not really knowing what BIM is. Many of the participants think that BIM is just another CAD software like AutoCAD. When asked how it is they have never heard of BIM, the participants stated that courses are not given on BIM and there are no journals permanently dedicated to talking about recent developments both locally and internationally. Another participant took a different perspective to the barrier of adoption BIM in Jordan, suggesting that it was a matter of fashion. Let's look at a few comments relating to awareness of BIM in Jordan.

"We are not exposed to the global evolution. I mean we have traditions we follow, no one comes and tell you there is something new or I read about something new"

"The courses done in Jordan about BIM were very weak and not useful at all. The weakness of education about this subject is one of the main reasons. There is no permanently journals to talk about the development that happens."

"as a construction engineer I worked in Germany, we used there a programme called Alpine, it is a German programme, and in USA & UK they call it Rivet. Because here Rivet becomes more common, when it comes to work they ask you "do you know Rivet?' 'No. I know Alpine, sorry you cannot work here!" Although it is the same programme but a different name, but because that name is more common it is used more. So its all about ignorance and fashion."

5.9.1.2 Lack of Awareness of customers

Hitherto, demand from owners for more efficiency in creating capital improvements condensed delivery times fewer disputes, and reductions in waste and unproductive expenditures has since propelled the AEC industry entities to create effective processes (Foster, 2008). It should be no different for BIM. Since Building Information Modeling (BIM) has not gained traction in Jordan yet, clients are completely unaware of the advantages and innovation BIM can provide for them and therefore, do not demand its application on their projects. 25% of the research participants were of the opinion that their customers either do not demand for the use of BIM or will not pay for its use. In one of the interviews with an owner-contractor, the researcher ask the contractor if he had faced any difficulties while dealing with his customers to explain design plans by using computer, the contractor replied by first saying 'yes' and then pointed that even if they did adopt BIM, clients are not willing to pay extra for BIM designs. This is not just a problem in Jordan. It is also seen in the UK and the rest of Europe. Clients are pleaded with, on some projects to match the efforts put in by designers on BIM services, in the form of additional consideration. In Jordan, the nature of the customers must be considered. Customers prefer dealing with contractors on the old system to save money, *"why would I pay more for a design?"* they would say. Another similar comment is; "*why use BIM if AutoCAD is doing the same job, better to stick on what I already know."* Foster (2008) demystifies the whole paradigm of compensation in BIM adoption in the paragraph below.

"The use of BIM provides opportunities for increased service and quality to the Owner. BIM provides unprecedented opportunity to provide enhanced scope of service for design professionals. BIM has reduced ambiguities and inconsistencies among the design information provided by the design teams, which results in projects built in less time with fewer conflicts and claims. Unfortunately, this author understands that there has been little financial benefit provided to the design professionals. BIM requires a significant investment by design firms that are willing to change their existing procedures and enhance their services. Owner's must take responsibility and provide the designer with a portion of benefits related to increased efficiency and lower project costs by adjusting existing design fee structures. BIM lends itself to performance-based bonuses based on actual construction costs versus budgeted construction costs. Meaning, there must be shared benefits for the project participant based on project success. In variably, value based fees would certainly encourage the wide spread adoption and growth of BIM technology among the remaining non-users."

21% of the participants also suggested a form of *Incongruence with other parties involved on a project* who have not yet adopted BIM. BIM is a collaborative framework and for it to be effective, all the different stakeholders are needed, to extract, insert, update or adjust information in the BIM model in the different steps in the facilities' life cycle (Lindblad, 2013). Participants expressed concern that even if they wanted to adopt BIM, the other parties to the contract might not want to. However, if the clients were to demand for it, then it would be incumbent on the other parties to the project to learn and adopt BIM as well. Similarly, a study conducted by Tse et al (2005) in Hong Kong found that architects were reluctant to change to BIM because of lack of request from clients and other project team participants. This was coupled with another finding that architects affirmed that their existing entity-based CAD systems could fulfill their drafting and design needs and, therefore, did not need BIM.

Another participant from a small company said that they do not believe that IT would help them even if they adopted it because of the nature of their clients. These clients are not IT literate and therefore do not understand it. Hence, the contractor feels it would be a waste of money to implement IT for the sake of the client. For internal processes the basic IT of desktop computer and printers is enough. One other participant pointed to a current and significant limitation of Information Technology as a barrier, and that is, electronic signature. This makes most of the client prefer paper to computers.

"In my opinion, IT appears and spreads quickly via TV and programmes. The costumers have an idea about the nature of engineering projects. But the signature still has to be in paper, it has not got to a stage that we can depends on electronic signature, it has to be signed on printed papers."

5.9.1.3 Language of the product

42% of the research participants stated that the language of the software is what holds them back from adopting BIM and other IT tools. They feel unease because their English skill is not very strong and that most of the IT software are developed in English.

"And one of the main problems that all the technology is in English. The language is a barrier for too many engineers, because our main language in Jordan is Arabic, so in order to learn English programme we have to learn the language first. Too many engineers do not have time to learn the language in order to take this programme, the language is a big barrier."

"Even the engineers are unfortunately unqualified, for example I have poor English so when I attend a lecture and the lecturer speaks English I leave, because my English is very poor"

BIM developers have the responsibility of producing BIM software in many different languages and compliment the software with easy to follow tutorials.

5.9.1.4 Cost of installing the product

According to National BIM report (2013), *"cost is the most significant barrier to adopting BIM."* There is obviously a high cost associated with the adoption of BIM especially for the first time where initial setup cost could be huge, skill and knowledge has to be sourced externally, as well as educating individuals connected to the project. This high cost serves as a barrier to adoption of BIM to some of the contractors in Jordan. 50% of the research participants said that the cost of adopting BIM is a barrier to them. Also, there is a period of time where the company does not start to see return on investments. This is a period where a great effort has to be devoted to implement BIM successfully. Here, the adoption of BIM has to make sense in order to keep going until it starts to see a return on investment. The justification of IT investments is one of the many challenges facing managers in the construction industry today, as investments in IT are difficult to evaluate (Andresen et al, 2000). There is difficulty in evaluating costs (particularly intangible costs) and the benefits are hard to quantify. Besides, there are often hidden costs and benefits, which are not easily identified in the planning and resource allocation process. However, there are numerous evaluation techniques out there and their use differs from organization to organization. Let's look at a few comments from the research participants.

"One of the reasons is that there is a big number of medium companies and the SMES, there is a high competition between them, and the income is kind of low. The cost for using a new programme, the cost for training the employees, and the time spent on the training, and changing from one programme to another will reflect on the profit and the competition in the market"

"The main reason why they do not use new IT is to save money, for them why to use BIM if Autocad is doing the same job, better to stick on what I already know."

"This system is not available in Jordan because it is so expensive, and downloading the programme could be difficult for most of the engineers. We never took any course in this company because they always think it is expensive."

Looking at these comments closely, some of these SMEs are so small that installing some sophisticated IT systems might just be counter intuitive – costing the company more money than they are making. According to Gu and London (2010), large firms who operate more on "large projects will prefer tools with greater flexibility in customizing project environments, smaller firms, on the other hand, are more likely to prefer more intuitive project environments" that does not cost them money. Two small contractor firms affirmed that they would love to implement IT in their companies but the costs of doing so might overwhelm the company. This is only the direct cost of infrastructure; equipment cost, installation, training etc. not to mention indirect costs. In the words of one of the respondent *"the main barrier is the cost…*

BIM is impossible on small and medium projects." When one of the contractors was asked if price of installing IT was a barrier, he answered; *"Yes at the beginning it was, I considered it too expensive and I communicate with 3 companies and got the best quote. As I was beginner in using such a programme I had to send staff for training.*" Later on, he was asked if maintenance of the programme was an issue he had? He also replied; *"Yes, it was too expensive!"* However, he also said that his annual *"profit increased"* due to work speed.

5.9.2 Distrust of IT/BIM

Two of the research participants affirmed that they do not trust IT. One contractor-owner from a small company said he has no plan to implement IT. His excuse is, he does not trust IT. He is quite old and very traditional. It is a cultural issue; stating that he does not like emails, and does not trust the Internet. He prefers face-to-face meetings and hand-to-hand delivery and sharing of documents. Drawings are done the traditional way with pencil and paper. He does not utilize CAD or any drawing software. Many of the IT literate professionals also attested to experiencing this clash of cultures between the now young IT literate professionals and the aged traditional professionals.

"I have faced this problem myself, for example I told an old engineer to leave the atelier and work on the computer, he said "no I don't trust it, I might make mistakes and It might delete". So they trust work with papers more."

"According to my work as a contractor we do our best to stay far away from IT but not too much"

5.9.3 In terms of process

5.9.3.1 Culture and Tradition of work

Adopting new technology require a change of traditional work process. New business procedures have to be adopted and the roles of different actors will be affected (Gu and London, 2010; Lindblad, 2013). The current work practice will have to change to the new one and most firms find this a deterrent to employing new technology. The implementation of BIM is no different. Though benefits are unquestionably great, the change however, requires a substantial overhaul of the traditional ways of working.

The finding have shown that 75% of SME contractors in Jordan, affirmed that changing their traditional ways of doing things is what keeps them form exploring new technology like BIM. The mere thought of changing how they are used to doing things puts them off the idea of adopting BIM. According to Arayici et al (2009), the adoption of BIM usually has a huge effect on the company's existing work processes and traditional roles. And that, those who are uncomfortable with change will have to navigate their emotions through workflow redesigns, staff reassignments and reallocation of responsibilities that comes with adopting BIM.

5.9.4 In terms of people

The success of BIM implementation is tied to one significant factor – the people actually working with the new technology. All the industry actors involved with BIM need to be skilled in the use of BIM in order to take advantage of the numerous benefits it offers. Therefore, in this section we will talk about a group of barriers limiting the adoption of BIM that are related to the people involved with BIM.

5.9.4.1 Ignorance

25% of respondents stated that the ignorance about the benefits of BIM is a barrier to adopting BIM in Jordan. According to a participant, it is not required of the staff to know BIM therefore no one is interested in finding out anything new. He comments:

"Unfortunately our work did not imposed using the new Software so we do not use it at all… I have been working 20 years as an engineer and I do not care to look what is new as long as I am working and getting my salary why the headache. Because the research and studying is expensive, and the no courses imposed on us by the Engineers Association, this is the main reason in our ignorance in these programmes"

Similarly, another participants comments;

"The company did not make any courses and did force us to do one. I am working on what I learned from university long time ago"

5.9.4.2 Experience, Habit and Age

One of the hardest things to change in life is 'habit'. When someone has become so used to doing a particular thing that it has become a part of them so much so that a better alternative does not look all that better and possibly less effective. In construction, habits are acquired through experience and experience is more often than not, built on age. Therefore, you find on the construction site, some older workmen who are used an archaic method of executing a task and would not adopt or even try a better and effective modern approach. 25% of participants said experience and habit of contractors was a barrier to adopting BIM and 13% said the age of contractors was a barrier. For example, below are comments by participants.

"Most of the employees are old and have 30 or 35 years of experience, so when you tell him about programmes immediately he refuses the idea. Of course 100% he will refuse, age plays a great role, because he will say "I thinks its like this" "I have been working 30 years and now you are trying to convince me that this programme will do what I was doing all these years!! " he wouldn't understand or get the idea. The age and experience play essential role"

"The nature of the employees, their primitive methods and refusing developing, (they have no faith in new IT)."

5.9.4.3 Nepotism

21% of the research participants stated that nepotism hinders their progress at work and hence the adoption of information technology. This is not a surprise given the Arabic culture of the people that is built on personal relationships, where most of the company employees and top management know each other outside the office and most likely related. In such situations, when an opportunity for a role arises, such as IT manager, we may find that those who have the skill and know the stuff are sidelined for the brother, cousin, son, daughter or in-law of the top management, who has no skill or limited know-how in the area. One of the contractors from a medium sized company said that one of the major challenges they faced was training all their employees on CAD and other software. Also a few employees were not willing to be trained on the new system. This however, proved to be a big problem in terms of productivity. The managers found it difficult to fire the employees and get competent hands because of the relationship culture in Jordan where personal relationships and emotional connection comes first and most employees are related to their managers, or related to the owners. Therefore, managers are forced to bear with incompetence just to maintain personal relationships.

"Nepotism has an essential role in not hiring qualifications at work."

"Most of the employees that work in construction are unqualified in IT and don't have degree."

5.9.4.4 Low level of education

Apart from knowledge and skill of BIM and IT, several participants (29%) raised 'low level of education' on the part of the handymen or ground workers as a barrier to adopting BIM. Their point was that, engineers and other construction professional understand IT and can learn new technology short amount of time but not so with some trades men with little to no education. Explaining and applying BIM will be very difficult.

"Regarding employees and handymen they cannot deal with IT, because they are low profile, so they do not use it. Maybe in the future they will. The engineer explains the plan for the employees but they cannot understand it by themselves… I think that in the future using IT will be wider and better and it has to deliver to everybody. But it will take longer time for employees than engineers because of the educational attainment."

Another barrier in this category mentioned by participants is the tendency of professionals to not add to their learning – to not improve on their education after university. As one participant succinctly puts it, the barrier to BIM adoption in Jordan is *"Not reading, ask any engineer about the last book he read he would answer when I was at university.* (Also) *there isn't project management so how will there be BIM? Education is one of the main reasons."* This participant is not alone as another stated that *"This is a problem, because there is no will to learn, research, or doing courses that might be expensive in their point of view."*

5.9.4.5 Lack of knowledge and Skill

With regards to the knowledge and skill of information technology or BIM amongst construction SMEs, all the participants affirmed that the lack of BIM knowledge and skill in Jordan was a big barrier to BIM adoption. The level is quite low. The skill is absent and no visible interest or enthusiasm to learn it. One of the participants when asked to evaluate IT use in their firm said this:

“Unfortunately it is weak because of delaying in work. We are taking long time to explain the work for the employees and contractors. It will take long time and too much effort unless they start from the beginning of the project by choosing qualified team, have the same level of knowledge, in this case, the role of IT becomes vital and 100% effective.”

“There is no specialist BIM in Jordan, so it is weak in Jordan and rare”

This is also evidence that when management does not take the time to train its staff on IT or when IT is not used appropriately and with the right people, it could turn out to be counter intuitive. That is to say that, management should be careful contemplating the adoption of new technology or it could end up perpetuating the same problems it was trying to eliminate by the adoption of new technology. There is though, a positive feeling amongst the participants the BIM will become the norm in Jordan. In my words of one of the participants, *“in my opinion, sooner or later it will be a must that we learn about BIM.”*

5.9.4.6 Training daunting

According to Arayici et al (2009), for BIM to be successfully implemented on a project, it is imperative that all affected members be skilled in the use of BIM in relation to their respectful fields. If they do not have BIM proficiency, the individuals must be sufficiently trained first in order for them to be able to contribute to the changing work environment (Gu et al, 2009; Gu and London, 2010; Lindblad, 2013). Many participants affirmed the assertions of several researchers from literature who documented that cost of training employees on new technology was a major barrier to implementing BIM. Not only cost, but also social and habitual (Lindblad, 3013) factors are responsible for the resistance associated with BIM adoption.

In our study, 58% of the participants mentioned that they were not motivated to learn a new technology. One participant mentions two construction groups that started giving courses on BIM but could not sustain it because of people thought BIM was complex and difficult to learn compared to AutoCAD.

*“There are two companies like CC Consultants Union and Sigma. They started giving courses for everybody and especially for engineers, but they (*the engineers) *were not very motivated because it is not very reliable for them. They learn it then they find out that it is easier to get the result from AutoCAD”*

Whether this is the case or not, it is conceivable to think that BIM is more complex than AutoCAD especially at the beginning where the entire infrastructure is set up and training begins. One can imagine how daunting it can be to some people starting to explore information technology most of whom are computer illiterates.

5.9.4.7 Time to invest in research and training is time away from productive work

The participants were also asked what their company vision was regarding the use of IT? 67% of the respondents stated that finding the time to invest on adoption of BIM was a barrier to them. One participant from a medium sized company said they are happy with the current IT they have and do not have any future plans on making more investments on IT; at least for the time being. However, another medium company said they would like to improve on the IT system in the company but do not have time to investigate what is out there that could prove useful to their current system. ‘Time’ again, comes up as a barrier.

One of the participant contractors when asked if financial reasons is the main problem stopping his firm from adopting BIM, he said, *“No it is not a problem as long as it is going to improve our business. But the main problem is time.* He was then asked if he believe that the main problem is the time not the financial issue?” He then replied by saying, *“Yes the time.”* was the main barrier for him.

Figure 5.10: Barriers to adopting BIM listed by Participants

5.10 Drivers to adopting BIM

It has been established from the findings that there is zero adoption rate of BIM amongst construction SMEs in Jordan. Now, having discussed the many barriers to adopting BIM amongst construction SMEs in Jordan, the lingering question is then, who should be responsible for driving the initiative? 53% of the participants feel the public client (government) should be the main driver of BIM initiative, 28% feel the Jordanian construction associations should be responsible for driving the adoption of BIM, 13% feel clients should demand for BIM implementation on their projects, while only 4% feel that large construction companies should play a bigger role. The statistic perhaps reflects the picture of the public client (government) being the largest costumer of the construction industry in Jordan.

5.10.1 Government

The findings of this research have shown that it is almost a general consensus that the party who should drive BIM adoption is the public client (government). These findings are properly in line with the works of Kiviniemi, (2013) and, Howard and

Bjork, (2008), who advocate that change must come from top (government) to down (users). The top question in this category the researcher asked the interview participants was; "Does the government have a role in the development of BIM and IT in the construction sector or should the private sector take responsibility for driving BIM?" although most of the participants feel that the government should be more involved in driving the adoption of BIM in Jordan, most of them said the government does not contribute and did not make any rules regarding BIM adoption. According to the participants, the government's position was "*do whatever you like to do", it left the market free, and allow open market."* This statement generally implies that the government is a bit lethargic in promoting new technology or efficient systems in the Jordanian construction sector. Another participant stated that there are no restrictions imposed on construction sector to use advanced programmes, unlike in the United Kingdom where the government has become active in the procurement of public works, imposing a compulsory BIM competency level on any contractor bidding for public projects. However, most of the participants feel that the government has a role to play and should step in to promote more awareness of BIM. Only one of the participants was bold to suggest that the government must enforce BIM by law on construction companies – *"The government must impose it like in the UK. Enforcement from law on companies."* The benefits with BIM are ultimately most benefitted by the owner of the project (Lindblad, 2013) and this is usually the government. It is ironic, because the government is the biggest client of the construction industry in Jordan. Therefore, they should be behind the initiative more proactively in order to enjoy the benefits of implementing BIM. This research recommends that the Jordanian government should propose 'grants' that will help SME's adopt the technology easily. Also, the Jordanian government must follow and learn from the British government, Norway, Sweden and other European countries by including BIM adoption in industry standards and procurement.

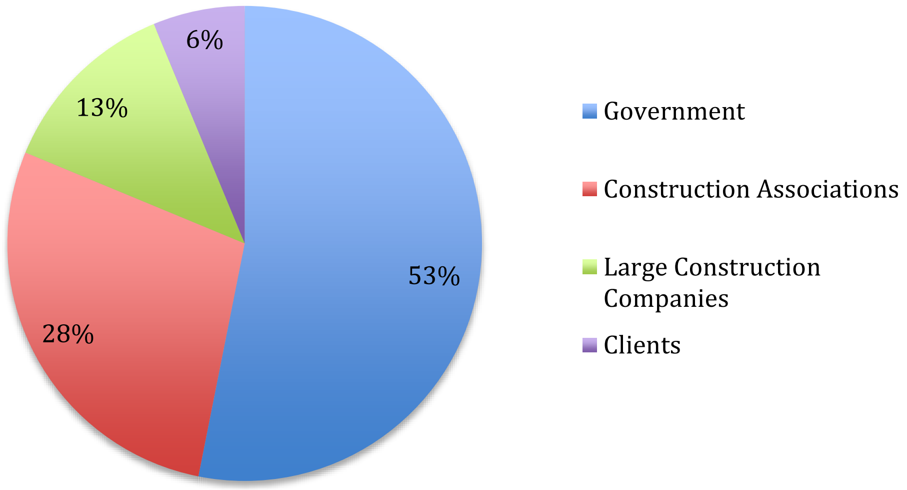


Figure 5.11: Drivers of BIM adoption in Jordan

5.10.2 Industry Associations

Participants were also asked if Contractors' Associations do obligate any work system like BIM? It was unilateral "No. Nothing was obligated." The only obligation was that the work is in Autocad. Therefore, it is evident that the contractors' associations have some degree of influence to push an initiative. Pushing BIM when the industry is still maturing on AutoCAD would be difficult and perhaps discouraging to those who want the keep with pace with technology in the industry. But if it is done wisely, by communicating benefits through workshops and other avenues, perhaps it might all embrace subtly.

"In Jordan, such a programme is entered by the association or the market. For the association, it did not give any courses in BIM, and if it did not give such a course how would people know it. I think even the employees in the association do not know about BIM. To spread this programme there must be somebody to impose to enter it. The nature of the people play a role, there are people who do not like to use something new so that they do not spend time learning about it, so its easier for them to stick to the old system."

"The engineers centre must give courses on these programmes and explain by theories and practicals the systems that the developed country has reached. We are still extremely underdeveloped as a construction sector or system in the country. We have not reached a technical level and technology in construction as in Europe. We are still primitive and traditional at the same time"

5.10.3 Project Owner (Client)

This research study has already shown in the literature review the importance of the drivers of BIM. From the findings, we have seen that the lack of awareness on the part of the clients means that there is no pressure from the same for BIM to be adopted on their projects. According to Lindblad (2013), the actor in the best position to affect the work processes of others on a project is the project owner who ultimately pays for the project and can therefore make demands regarding contractual requirements of BIM and how consultants and contractors should work. But the projects owners (clients) lack awareness of BIM and its benefits and therefore cannot demand the implantation of BIM. This means that the Jordanian construction industry is one short on the important drivers of BIM. However, once BIM is promoted in such a way that government, construction organizations, and construction clients are very much involved in the awareness campaign, clients and the industry at large can start to enjoy some of the overwhelming advantages of BIM – clash detection, cost savings through reduced re-work, improvement of design quality, automation or schedule/register generation, accurate construction sequencing, improved built output quality, improved communication to operatives, improved capacity to provide whole life value to client, innovation, design health and safety into the construction process, increased pre-fabrication, streamlined design activities, and facilities management activities. According to Eadie et al, (2013), many of the advantages listed above are actually drivers of BIM. Further research to this study could be to study the impacts of BIM when a small or medium sized company in Jordan adopts BIM on a project. It will be interesting to see what the findings on the drivers of BIM are.

5.10.4 Large construction companies

The construction companies that have the resources, for example large construction companies, should drive the adoption of BIM in Jordan. Large construction companies can afford research and development (R&D) whether as permanent or as temporary departments. They are able to dedicate resources to test new technology such as BIM and also document results, taking into consideration the context of Jordan. These results can easily be adapted to small projects, which most SMEs are specialized in. When there is a strong proliferation of BIM among large firms, the small and medium sized companies may be pressured into learning and using BIM in order to work comfortably and alongside these large companies. Those SMEs with no knowledge of BIM are left out of high-end and note-worthy jobs.

5.11 Summary

This chapter starts by emphasizing that the decision to investment in IT must most not be for the sake of the technology itself but because the technology will supports existing business strategy, and, that the development of standards, integrated databases and interactive applications must also focus on the people and their needs otherwise, the endeavor will be unsuccessful. The chapter also shows that the Jordanian construction industry is still lacking behind in its adoption of BIM. Hence, the SME sector of the industry has not signed a single BIM adoption success.

S/N	Findings
1	The use of basic IT such as Microsoft application packages, e-mails and telephones, and AutoCAD were among the top software utilized by the industry.
2	BIM has above average awareness level among SMEs but not currently using BIM yet.
3	BIM awareness was mostly among people aged between 30-49
4	67% of participants believe BIM will improve their business
5	59% of participants are willing to adopt BIM but will do so ‘sometime in the future’
6	Lack of awareness, and cost, seemed to be the biggest barriers to adopting BIM amongst SMEs
7	The project owners (government and private), construction associations and large construction companies to drive the adoption of BIM in Jordan

6 CHAPTER 6| DEVELOPMENT OF FRAMEWORK

6.1 Introduction

As observed in the analysis, the lack of industry experience with BIM adoption has resulted in limited feedback from the industry on technical requirements for BIM adoption amongst SMEs in the construction industry in Jordan. However, participants have provided non-technical requirements for BIM adoption for the same group. Further research could be, to have a small or medium contractor adopt BIM on a project in order to obtain information on the technical issues. From the interview analysis, the researcher is obliged to suggest that the construction industry in Jordan is stuck in a status-quo loop. This is the state where the lack of knowledge and awareness about BIM results in a lack of confidence and motivation to adopt BIM-based collaboration. Conversely, as a result of the inhibition to adopt and use BIM, the level of knowledge about BIM remains low (Gu and London, 2010). Furthermore, in the case of Jordan, much of the SMEs in the industry are still struggling with learning AutoCAD, and now, there is BIM. The rate of development of new technology has surpassed the rate of consumption. Participants feel they have not finished learning AutoCAD and more systems are coming out claiming to be better. This does lead to dissatisfaction and discouragement among users. According to Gu and London (2010), the only way to improve is with experience and feedback, for which early trial and adoption are essential. Hence, they propose a change in the status-quo loop, which they called a 'recursive development cycle'. It suggests that the introduction of new work practices and introduction of new ICTs must go hand-in-hand.

Figure 6.1: Status-quo cycle inhibiting technology adoption and enhancement (Gu and London, 2010)

Figure 6.2: Recursive development cycle for technology adoption and enhancement

But this is the ideal. The real situation now in Jordan is that AutoCAD is still maturing, BIM has come to stay, and professionals do not feel their work demands the use of BIM or a change in existing technology or work practices. For example one of the participants expressed these concerns:

"Unfortunately our work did not impose using the new Software so we do not use it at all ... For example I have been working 20 years as an engineer and I do not care to look what is new as long as I am working and getting my salary why the headache."

"Until now they are fixing the primitive methods they are using for long time. In general, for many companies there is no development."

"we have not reached a technical level and technology in construction as in Europe, we are still primitive and traditional at the same time. We have engineers 70 years old retirement age, if you ask them to log on computer, they will tell you sorry 'I do not know.' This is a problem, because there is no will to learn"

Therefore, for BIM to succeed and be adopted throughout the Jordanian construction SMEs, all the stakeholders (project owners, government, large construction companies, and construction associations) have to be informed about the potential benefits of BIM to their respective disciplines and the project and similarities but yet, the superiority of BIM to AutoCAD. The interview analysis showed that there is: lack of awareness of BIM amongst small and medium sized contractors; there is lack of BIM knowledge and skill; focus is more on 2D paper drawings and AutoCAD than BIM; the government, large construction companies, and construction associations need to drive the change; and ultimately the non-technical issues such as, culture, language, age, experience and habit, distrust of IT, cost of setting up the system, training and so on, are heavy challenges to adopting BIM amongst construction SMEs in Jordan. All the industry stakeholders need to get involved in pushing the initiative through. The Jordanian Ministry of Works and Housing need to make it a priority to see that value for money is achieved for the client. At the moment, BuildingSMART is engaging the government to promote BIM through workshops and programmes. However, it has not yet reached a time to make BIM compulsory on companies yet. Awareness has to spread and then the know-how has to be achieved by at least 15% of the industry before it can be made legislation.

6.2 Government Grant

It is in the interest of the biggest client for construction – the government, to establish Grants for BIM adoption because of the long-term economic gains. The government should provide grants and technical support to small and medium sized companies to help offset the cost of installing the technology. The Jordan Enterprise Development Corporation (JEDCO) in collaboration with the Ministry of Public Works and Housing (MPWH) could corroborate to provide a grant for any company who can successfully show that BIM supports it's business strategy.

The SME's in this research have repeatedly stated that the cost of installing new technology like BIM is a major deterrent. Grants will go a long way in encouraging SME's to adopt the technology. It is a win-win situation for the government – they help the SME's increase efficiency through BIM adoption and in turn, get rewarded in the form of cost and time savings, improved accuracy and quality, cost certainty, and generally, peace of mind. It is important that government officials understand that though it may be that large amounts of money will be dedicated to this cause, the long-run savings will more than triple the initial spend because of economies of scale.

The nature of the grant must be enough to cover or come close to covering all of the expenses for installing the BIM system and providing support. However, the SME applying the grant must be able to show that it has satisfactorily prepared a solid business case for the adoption of BIM which is consistent with the company's business strategy and will record improvements in cost, time, quality, certainty etc. the government should also provide technical support to the SME at the piloting stage. They should provide documents detailing the nature of BIM contracts regarding; ownership, coordination and interoperability, legal issues, creation of database and BIM library, and so on. With this support, the SME piloting BIM is less likely to err.

Other private project owners also need to get involved by demanding the adoption of BIM on their project in order to harness all the benefits BIM promises. However, it is imperative that project owners, public and private, augment designers and other professionals for BIM designs and improvements. The Jordanian Construction associations have a big duty to the industry to promote best practice. The many BIM needs to shown through workshops, programmes, seminars, events and so on, while Large construction companies with plenty resources need to pioneer the BIM initiative on existing project, gain the much needed experience and then promote the technical benefits BIM brings. These drivers together will encourage the small and medium size companies to adopt BIM possibly shadowing one of the large construction companies for starters.

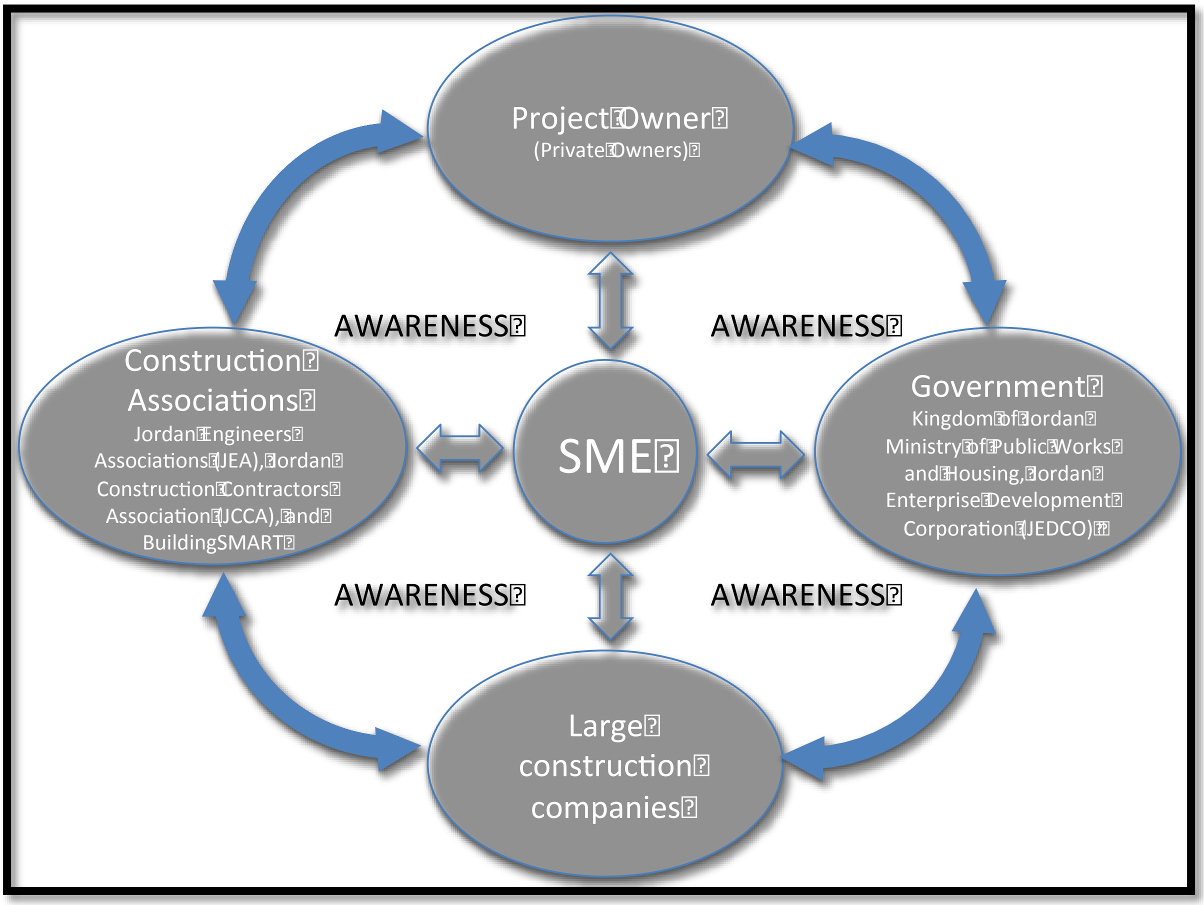


Figure 6.3: BIM Awareness Loop

6.3 Management commitment to Adopting BIM

Hayes (2002) states that unfreezing behavior involves alerting organizational members to the need for change and motivating or coursing them to let go of the traditional ways of doing things. This is where management commitment plays a massive role in causing effective change. But as we know, this is not always easy. This paper hopes to encourage construction managers in Jordan to allow themselves to kick-start such efforts. Management needs to be open to exploring the BIM alternation to business and project delivery. Al-Hegelan & Palmer (1985) found that Arab managers avoid responsibility and risk-taking. Small and Chen (1995) point out that, when management is not committed to rigorous justification of IT, organizations may be forced to either: refuse to implement an IT infrastructure that could be beneficial to the long-term competitiveness of the organization; invest in IT as an "act of faith"; or use creative accounting (assigning arbitrary values to benefit and costs) as a means of passing the budgeting process. And when such uninformed decisions are taken, it is more than likely that the company would not achieve the result hoped for. What Love and Irani (2001) advocate is that management must set up guidelines that strongly justify the adoption of IT, in this case BIM, and must not adopt IT without reasonable certainty of benefits rather than simply refusing to implement IT because they have not taken the time to investigate the option.

According to Carter et al. 2005 in the event of an organizational change, managers should not make the mistake of focusing first on finding the right change management model or the best system or model in the world. He asserted that the best system or model is not going to do any good to an organization unless they have a top-down commitment to making it work. He continues to state that "...the board of directors, CEO, and senior management team have to be firmly and passionately committed to becoming the 'best of the best'...it's absolutely imperative that they recognize the need for major change and be the catalysts for making it happen."

The top-down approach to leadership is compatible with the Jordanian culture. This top-down approach to leadership and change goes well with the Jordanian culture where the head passes instruction and it's done with no questions or challenges. We have mentioned earlier that the prevailing organizational culture in Jordanian construction companies is “power” (personal power rather than organizational power) where top executives demand complete submission from their employees, and employees in return do not take initiatives that may not be sanctioned by top managers (Ali and Sabri, 2001). Top executives make all decisions and are unlikely to delegate because of the need to centralize power, to glorify their position as the “all-knowing” and “supreme authority” within the organization. Therefore, BIM implementation has to come from top management, and they must believe it is their idea so there is personal commitment from them.

However, in order to implement BIM successfully, the top executives will need a little shift in their attitudes and expectations. They must be willing to relinquish some ‘personal power’ and be more oriented towards ‘organizational power.’ It therefore means that, for them to implement BIM successfully, they’ll have to delegate a lot and listen to everyone on the project because the nature of BIM is collaboration without which the software is reduced, simply, to design software only.

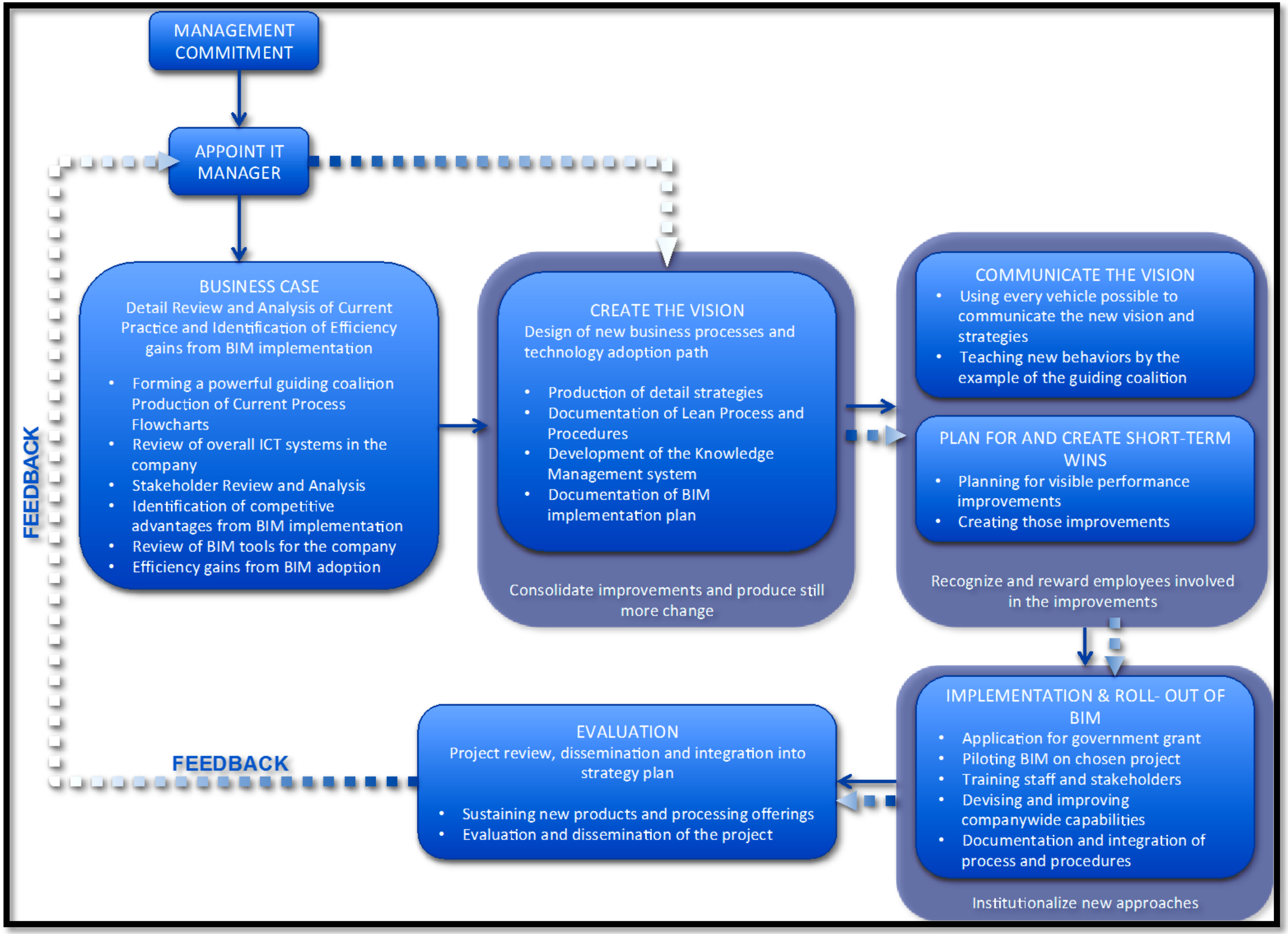


Figure 6.4: BIM Adoption in Jordan Framework

6.4 IT Manager

Once management is committed to exploring the adoption of BIM, an IT manager should be appointed. This is the person that will oversee the whole adoption process from start to finish. At this point a BIM manager is not appointed until at the project implementation phase or Test phase, although the IT manager would most likely be the BIM manager at the test phase. However, the IT manager must be a person with the right skills to evaluate the investment. It is important that the person chosen as the IT be a senior employee, a manager, or even the business owner, for the simple reason of the top-down culture already existing in Jordan. To be effective quickly, the company should embrace certain aspects of the culture and make positive use of it. The researcher feels that, in a country like Jordan, systematic changes begin to run into problems and face more resistance when it tries to dilute the sociocultural values of the people. Jordan is a social culture. The culture is made up of the fabric of social relationships within families, between families, and between communities. Therefore, this relationship culture must be harnessed for the good of BIM adoption.

The IT manager must be competent in ICT and knowledgeable in construction processes. Training must be provided in case he/she is not knowledgeable in BIM. He/she will play the role of a 'coordinator'. They will be a person able to: "deal with the BIM system as well as the project participants; provide and maintain technological solutions required for BIM functionalities; manage information flow, and improve the ICT skills of the other stakeholders" (Linblad, 2013). That means, preparing a case, which will incorporate, cost of implementation (direct and indirect), technical issues and means of implementation, risk assessments, procurement strategy and benefits. This business case is to justify the investment. If its not a justifiable venture, management must abandon the endeavor and consider other alternatives because inappropriate application of IT in a business could be detrimental to the long-term survival of the company. However, if the venture proves to be viable, the IT manager, must now prepare the change management plan which will incorporate; the creation of the vision, how the vision will be communicated to the employees, the politics within the organization, training and development, and leadership – planning for and creating short term wins, particularly for motivation, implementation and rollout of BIM and then evaluation. It is important that the IT manager gets the employees on board with the change. Once, the programme is in full flight, the IT manager must keep records of benefits realized and also expected future benefits with time lines. An evaluation of the process and benefits will feedback to the IT manager whether the process is working or not so changes could be made by consolidating improvements and producing more change; recognizing and rewarding employees involved in the improvements; until the BIM process works as expected; and then institutionalize the new approaches. The framework is a combination of this research findings and the works of Goh (2005); Arayici et al (2012), Andresen et al (2000) and Kotter (1995). Now let's look at each section in detail.

6.5 Business Case

The key to successful business exploitation is identifying the business case. However, first things first, the IT manager needs to form a *'powerful guiding coalition'* who will champion the change. This is a group of people (put together by the appointed IT manager) with enough power and credibility to initiate the required change program (Kotter, 1995). Inferring from Kotter (1995), and Pfeifer et al. (2005), "a strong leadership coalition is indispensable". Kotter suggests that senior managers form the core of the group, but sometimes board members, stakeholders or a representative from a key customer could form part of the team. This top-down approach is perfect as it coincides with the Jordanian power culture. Kotter (1995) recommends that for a successful transformation, the chairman or president or division general manager, plus another 5-plus people should come together to form the coalition team (See Appendix 4). This consists of only three to five people during the first year of the BIM implementation effort. The IT manager and his team would start by gathering hard information on the company's competitive situation, market position, technological trends, and financial performance (investigation phase) and then communicate this information broadly and dramatically, especially with respect to crises, potential crises, or great opportunities that are very timely (Kotter, 1995)

At this stage, the coalition team must make the case for BIM adoption. The company must be able to answer satisfactorily the reason why the business requires BIM implementation to be made. In order to achieve this, the guiding coalition must make a detailed review analysis of current practices and identify efficiency gains from BIM implementation. This stage involves a thorough understanding of the current work practice of the company including but not limited to issues such as: challenges, problems, and inefficiencies in the practice; choosing the right BIM tool for company's specific features and priorities; and outlining the lean efficiency gains required for improvement (Arayici et al, 2012). The purpose of the analysis is to eliminate waste in company work practices and to identify any value generation possible. In order to understand how different BIM tool aligns with specific company requirements, the coalition team would need to experiment on the different BIM tools available. This experimentation would not only help the team observe and measure the capabilities of the different BIM tools, it will also get them acquainted with the nature of BIM and ultimately help them make the right choice of BIM technology to adopt for the company. From the findings of the research, most of the contractors are using AutoCAD and other traditional methods. The experimentation at the early stages will also help curb much resistance from the staff. Management should expect resistance and quite understandably so, because, before now, there was hardly any knowledge of and awareness of BIM.

The construction company must be able to justify that the adoption of BIM will bring improvements to the following areas; efficiency, effectiveness and performance (see Appendix 5). The efficiency and effectiveness of BIM implementation are measured in monetary terms and in operational improvements respectively, while performance is measured in market share. It is important to note that a relevant and universally acceptable calculation methodology to properly evaluate BIM's benefits has not yet been established (Barlish and Sullivan, 2012; CIRIA, 1996). Other successful strategies can be used that do not involve formal cost-benefit analysis. In preparing the business case, an understanding of how the cost of IT is spread around will be very essential here. The IT manager needs to know that the cost of the software and hardware are only a fraction of the cost of adoption. The time spent in research and documentation and costing of even the littlest item; and among others, staff training, often cost more than the system. Therefore, a high level of detail and care will be needed in this phase. The IT manager can assess the company's needs based on the checklist of IT investment benefits collected by Andresen et al (2000).

The problem of preparing the business case and justifying the cost and benefits of IT investment is not a problem that is exclusive to the construction industry. All types of business sectors and organizations face the same problem. The fragmented nature and the low capitalization of construction, has made it more egregious to the industry. IT investment is usually secondary to other primary construction investments. Therefore, management has to make such investments in IT count. The IT manager is usually responsible for preparing the business case for IT investment in construction while top management makes the final decision whether or not the initiative is worthwhile (Andresen et al, 2000).

6.6 Create the Vision

Here, the BIM implementation plan is developed and it is supported by the design of new processes and technology adoption path. The IT manager and his team (guiding coalition) have to develop a picture of the future that is relatively easy to communicate and appeals to consumers, stakeholders, and employees. It takes 3 or 5 or even 12 months to create a sound vision says Kotter. However, Kotter (1995) asserts that the vision must be clear and succinct enough to be communicated in five minutes or less and get a reaction that signifies both understanding and interest It is very important that the coalition team have a good grasp of the vision because the employees will be looking to be told exactly what to do. The Jordanian SMEs are very power centric. Therefore, employees will not freely take initiative but will wait for the coalition team to assign duties. Creating the vision involves: Developing BIM implementation plan; Production of detail strategies; Documentation of Lean Process and Procedures; and Development of the Knowledge Management system. Here, the SME prepares and plans the actual implementation plan of the new BIM system on a future project – the procurement of the software and hardware, choosing the right project to suit all stakeholders, allocation of time for training of members of staff who will use the BIM software, creating BIM object libraries and office BIM standards and so on.

Further research together with the previous experiments in stage one, will lead to increased awareness and understanding of BIM and knowledge management which will further lead to the development of lean design processes that will eliminate wastes in the current work processes. These are the seven wastes of commonly found in the production system; waste of overproduction, waste of waiting, waste of transportation, waste of over-processing, waste of inventory, waste of motion/movement, and waste of defects. Arayici et al (2012) found that actual design information modeled in BIM was responsible for efficient handling of project support information in the areas of marketing, administration, finance, and contract documentation. These findings showed that BIM implementation leads not only to lean improvements at the project level but also at the organizational level in the form of knowledge management.

Figure 6.5: The 7 Wastes to be Eliminated

According to Andresen et al (2000), the business benefits are only likely to arise if they are strategy-driven. This stage involves checking the fit between BIM systems and the company's business strategies. After establishing the vision, the 'guiding coalition' is to empower others to carry out the plan. But first, they'll need to communicate the vision.

6.7 Communicate the Vision

In order for the organization to achieve a strategic vision, the IT manager and his team must ensure availability of information to the entire workforce of the organization thereby encouraging a collective pooling of knowledge and information. This in turn, will enable coordination of the actions required to achieve the necessary changes (Burnes, 1996; Pfeifer and Schmitt 2005). Kotter (1995) argues that it is impossible to achieve a successful transformation unless hundreds of thousands of people are willing to help. Doing this requires winning the hearts and minds of the employees through credible communication. Knowledge and information can be communicated in many forms, which include, but not limited to; formal processes such as meetings and presentations; and non-formal processes such as; stories and storyboards, proverbs, scenarios, content inventories, analytics, user surveys, concept maps, process flows, style guides and design patterns (Arayici et al, 2012). Another subtle way of communicating how people should be is to lead by example. The Coalition team must teach new behaviors by living them. They must embody the new processes and be examples for others to follow. Thus encouraging others to act on the vision.

To some degree, a guiding coalition empowers others to take action simply by successfully communicating the new vision, but in itself, it is insufficient to remove obstacles to the change process says Kotter (1995). The IT manager must support communication with action. Like providing soft training and support for staff, making the IT system user-friendly etc. Burnes (1996) recommends that managers must recognize and be able to cope with resistance to change. Adam's (1987: cited in Carnall, 2003) classifies these blocks under five headings; perception blocks, emotional blocks, cultural blocks, environmental blocks and cognitive blocks. The strategy advocated by most writers to identify blocks is the force field analysis. This helps to identify the pressures supporting old traditions and change obstacles as well as change drivers (Johnson et al., 2008).

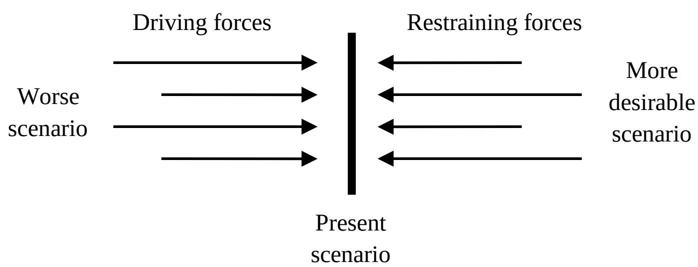


Figure 6.6: Forced field analysis (Hayes, 2002)

As already stated, managers in Jordan are very risk averse. Managers will have to remove blocks to change by; simplifying complexities in the change, remove fear of taking risks and making mistakes, remove external threats, and give appropriate support. Kotter (1995) advised that if the blocker is a person, he or she should be treated fairly and in a way that is consistent with the new vision. Hayes (2002) proposes the use of Kotter and Schlesinger (1979) six methods for dealing with resistance:

- education and persuasion (training and development)
- participation and involvement
- facilitation and support
- negotiation and agreement
- manipulation and cooption and

Direction and a reliance on explicit and implicit coercion

6.8 Plan for and Create Short-term wins

This stage involves planning for visible performance improvements and the creation of those improvements. A complete change in company's culture and processes takes a long time, usually five to ten years (Kotter, 1995). In order to sustain the momentum, Kotter advises leaders of change to seek short-term wins and plan visible performance improvement that can be celebrated along the way. He states that most people will not go along with the stress of change unless they see compelling evidence within 12 to 24 months that the journey is producing results. Such short-term wins could be a successfully completed project in which the BIM system was used. Kotter (1995) advocates that whilst celebrating a short-term win is fine, declaring the war over is dangerous. He adds that premature celebration of victory kills momentum and opens the door for old traditions to suffice. After assessing the benefits system and learning from mistakes done on the previous project, management should launch the BIM system on a fresh project to consolidate improvement. They must not allow complacency.

6.9 Implementation and Rollout of BIM

Application for government grants involves the SME creating a solid justification for the adoption of BIM in all the previous stages of the framework. The government should assess all applications to ensure; economic benefit of BIM to the company, the longevity of the company in terms of capacity and resources, and that BIM supports the company's business strategy.

BIM benefits have been well documented in literature. But sometimes there is a need for a trial that will show both the profitability of BIM and reveal how the process issues have been addressed in these projects. This stage involves piloting BIM on a real life project chosen earlier by the Coalition team. It is important that the project chosen be complimentary of the typical projects executed by the company so that the company takes optimum advantage of BIM and so that lessons learnt can be duplicated on future projects. Arayici et al (2011) states that such lessons will be in the line of proper understanding of specific order of decisions that are necessary to produce BIM models and the requirements for accurate and complete information for when developing BIM models. The piloting exercise will also give an opportunity for training of staff and stakeholders and increase their skills to a good standard. Subsequently, that knowledge can be managed and passed on to others and used on future projects. The pilot implementation will also enable the coalition team to observe how much efficiency and effectiveness can be achieved with BIM as compared to the old system. Areas in which efficiency can be observed are in; accuracy, consistency, speed and time saving, and communication. Any improvements in these areas would be counted as efficiency increase.

The general aim of piloting BIM on a company project is for stakeholders to see, evidently, what BIM can do, and ultimately, have a good understanding of what is needed for BIM modeling. Technically, it will help the team improve sequences and steps to get the optimum results from BIM; develop an effective BIM object library which could prove particularly useful in generating design solutions in the future; and have an understanding of the communication and coordination of stakeholders via BIM. According to Arayici et al (2011) the major benefit of this stage is the increased awareness of the BIM tool and its impact on company strategy, efficiency, effectiveness, and performance. It also imperative that the coalition team record all experiences in the company's knowledge database for future references.

6.10 Evaluation

The evaluation stage involves reviewing of the pilot project, dissemination and integration into strategy plan. It literally means an assessment of the lean efficiency benefits achieved and lessons learnt, and then forming a strategy to consolidate them. The benefit evaluation can be divided into three categories: typical efficiency benefits; typical effectiveness benefits; and typical performance benefits. In Appendix 1, Table 1, 2, 3, 4, and 5 that show frameworks for evaluating business efficiency, effectiveness and performance benefits which the IT manager uses to identify the business processes that will be affected by BIM and select the specific IT benefits that might be realized using the checklist in Table 1. Basically, Table 2 details the expected benefits to the company as well as risk analysis or implications to the company of not making the BIM investment; Table 3 measures the likelihood of the benefits occurring and the estimated value or impact of the benefit; while Table 4 involves measuring the benefits that have occurred after BIM has been implemented; and lastly, Table 5 documents the results. This result is then feedback to the IT manager who takes action and implements corrective measures if needed.

A construction company may choose to adopt Barlish and Sullivan (2012)'s methodology for measuring the benefits of BIM. However, Andresen et al (2000) drew out a more thorough method. The Tables in Appendix 1 shows the framework for evaluating business efficiency, effectiveness and performance benefits proposed by Andresen and his colleagues. They proposed ten construction business processes that need to be considered when adopting new technology in construction. They are: information management; business planning; procurement; marketing; finance; design; client management; construction; occupation and maintenance; and human resource.

The three tables are a guided methodology for users to walk through each stage of the measurement process which in the end would tell whether or not the IT investment will bring about improved business processes in the construction company

6.11 Feedback

After piloting BIM on a real remote project, it is conceivable that knowledge and skill of BIM will increase exponentially and a better-shared understanding of BIM will be established within the company. The changes and improvements made along the way in order to achieve the benefits of BIM should lead to Consolidation of improvements and still produce more change. This means that the outcome should lead to forward thinking that will lead to how further efficiencies could be gained. In order to consolidate improvements, there must be further staff training programmes, which will include: training of staff members and stakeholders both inside and outside the organization; informing the users of the BIM tool about the improvements and changes through presentations, meetings, seminars, demonstrations, and exhibitions. Also, employees that were involved in the changes and improvements must be recognized and rewarded.

The IT manager and the coalition team should continue to identify needs for further improvement and establish company specific standards to BIM modeling so that similar future project could benefit. This should be in the form of BIM object library and guidance document. With continuous repetition, it is inevitable that the BIM process will become leaner and smoother to execute.

Finally, the IT manager, his team and the senior management are advised to consolidate the change process through organizational learning. Hayes (2002) argues that "achieving sustainable competitive advantage depends on the ability of the company to learn from their experience and use this learning to enhance their collective ability to act more effectively in the future."

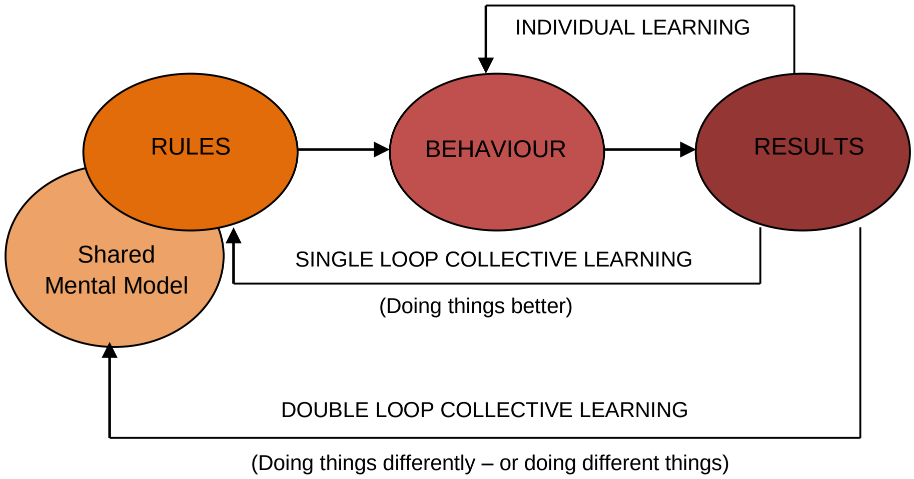


Figure 6.7: Individual and collective learning in organizations (Hayes, 2002)

6.12 Institutionalize new approaches

This is the stage after the BIM library is built and the guidance document of BIM processes and procedures is produced. Here, the lessons learnt have to be institutionalized. That means that in future projects, the implementation of the object libraries and the guidance manual must be carried out explicitly but still making room for improvements. After consolidating gains and producing more changes, the IT manager and management nees to ensure that the changes are anchored in company culture (Pfeifer et al., 2005). Change is complete when the new behavior becomes the social norms, values, culture and pattern of doing things in the company (Kotter, 1995). The notion is that the organization will move successfully from the state of the unconscious incompetent to that of the unconscious competent, where the organization has now mastered change that it no longer thinks about it (Carnall, 2003). According to Kotter (1995), two factors are vital in anchoring change in corporate culture. The first is a conscious step to show how the new approaches, behavior, and attitudes have helped improve performance. And second, is to take sufficient time to gather knowledge of how the employees dealt with the change. This is to ensure that the next generation of top management understand and personify the new approach enabling them to react more quickly and more flexibly to pressure to change in future situations (Pfeifer et al., 2005; cited by Kotter, 1995).

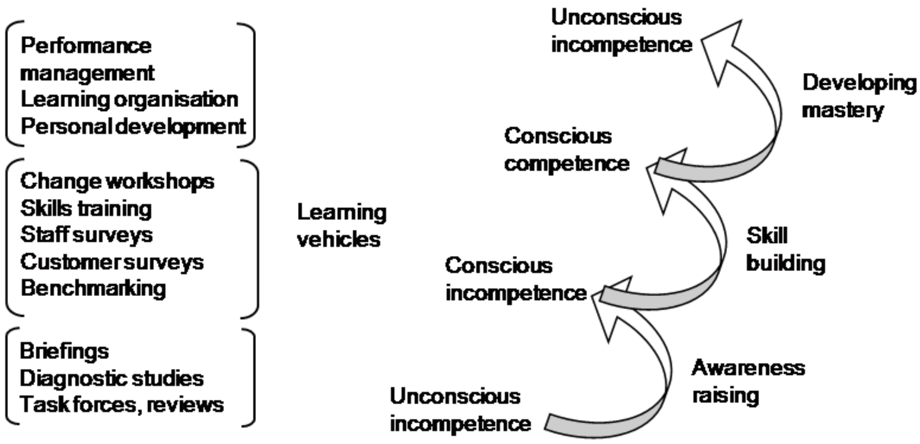


Figure 6.8: Competence development in change (Carnall, 2003)

The IT manager's approach to managing the change process could be supported by a variety of change management approaches to managing change. Lewin's Three Step Model is one of the most used and perhaps the most popular approach in literature. According to Cole (2004) the Three Step Model follows a process of: Unfreezing existing behavior, changing behavior, and refreezing new behavior. This recognizes that before new behavior can be completely and successfully adopted the old behavior has to be discarded (Burnes, 1996). The IT manager could use this change management approach to aid the process.

Unfreezing

Here, the IT manager must try to get people to accept the change and educate them on the need for the change. Management commitment also plays a massive role in the change process. But as we know, this is not always easy but they must work at effectively communication the vision for the new IT system and get everyone on board.

Changing

The change stage, according to Cole (2004) and Burnes (1996), requires IT manager to develop new behaviors, attitudes, values, and actions and helping the people to acquire ownership of the changes through redesigning of organizational structures and processes while preventing a relapse into the old ways of doing things. Cole (2004) and Burnes (1996) are strong advocates of this. The IT manager must also support communication with action, like providing soft training and support for staff, making the IT system user-friendly etc. Cole (2004) argues that the role of a change agent (IT manager) at this stage cannot be overemphasized.

Refreezing

The refreezing stage is aimed at consolidating and reinforcing the changed behavior by the use of various support mechanisms (encouraging, promotion, participative management style, more consultation, etc.). After assessing the benefits system and learning from mistakes done on the previous project, management should launch the IT system on a fresh project to consolidate improvement. They must not allow complacence. The IT manager and management need to ensure that the changes are anchored in company culture (Pfeifer et al., 2005). Change is complete when the new behavior becomes the social norms, values, culture and pattern of doing things in the company (Kotter, 1995).

6.13 Summary

This chapter shows that the Jordanian construction industry is currently in a status-quo loop where the lack of knowledge and awareness about BIM results in a lack of confidence and motivation to adopt BIM-based collaborations. Conversely, as a result of the inhibition to adopt and use BIM, the level of knowledge about BIM remains low. The SMEs in the industry are still perfecting the use of AutoCAD. Granted that there is a gap between learning and the coming out of new technologies, it was obvious that the overarching theme amongst all participants was “Lack of awareness” of BIM. It was deemed that for BIM to get a head way amongst construction SMEs, much has to be done by Large construction companies, construction associations and public and private project owners to create awareness of the benefits of BIM. It was also deemed that the government (public project owner) will need to support BIM initiative by providing grants to every SME that can prove that BIM supports it’s business strategy and will create value for the customer. Also, technical support is to be provided alongside the grant. The framework shows the construction SME objectives or goals to achieve in order to adopt BIM in a company. The goals are: Achieving Management Commitment, Appoint IT Manger, Create The Business Case, Create the Vision, Communicate the Vision, Plan For and Create Short-Term

Wins, Implementation and Roll-Out Of BIM, Evaluation and Good Feedback for creating more change.

7 CHAPTER 7| VALIDITY AND RELIABILITY OF THE RESEARCH

7.1 Introduction

The reliability of any finding is when upon accurate retesting, it holds to be true, irrespective of who tests it. That is, it proves to be consistent. On the other hand, a finding is valid if it reflects the true picture of the subject under study (McNeill and Chapman, 2005). For example, in qualitative research where interviews were used, invalidity may occur when the conclusions do not reflect the true meaning of the data submitted by respondents. It is somewhat easier to prove reliability and validity in quantitative research then in qualitative research because in quantitative research, where we deal with numbers and frequencies, it is easy to recheck the data. However, in qualitative research, where we are dealing with opinions and/or feelings, it is a bit more difficult to separate the true meaning of the findings of the research from the researcher's own personal interpretation of the data. Although, researchers in both qualitative and quantitative research, are encouraged to divorce the true meaning of the data collected from their personal opinions (Cohen et al, 2000). The generalizability of the research is also very important. This is the ability to extrapolate the findings from a small sample group and apply it unto the larger population successfully. The potency of transferability of results is paramount is qualitative research because it shows that the research is relevant when applied to another group.

There are different approaches to measuring the validity of a finding. In qualitative research: the degree of honesty in presenting, discussing, and analyzing the data as was received is something determine how valid or reliable the conclusions would be; the richness of data also determine validity and reliability as not much inference can be drawn from a weak data; triangulation, can also be used to ascertain that the same conclusion can be reached if the same data is received in another form, say, interviews triangulated with questionnaires; depth of the research and the objectivity of the research are also looked at to ascertain the validity of a research finding. Whereas, in quantitative research other tools like, statistical error, sampling, choice of appropriate instrument are looked at to measure the degree to which a research is reliable of valid.

However, the members of qualitative research school of thought such as Finlay (2006) reject the concept of validity, reliability and generalizability as frameworks for evaluating qualitative research. They argue that these concepts are mainly for evaluating quantitative research. Finlay (2006) adds that the nature of qualitative data does not allow for obtaining ‘consistent result’ to show reliability. Also such data, which are people’s opinions and subjective views, may not represent the true picture of reality.

7.2 Evaluation of Qualitative Research

Evaluating qualitative inquiry requires the use of a number of criteria: credibility, transferability, dependability and conformability (Lincoln and Guba, 1985).

- *Credibility*: this measures the degree to which the findings are make cognitive sense. This is also used in quantitative research to prove internal validity.

- *Transferability*: this is a measure of the degree of relevance and/or applicability a research can be to other groups. This method is also used in quantitative research to show external validity.

- *Dependability*: this involves having a strong level of conviction in the research method, decisions taken, and ultimately the data collected so that the whole process can be documented for external inquiry or use.

- *Confirmability*: this is achieved if after an audit of the results is performed, by the same or other means, and the same conclusions are reached, or the same quality is attained. In quantitative research, this is known as objectivity test.

In evaluating qualitative research, several strategies have been suggested in literature. The choice of which one to use varies from researcher to researcher and most often hinges on personal preference. They are:

Table 7.1: Strategies for Evaluating Qualitative Research

Strategies	Authors
1. Member checking 2. Use of rich descriptions 3. Presenting negative or discrepant information	Creswell (2003) Creswell and Miller (2000)
4. Triangulation 5. Examination of previous research to frame findings 6. In-depth methodological descriptions	Shenton (2004)
7. Peer debriefing	Lincoln and Guba (2005) Creswell and Miller (2000)

Literature is silent on which approach is best in what situations but it shows that researches do apply one or a combination to affirm validity. For example, Triangulation can be used to achieve credibility and confirmability, Dependability and Transferability can both be achieved with an in-depth description of methodology, and the use of context specific data, respectively. Creswell and Miller (2000) assert that the choice of which approach to use depends on the researcher's lens or epistemological perspective as well as the embedded research assumptions. Creswell and Miller provide a comprehensive list for the evaluation of qualitative research to achieve validity and credibility. See below.

Table 7.2: Validity Procedures within Qualitative Lens and Paradigm Assumptions

PARADIGM ASSUMPTIONS/LENS	SYSTEMATIC PARADIGM	CONSTRUCTIVE PARADIGM	CRITICAL PARADIGM
Lens of the Researcher	Triangulation	Disconfirming Evidence	Research Reflexivity
Lens of Study Participants	Member Checking	Prolonged Engagement in the field	Collaboration
Lens of People External to the Study	Audit Trial	Thick and Rich Descriptions	Peers Debriefing

Source: Creswell and Miller (2000)

7.3 Member Checking

Member checking approach is one of the best methods to achieve validity in qualitative research. Here, the final results of the research are sent to the research participants to verify is the research findings are accurate or if the researcher has articulated their responses accurately. The member check approach is considered a "quality criterion" to achieving credibility by a number of authors such as Shenton (2004) and Creswell and Miller (2000). The procedure for executing this approach may vary from researcher to research. However, the generic approach is that all (in case of a small group) or a subset of the sample population is selected and approached with the finding using whatever means, emails, presentations, focus groups, etc. They (research participants) then, give feedback on whether or not they agree with all of parts of the research. The researcher then takes this feedback and makes appropriate adjustment to the finding (if need be).

7.4 Use of Rich Descriptions

A rich description to the research findings allows for a much complete representation or captures in totality the experience of research participants. This process brings credibility and trustworthiness to the research as outside auditors can follow the rich descriptions and actually relate to participants experiences. These rich descriptions can be in the form of quotations of actual statements of participants or any documentation that relates to participants' experiences (Croswell, 2003).

This research has made adequate use of quotations to show the research participants' experience and even personality. Much of the quotations are not grammatically correct but have been left that way because that was how the participants said it and hence captures how they understand BIM in Jordan. This is understandable and forgivable because we know the participants' are not proficient in the English language. This richness, adds credibility and trustworthiness to this research.

7.5 Presenting Negative or Discrepant Information

This is a process of adding credibility to one's argument by presenting opposing views within one's own argument. This shows to readers that the researchers point or conclusions was rigorous and well thought through. Presenting a different perspective and contrasting with the research findings reinforces credibility of the research findings (Shenton, 2004).

7.6 Triangulation

This is the process of achieving validation by using more than one or a different data collection method other than the one used in the research in order to see if the data would be the same and hence same conclusions could be reached. There are two types of triangulation according to Shenton (2004):

- Triangulation by the use of different data collection techniques such as questionnaires, interviews, focus groups, and observations
- Triangulation by the use of a range of sample sets. Here, the data collected from one set is juxtaposed against that of another set hence illustrating richness and rigorousness and ultimately dependability in the research findings

Both methods, according to Shenton (2004) add to the credibility and confirmability of the research.

7.7 Examination of Previous Research to Frame Findings

In qualitative research the examination of previous research findings to frame findings is particularly useful for validation. This is the process of relating or comparing said research findings, with that of previous research findings in the same field. This helps to add credibility. Whether there is much similarity and/or differences the research will still be credible whatever the conclusions. It means that the research has not set out to give a wrong impression of findings but was rigorous in pointing gaps and/or bridges between the said research and the previous research findings.

7.8 In-Depth Methodological Description

This is the process that seeks to achieve validation through a thorough description of the adopted research methodology. Here, the research process must be detailed; questionnaires must be properly administered, all observations documented, interviews recorded, transcribed and safely stored. In qualitative research examination, this in-depth documentation allows for confirmability of the research. Also it allows for the research to be repeated adding to the dependability of the research.

This research has given a thorough description of it methodology in Chapter 4 and has recorded, transcribed and stored all its interviews in a manner that the research and be repeated, or audited. This brings credibility and dependability to this research work.

7.9 Peer Debriefing

This process involves selecting an independent mind that is; either disinterested in the research or is not part of the research and can not influence the research outcome; to question, analyze, criticize, and probe the researcher on his/her findings in order to bring to the surface aspects of the research which need more consideration, or need to be explicit rather than implicit. This person, though disinterested in the research, according must be knowledgeable in the research area to Hail et al (2011). This person can be a colleague, or a friend, whom the researcher trusts so as to allow the flow of opinions without duress. The purpose of this exercise is to detect any form of bias, improper assumptions, or misinterpretation of the data by the researcher in order to preserve the quality of the research (Lincoln and Guba, 1985).

7.10 Research Validation technique adopted

We have, in previous sections discussed the some of the validation techniques found in literature. Member Checking was deemed the preferable method of validation for this research because they were in the best position to say whether the framework will help them adopt BIM successfully as SMEs.

The researcher made use of Member Checking to validate the frame developed. All (24) of the participants were contacted for member checking process but only four (4) respondent. The four (4) participants are considered to be a subset of the sample population - two contractors and two engineers who were part of the initial data collection. The research report was sent across to participants and discussions were held with each of them via Skype on the adoptability and adaptability of the framework. First, the researcher went over the BIM adoption framework from ‘Awareness’ all the way to “Feedback”. Then, the participants were given an opportunity to ask questions or add to the framework.

7.11 Participants' comments on framework

The following are the areas that participants commented on:

After discussing all the details of the framework with the Participants, they agreed with most of the points, and expressed their admiration for the framework. Below is one comment from a contractor research participant:

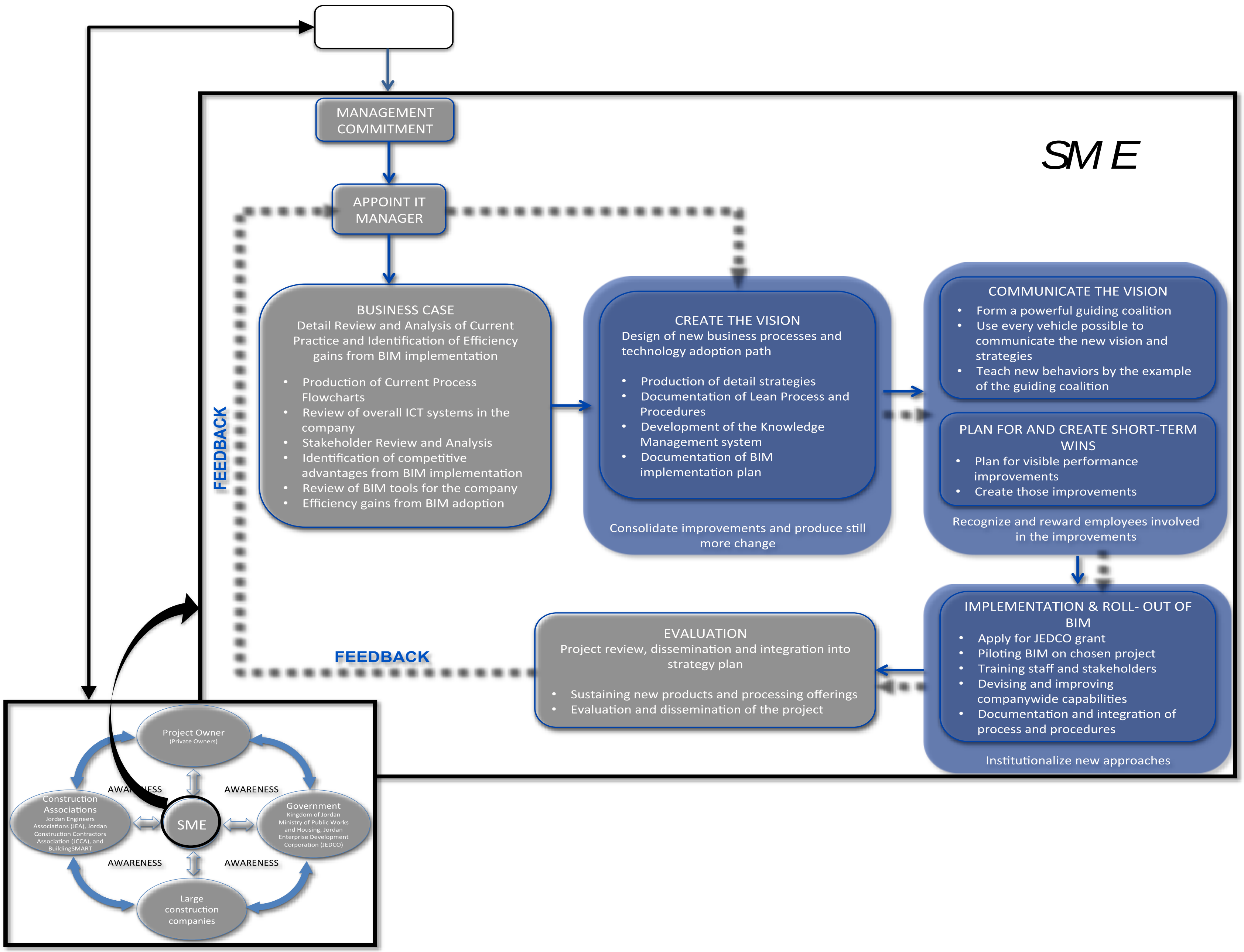
"Generally speaking, looking at the framework first time, I think this framework is a good stepping stone toward integrating BIM into construction in Jordan, and it will be viable when stakeholders in construction project start using it."

Here are the areas the research participants discussed. Much of what was said in the validation stage can be subsumed within the framework. In order words, nothing new was added to the original framework. Much of what was discussed was deeper unravelling of a particular step or suggestions on how to execute those steps. Now, let's look at those areas.

7.11.1 Management commitment

They all confirmed that 'management commitment' was the most important point, and it is the main point for the implementation of the BIM framework, without which the tool will not be effective. They also asserted that the top-down approach to leadership was compatible with the Jordanian culture because the head passes instruction and it's done with no questions or challenges. Again we have to reiterate that the prevailing organizational culture in Jordanian construction companies is "power" (personal power rather than organizational power) where top executives demand complete submission from their employees, and employees in return do not take initiatives that may not be sanctioned by top managers. Therefore, BIM implementation has to come from top management, and must believe it is their idea so there is personal commitment from them.

Figure 7.1: Final BIM Adoption Framework for Construction SMEs in Jordan



The above framework is a blow up of the SME in the middle of the Awareness Loop. The framework emphasizes that awareness of BIM has to be achieved through out the industry so that the SME is able to adopt BIM successfully. Awareness Loop at the bottom shows BIM Awareness at the top of the framework, while the Framework is for the Small/Medium Enterprise (SME).

The participants were also quick to point out that because of the corroborative nature of BIM, top management will have to diffuse power or authority for it adoption to work. The researcher will able to show them that the framework proposes the appointment of an IT manager and the assembly of a coalition team who will spearhead the adoption processes. Therefore, the framework captures the diffusion of power necessary. Top executives must be willing to relinquish some ‘personal power’ and be more oriented towards ‘organizational power’; listen and delegate.

7.11.2 IT Manager

They also pointed out that appointing an IT Manager was very important, however, they rightly pointed out that it was very hard to find expert IT Managers in BIM in Jordan. They also asserted that it was very important that the appointed IT Manager be from within the company. The IT Manager could be any employee interested in this programme. The researcher said that this point has been explained in detail in the thesis. The researcher explained that it was important that the person chosen as the IT be a senior employee, a manager, or even the business owner, for the simple reason of the top-down culture already existing in Jordan.

They raised the issue of ‘personal relationship’ i.e. culture in corporate environment, and stated that the IT manager must be from within the company. In the words of one participant:

“Because there is a belief among some business owners that they do not trust a person from outside the company to look at the documents of the company. So the company manager should nominate someone from within the company for that role to keep the confidentiality of the company.”

For BIM to be effective and quickly too, the company should embrace certain aspects of the culture and make positive use of it – i.e. the power culture. It was also explained to the participants that, in a country like Jordan, systematic changes begin to run into problems and/or face more resistance when it tries to dilute the sociocultural values of the people. Jordan is a social culture. The culture is made up of the fabric of honoring those above you. These people could be elders of the community, family, or ones own company managers. The social interactions within families, between families, and between communities is therefore, very important and must be harnessed for the good of BIM adoption.

7.11.3 Lack of BIM expertise

The participants also proposed solutions to the problem of lack of BIM expertise in Jordan. One participant who is a contractor said there must be intensive courses and orientations about BIM by experts in the Jordanian construction industry. He also added that if it is difficult to bring the industry to do these courses, in the mean time, the company could send the person that is interested in BIM to take courses in BIM; in UK for instance, even though, it may be a bit expensive. The participants also pointed out that the government should provide facilities to travel abroad, as it is so hard to get a visa to European countries.

7.11.4 Government Grants

Participants mentioned Jordan Enterprise Development Corporation (JEDCO), and The Ministry of Public Works and Housing (MPWH) among others as the best fit to provide grants for the SMEs. For example JEDCO was established in 2003 and mandated with a mission to support the establishment and development of enterprises to become globally competitive (JEDCO, 2013). In 2006, Jordan's Upgrading and Modernization Programme (JUMP) and the Euro-Jordanian Export Programme (EJEP) were integrated under the umbrella of JEDCO, thus facilitating enterprise modernization and enabling enterprises to face the challenges of globalization and the penetration of non-traditional markets. The following are JEDCO Strategic values:

- Increase the competitiveness of the SMEs in industrial, services and agriculture sectors.
- Participate in the development of the National Export.
- Develop and support the entrepreneurship and innovation.
- Identify and manage the sources of fund.

JEDCO best fits the profile of the government institution to provide such grants for SME adoption of BIM. This process can be done with strong collaboration with The Ministry of Public Works and Housing.

The participants strongly pointed out that the government should not only provide financial facilities but also remove all obstacles that may impede the adoption of BIM. For example, hire experts and instructors from abroad, to do courses in all areas in Jordan not only Amman the capital. This emphasizes the importance of the public and private sector cooperating to get rid of all the obstacles that face BIM, to develop the performance of the construction sector.

7.11.5 Awareness

The participants strongly believed that the contractor's associations distribute awareness leaflet about BIM so that the employees in construction sector keep abreast with developments in this sector.

"Awareness is the main factor to succeed in adapting BIM in Jordan. That is why government and association should work harder to sensitize employees in this sector."

The participants added to their earlier suggestion on the government driving the adoption of BIM by stating that the government should force SMEs to send representative of the company to attend orientations about BIM, so that SMEs do not ignore these orientations and conferences. Enacting a law, they said, can do this.

"Forcing BIM plays essential role like what happened in UK for example."

One participant also suggested that the government should classify the contractors that use BIM using a credit system; 5 stars or 4 stars for example, to encourage the other companies to adopt BIM. Another suggests was to give certificates to companies that use BIM. Such a certificate gives the company a competitive edge in the domestic market or priority in taking bids. If this were applied, it would be another incentive for companies to make greater effort to be able to compete for government tenders.

"In order to understand the importance and viability of BIM and utilization in the, employees and workers should not only be informed but should be made aware of the BIM advantages, and also be made aware of the weakness of the old fashioned way of doing the business in construction. What I mean to address specifically is the working drawing and the ambiguity and miss interpretation that goes along."

The participants were also shown that the thesis emphasizes the big task of The Jordanian Construction Associations. They have a big duty to the industry to promote best practice. The many BIM needs must be shown through workshops, programmes, seminars, events and so on, while Large construction companies with plenty resources need to pioneer the BIM initiative on existing project, gain the much needed experience and then promote the technical benefits BIM brings. These drivers together will encourage the small and medium size companies to adopt BIM possibly shadowing one of the large construction companies for starters.

The participants expanded on "Communicating the vision" by suggesting that one good way to introduce BIM to small companies is to have short specific videos to each construction trade. Such short videos should be made to carpenters, steel fabricator, mason, plumber, and so on.

7.11.6 Communication

Traditionally, communication is a big issue between all stakeholders. Misinterpretation is a common thing in construction. Starting from the conceptual design stages architects tend to do the concepts. Afterwards, draftsmen usually proceed with the finishing. Whence the drawing is produced and transferred to the contractor, discrepancies arise, as a consequences projects is halted until disputes are resolved, therefore BIM technology could play vital role to resolve this issue from the beginning by clarifying all ambiguity that might rise in the future. The participants also stated that in the design field, BIM could play big role from the beginning and early conceptual stages, which will also help customers to make their decision.

Having a strong communicating tool is needed, for small companies. And due to the fact that these companies usually can’t afford to hire a dedicate BIM engineer full time because of financial reasons, a solution could be by subcontracting the task to private entities or freelancer specializing in BIM.

7.12 Framework feedback

All the members selected for the validation stage confirmed that applying this framework would be extremely effective in adopting BIM. They also confirm that the Jordanian construction SMEs must change the culture step by step. Much of the criticism of the framework was that it needed to contain an awareness step. However, it was explained to them that the “awareness loop” diagram served that purpose and that the “Framework” was an extension of the “Awareness loop” as shown in the final BIM adoption framework in Figure 7.1.

7.12.1 The Business Case

The job of the IT manager is to prepare the Business Case but the identification of five other people with BIM skill or knowledge, would be quite difficult. The researcher explained that, at this point, even if it were only three strong people that form the coalition team, it would be enough. As Kotter (1995), and Pfeifer et al. (2005) suggest – “a strong leadership coalition is indispensable.” This stage involves a thorough understanding of the current work practice of the company including but not limited to issues such as: challenges, problems, and inefficiencies in the practice; choosing the right BIM tool for company’s specific features and priorities; and outlining the lean efficiency gains required for improvement (Arayici et al, 2012). The purpose of the analysis is to understand how different BIM tool align with specific company requirements. From the findings of the research, most of the contractors are using AutoCAD and other traditional methods. Therefore, the coalition team must choose a BIM platform that is AutoCAD friendly to facilitate adaptability. The Small or Medium sized company should adopt a more AutoCAD friendly software such as IDEA Architecture that offers an easy transition from AutoCAD and/or CAD software to BIM, and one that is affordable.

Again, the construction company must be able to justify the adoption of BIM using the efficiency, effectiveness and performance matrices in Appendix 5. The efficiency and effectiveness of BIM implementation are measured in; monetary terms and operational improvements, respectively, while performance is measured in market share. Once that is done, the monetary value together with the performance improvements and market share 'expected' is enough to inform decision for or against BIM adoption.

7.12.2 Creating the Vision

The participants were a little concerned that the creation of vision may be more work than anticipated. However, the researcher was keen to tell them that it imperative that there is a thorough understanding to the overall business process so that the appropriate plan and strategies can be developed. Lean processes and procedures, is also to eliminate waste in the production line. Such thorough detailing will also lead to increased awareness and understanding of BIM and knowledge management. This stage involves checking the fit between BIM systems and the company's business strategies. The IT manager and his team (guiding coalition) have to develop a picture of the future that is relatively easy to communicate and appeals to consumers, stakeholders, and employees. It takes 3 or 5 or even 12 months to create a sound vision says Kotter. It is very important that the coalition team have a good grasp of the vision because the employees will be looking to be told exactly what to do.

7.12.3 Communicating the vision

Participants were relatively at ease with this stage. It was necessary to win the hearts of everyone or at least a majority for the initiative to be successful they agree. This vision must be communicated quickly with a sense of urgency. However, there are several other strategies to communicate vision. Knowledge and information can be communicated in many forms, which include, but not limited to; formal processes such as meetings and presentations; and non-formal processes such as; stories and storyboards, content inventories, proverbs analytics, scenarios, user surveys, process flows, concept maps, design patterns and style guides (Arayici et al, 2012). Another subtle way of communicating how people should be is to lead by example. The Coalition team must teach new behaviors by living it. They must embody the new processes and be examples for others to follow.

7.12.4 Planning and creating short term wins

The participants stated that creating and planning for short term wins was very important as it serves as a boost in confidence for the employees. Kotter advises leaders of change to seek short-term wins and plan visible performance improvement that can be renowned along the way. However, celebrating a short-term win is fine say Kotter, but declaring the war over is dangerous. He adds that premature celebration of victory kills momentum and opens the door for old traditions to suffice.

7.12.5 Implementation and Rollout of BIM

The suggestion of a government grant was very welcomed by the participants. They encouraged the idea of JEDCO providing this grant. The researcher reminded them that while the grant was a good idea, the company attempting the adoption of BIM must show that it has the capacity in way that justify that BIM supports its business strategy. The government should assess all applications to ensure; economic benefit of BIM to the company. The general aim of piloting BIM on a company project is for stakeholders to see, evidently, what BIM can do, and ultimately, have a good understanding of what is needed for BIM modeling. Technically, it will help the team improve sequences and steps to get the optimum results from BIM; develop an effective BIM object library which could prove particularly useful in generating design solutions in the future; and have an understanding of the communication and coordination of stakeholders via BIM.

7.12.6 Evaluation

Of course the evaluation stage is to review of the pilot project, dissemination and integration results into a strategic plan. Participants found this relatively easy to understand and saw the connection with previous stages. This stage literally means an assessment of the lean efficiency benefits achieved and lessons learnt, and then forming a strategy to consolidate them. Here, the 'expected benefits' calculated using the efficiency, effectiveness and performance matrices adopted at the Business Case stage, is now measured against the actual 'measured benefits.' This result is then fed back to the IT manager who takes action and implements corrective measures if needed.

7.12.7 Feedback

Finally, the IT manager, his team and the senior management are advised to consolidate the change process through organizational learning. They should consolidate improvements and produce still more change, recognize and reward employees involved in the improvements, and institutionalize new approaches. After consolidating gains and producing more changes, the IT manager and management need to ensure that the changes are anchored in company culture.

8 CHAPTER 8| CONCLUSION AND RECOMMENDATIONS

8.1 Introduction

This study provides a detailed insight into the context of IT and BIM adoption and construction SMEs in Jordan. The study revealed that the adoption of BIM among construction SMEs in Jordan is virtually non-existent and that IT use in the Jordanian construction industry is basic with AutoCAD being the main design tool. The study also revealed that there is evidence the industry's SMEs could harness the benefit from BIM adoption. In conclusion, the Jordanian construction industry has not fully taking advantage of the benefits of BIM and could use a reliable framework that is easy to implement.

8.2 Summary of the Key Findings

The researcher addressed all the major concerns of study as raised in the objectives. The research findings are presented below.

The literature review was carried out to introduce information technology (IT) and Building Information Modeling (BIM) in construction globally and then the same, in the context of Jordan. This revealed the massive gap between BIM adoption in the construction industry in the west and BIM adoption by the same in Jordan. It also revealed the unequivocal need to close that gap.

A detailed investigation of the place of, and level of BIM adoption among SMEs in Jordan was carried out and the study revealed that the percentage of the survey sample actually using BIM is zero. That is, BIM adoption is virtually non-existent among construction SMEs in Jordan. However, instead of looking at the cup as "half empty", this research resolves to look at the cup as "half full". With this change in perspective, one can look at the Jordanian SMEs as a fertile ground for the introduction of BIM technology. The National BIM Report of (2012) states that, without the standardized approach to authoring of both geometrical and non-geometrical objects, any outputs form the model will be inconsistent and will not return valid results for schedules and other information-related queries. Already we know that even the pioneers of BIM such as the United Kingdom, USA and the rest of

Europe, are struggling with some of the limitations of BIM such as the absence of a prevailing standard contract document, the ownership of designs, interoperability etc. In Jordan, if standards can be made early enough before the BIM adoption takes full flight, then maybe we can have a more cohesive and smooth BIM implementation where much of the industry is making use of a common standard. Vehicle for the delivery of standardized and consistent construction information regarding quality, specification, vendors, facilities management, live cost analysis, scheduling, and so on.

It was also revealed that most professionals within the construction SMEs in Jordan are aware and using information technology in their everyday activities. Only a handful ‘do not use’ IT at all. Most of the SMEs agreed that the application of IT on their projects has helped them to save time and cost. However, the finding is not the same with BIM. Many professionals and contractors were aware of BIM but have never used it. Some were also aware of the benefits of BIM. But, a good number stated they were unaware of anything like BIM. Similarly, this study revealed that those professionals who were aware of BIM were between the ages of 30-49. With the older generation there is lack of interest to learn new technology while, the younger generations who haven’t had much travel or exposure do not have much awareness of BIM either since Jordan is only starting to promote

Also, most of the participants did not dispute the benefits of BIM and would like to improve on their systems. Almost two-third of professionals believed that BIM will improve their business, while one-third were on the fence and quite unsure whether or not BIM will improve their business. The survey revealed that 59% of the respondents are ‘willing to adopt’ BIM but neither of them showed any commitment. All of the participants, who said they were willing to adopt BIM, maintained that they would do so “sometime in the future”. This can be associated with the lack of awareness of the benefits and applicability of BIM.

The research participants identified a number of barriers relating to the adoption of BIM in Jordan. Contractors mostly agreed that the lack of awareness of both the clients and the industry was responsible for the slow adoption, followed by cost of installation and understanding of the product, while distrust of IT and nepotism seem to be the least among the barriers that participants were concerned about. Process issues such as changing traditions, cultures, and ways of work was also one significant barrier that participants were concerned about.

Table 8.1: Barriers to adopting BIM in Jordan

Product issues	*Lack of awareness of professionals and firms*
	Lack of Awareness of customers
	Language of the product *Cost of installing the product*
	Distrust of IT/BIM
Process issues	*Culture and Tradition of work*
People Issues	*Ignorance*
	Experience, Habit and Age
	Nepotism
	Low level of education
	Lack of knowledge and Skill
	Training daunting
	Time to invest in research and training is time away from productive work

Majority of the participants were of the opinion that the public client (government) should be the main driver of BIM initiative, 28% feel the Jordanian construction associations should be responsible for driving the adoption of BIM, 13% feel clients should demand for BIM implementation on their projects, while only 4% feel that large construction companies should play a bigger role. The statistic perhaps reflects the picture of the public client (government) being the largest costumer of the construction industry in Jordan. Small and medium-sized companies in the Jordanian construction industry do not have the finances, and oftentimes, do not have the resources to implement BIM on their own initiative. Therefore, this research recommends that the government gives grant to SME's willing to adopt BIM and have shown that BIM complements its business strategy. This is a WIN-WIN for the public client (government) since they are the direct recipients of the cost and time savings afforded by BIM. In conclusion, **if public and private clients (knowing the advantages) demand for the implementation of BIM on their projects, then, they can be convinced to pay the extra consideration for using BIM. Therefore relieving the SME of bearing the entire cost of implementation and making the SME willing to adopt BIM on future projects.**

It was also evident that implementing BIM would be difficult because of the low skill in IT and educational level of the trades men and other project parties who need further explanation of what the designs mean and what is needed of them. it is therefore advised to find a fully qualified team from the beginning of the project before adopting BIM. At this moment it may prove difficult to assemble a team locally that understand and use BIM.

Time factor was mentioned a lot by contractors as one of the major deterrents to adopting BIM. Even though they are aware of BIM, they would not take the time to investigate how it can support their companies' strategy because of limited resources. The major reason given was that the time and resources invested in research and training is time away from immediate productive work that can earn a profit.

1. Culture rules how communication in business is done, where face-to-face interaction is generally preferred to virtual communication
2. Most of the participants did not dispute the benefits of BIM and would like to improve on their systems

Participants linked the non-adoption of BIM technology among small and medium-sized companies in Jordan to different barriers, many of which are contextual to the nature of the people and their ability to adapt to new changes. BIM poses a big paradigm shift in the Jordanian construction industry with massive changes to how projects are to be executed both technically and administratively. BIM adoption brings with it many changes in individual roles that are not compatible with the traditional adversarial culture of the industry. This situation is even more complex to resolve given the prevailing organizational culture in Jordanian organizations is "power" culture (personal power rather than organizational power) where top executives demand complete submission from their employees. Therefore, there will be high resistance to changes brought by BIM because of the traditional nature of the people. Training and education of individuals who will be working with BIM should be high on the priority list of BIM drivers. The participants stated that courses are not done about BIM and there are no journals permanently dedicated to talking about recent developments both locally and internationally. The public client (government), the project owners, large construction companies, and construction associations such as Jordan Contractors Association and Jordan Engineers Association must all put more effort in driving BIM and creating awareness in the industry through, programmes, courses, seminars and so on.

8.3 Framework

Keeping in mind that technology must not be adopted for its sake alone, and that the technology must support existing business strategy and people, there is no doubt that BIM technology addresses two of the main factors that cause inefficiencies in the construction industry – fragmented nature of the industry and lack that of collaboration. BIM encourages better collaborative work processes to be adopted because of its ability to manage information and improve productivity in construction projects. Therefore, companies contemplating the adoption of BIM must understand that BIM technology is not the goal in itself because it has no value in its own right, but it is important because it enables changes in processes and makes them more efficient. That is why developing the business case and the vision that aligns with company strategy must happen before designing new processes for BIM adoption within the company. This means that BIM follows strategy or vision.

The framework is a combination of the findings of this research and the works of Goh (2005); Arayici et al (2012), Andresen et al (2000) and Kotter (1995). All these authors along with other authors in this research provided a platform upon which the framework was created. The framework emphasizes "government grant" as a very important factor for SMEs to adopt BIM. Also, the government should provide technical support to the SME during the piloting of BIM on the chosen project. Management commitment is another factor emphasized by the framework. This commitment will serve as an impetus to the IT manager and his team in the: creation of a business case, matching vision and company strategy, communicating the vision, planning for and creating short term wins, implementing BIM; and in the consolidation of improvements and producing more change.

Hayes (2002) states that, during change, unfreezing behavior involves alerting organizational members to the need for change and motivating or coursing them to let go of the traditional ways of doing things. Literature provides a variety of change management approaches to managing change. Lewin's Three Step Model is one of the most used and perhaps the most popular approach in literature. According to Cole (2004) the Three Step Model follows a process of: Unfreezing existing behavior, changing behavior, and refreezing new behavior. This recognizes that before new behavior can be completely and successfully adopted the old behavior has to be discarded (Burnes, 1996). **With respect to the framework developed by this research, unfreezing behavior aims at educating SMEs on the need for BIM in the industry and getting the people to use the framework to accept the change**. For the change to take effect, there needs to be the development of new behaviors, attitudes, values, and actions.

8.4 Recommendations

Table 8.2: Barriers and how to address them

BARRIERS	RECOMMENDATIONS
Cost of Investment	- Grant; Use government grant to offset the cost of investment. The Jordanian Jordan Enterprise Development Corporation (JEDCO) and/or Ministry of Public Works and Housing could be the provider of such grants. - Use low cost but effective BIM software and systems.
Language of product	- Select software that has Arabic language and functions
Age of staff	- Train the young generation coming through the ranks in IT and BIM because they are the future of the company
Time to invest	- Preparing the Business Case will enable management make the decision whether or not the endeavor is worth pursuing
Culture, tradition, Habits	- Change management; communication, training, and streamlined processes - Create Awareness
Lack of skill and knowledge/AutoCAD Proficient	- Educate employees - Use more AutoCAD friendly software such as IDEA Architecture that offers an easy transition from AutoCAD and/or CAD software to BIM. Cheaper than Revit; low cost but effective.

Distrust of IT/BIM	- Train staff so they trust and have confidence in the BIM process - Change management; communication, training, and streamlined processes - Create Awareness
Ignorance	- Change management; communication, training, and streamlined processes - Create Awareness
Lack of awareness	- Generate awareness by sending staff to attend BIM conferences, arranging seminars, etc. and ultimately get first hand knowledge by adopting BIM on a pilot project - Organizations such as the Ministry of Public Works and Housing, Jordan Engineers Association (JEA), Jordanian Construction Contractors Association (JCCA), and BuildingSMART can collaborate to generate the necessary awareness to drive BIM forward within construction SMEs in Jordan.

8.5 Further research

For better understanding of how this framework will be useful among SMEs in the Jordanian construction industry, it needs to be implemented on a case project so that actual results of BIM adoption can be presented, documented and analyzed to see the practicality of the framework. Furthermore, the actual effects of BIM adoption on change management issues such as people and work processes and the adaptability of the framework in streamlining practices need to be documented. The aim is to understand from practice, the usefulness, clarity, simplicity and applicability of the framework in these companies. The feedback will be taken on board and appropriate modifications can be made to the framework for best practice. Additionally, the perspective of government institutions on grants can be included in the next study.

Also, the future of this research can be conducted on the; efficiency, effectiveness and performance measurements of BIM by SME contractors in Jordan using the matrices provided in Appendix 5. This is so we can measure between the ‘expected benefits’ and the ‘actual benefits’ achieved.

8.6 Contribution to knowledge

This study will be of significance to construction SMEs in Jordan due to the absence of a reliable framework for adoption of BIM for the Jordanian context. This research is poised to expand the area of BIM and to create more awareness of the benefits, applicability and implementation of BIM among SMEs in Jordan. This framework can be carried through further research, practically, so that technical benefits and challenges can be documented. Large construction companies in Jordan could also attempt to use it.

BIM knowledge and awareness in the Jordanian construction industry is poised to increase if the Jordanian government (public client), project owners, large construction companies and construction industry associations increase the level of exposure to BIM technology. With increased knowledge and awareness of BIM benefits, top managers and owners will be more willing to develop strategies to support BIM adoption and implementation. This research agrees with Attar and Sweiss (2010) that while it might appear too late to change the attitudes of most present-day decision makers, who are mostly traditional in their ways, increased investment in IT and BIM training and knowledge in Jordan could produce the future crop of leaders who will ensure optimum use of IT in their organizations. Training and increased awareness would encourage industry professionals to go beyond basic IT applications to more efficient interoperability and collaborative tools such as BIM.

8.7 Disclaimer

This research has not approached any government body with regards to giving grants. In order words, none of the following; JEDCO, MPWH, JEA, BuildingSMART; have promised to give any grants. The mention of these institutions in this research is to be seen by the reader as suggestions to that effect.

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10 APPENDIXES

10.1 Appendix 1

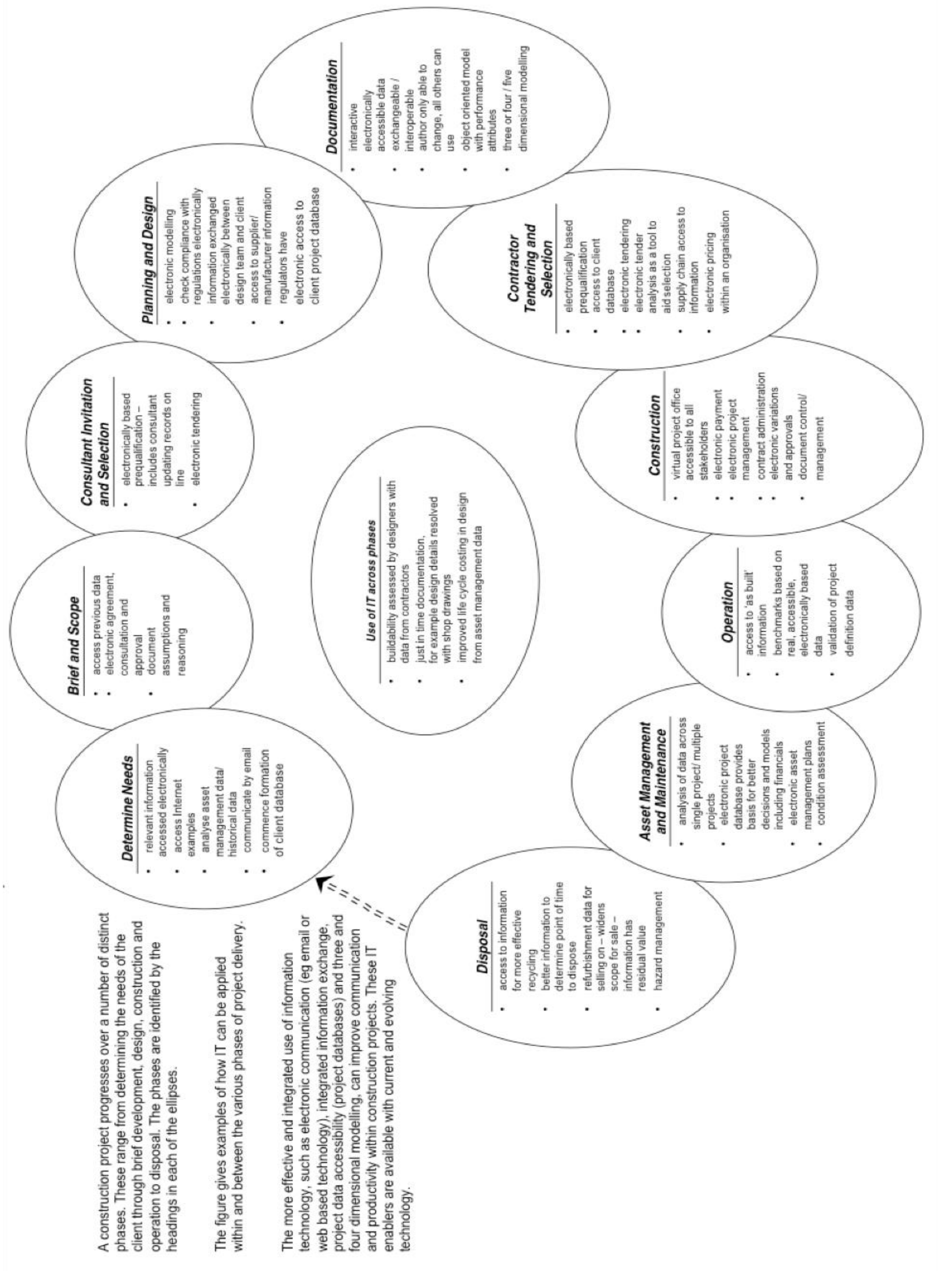
IT Involvement in construction organizations' functions and tasks

Phases	Functions and Tasks
Front end Planning	• Conduct market analysis or need analysis for a new facility • Develop, evaluation, and refine the project's scope of work • Diagram the manufacturing process • Estimate a budget from the scope of work • Prepare milestone schedule • Acquire and store site investigation data for use during design
Design	3. Access supplier product information 4. Input on construction methods and sequencing 5. Analyze construction methods 6. Detailed design from conceptual design 7. Prepare floor plans 8. Design fluid systems 9. Design structural systems 10. Design electrical systems 11. Design HVAC systems 12. Document the assumptions used in developing the budget, and pass to the next phase 13. Detect physical interference 14. Prepare specifications 15. Check the design against owner requirements and code requirement 16. Track design progress
Procurement	• Determine procurement lead time • Conduct a quantity survey of drawings • Link quantity survey data to the cost estimating process • Link supplier quotes to cost estimate • Refine the preliminary budget estimate • Develop the milestone schedule • Transmit requests for proposal to suppliers and subs • Prepare and submit shop drawings • Acquire and review shop drawings • Compile quotes into bid • Monitor fabricator progress • Plan transport routes
Construction Management	- Develop the construction schedule - Tract field work progress and labor cost code charges - Maintain daily job diary - Update cost forecast - Communication construction progress

	- Track site material inventory - Link field material managers to suppliers - Develop short--term work schedules - Communicate requests for Information and responses - Provide feedback about the effects of design changes - Communicate changes to field - Communicate status of change orders to field - Update as--built drawings - Submit request for payment - Transfer funds from owner's account to contractor
Construction Execution	- Evaluate subsurface conditions - Carry out earthwork and grading - Fabricate rebar cages - Weld pipes - Select the appropriate crane for heavy lifts - Provide elevated work platform - Fabricate roof trusses - Manipulate/hang sheet rock - Acquire and record laboratory test information - Apply paint/coatings
Startup, operations, and maintenance	- Conduct pre--operations testing - Train facility operators - Use as--built information in personnel training - Track equipment maintenance history - Develop equipment maintenance plans - Monitor and assess equipment operations - Facility operators request maintenance or modifications - Update as--built drawing - Monitor facility energy consumption - Monitor environmental impact of facility operations

10.2 Appendix 2

Application of IT through the life cycle of a project



10.3 Appendix 3

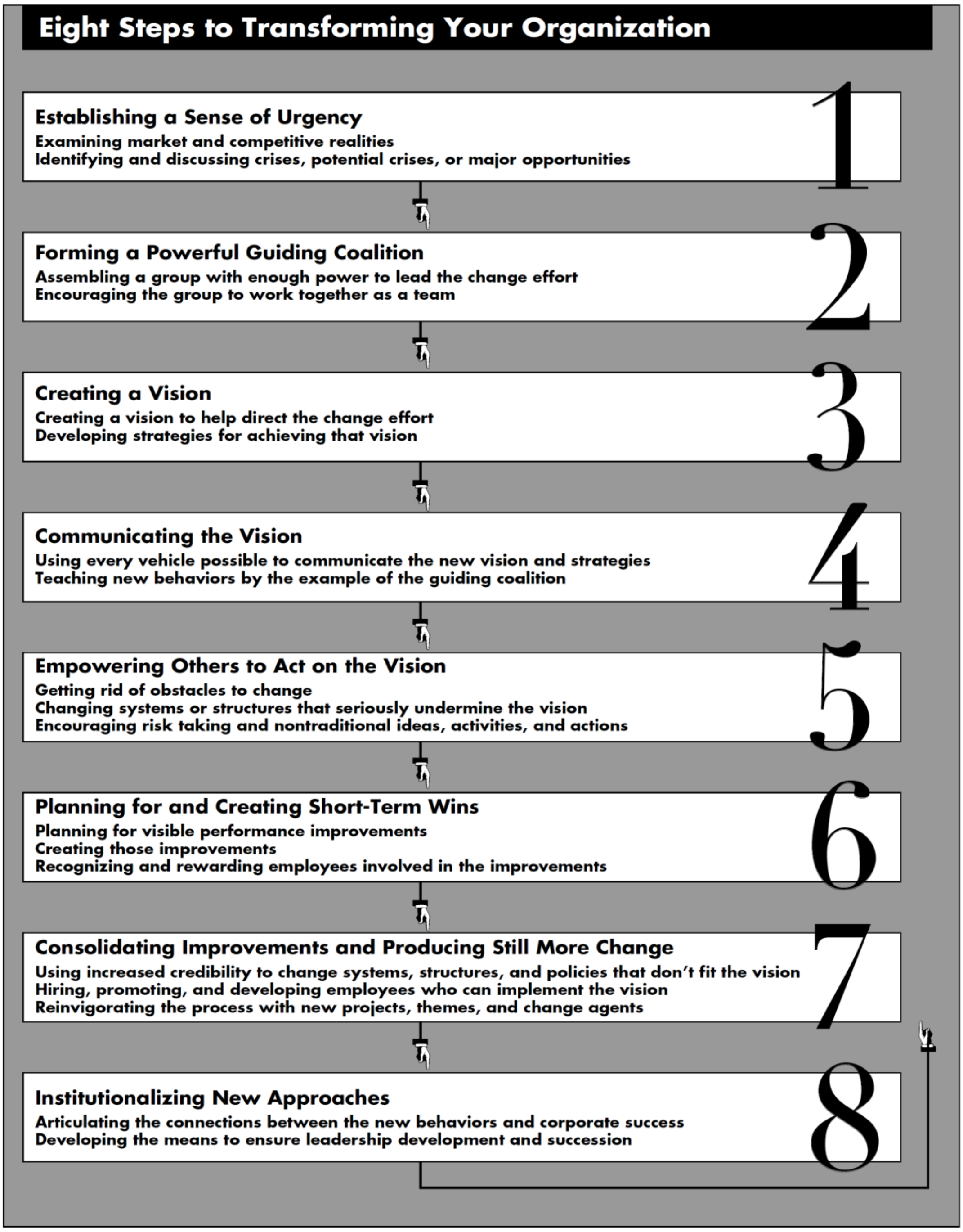
Current state of the Industry vs Vision of Construction ICT

Current State	Vision
Customized ICT is needed to meet varying needs of users. Tailor-made solutions for new situation require manual configuration, maintenance, and support.	Adaptive systems learn from their own use and user behavior, and are able to adapt to new situations without manual configuration, maintenance and support.
Information access to company and project data is available via LANs and web.	Ambient access anytime, anywhere regardless of physical location: office, construction site, home etc. Provided by industry-wide communications infrastructure, distributed and embedded systems, ambient intelligence and mobile computing.
Teamwork between distributed experts in participating companies is supported by web-enabled file and document management systems with basic team collaboration support ("project web sites").	Collaborative virtual teams combine distributed competences via global collaboration environments that support cultural, linguistic, social and legal transparency. Distributed team members collaborate across organizational, geographical and time boundaries as if they were co-located.
Construction site is an ICT island where mobile phones provide the only ICT connection.	Digital site connects mobile workers, intelligent products and site machinery to location and context aware real-time information and services.
Data exchange between different applications and companies is file based mainly using proprietary formats at low semantic level.	Flexible interoperability between heterogeneous ICT systems enables seamless interaction between all stakeholders. ICT tools and systems of different enterprises are interconnected very rapidly in unforeseen conditions.
Basic skills to use common tools are supported by heterogeneous learning initiatives	ICT skills & awareness promoted by systematic technology transfer, training, e-Learning and built-in learning support in ICT tools.
Experience and previous solutions are available in personal and departmental archives but new solutions are regularly re- invented in every project.	Knowledge sharing relies on industry-wide sharing of previous experiences, best practices and knowledge within and, increasingly, between organizations.
Contractual practice is based on paper documents, and digital versions of them, limiting the use of ICT to its full potential.	Legal and contractual governance supports ICT as the main means of contract preparation and enactment, inter-company communication and conflict resolution.
Document based ICT augments the creation and sharing of information, which still requires human interpretation and re-entry.	Model based ICT enables system integration at high sematic level, context awareness, automation, simulation, user specific views and visualization based on computer interpretable data.
Business process is driven by lowest investment cost, while customers are becoming increasingly aware of whole life costs, perceived value and intangible assets.	Performance driven process ensures conformity to customers' needs and emphasizes end-user satisfaction and value.
Buildings and products are at best equipped with isolated intelligence using vendor specific platforms and protocols.	Smart buildings and products support interactive workspaces, location & context aware services, ambient control and self-reporting.
Applications are dedicated to specific engineering functions and traditional sequential process phases. Sub-optimization is the norm.	Total Life Cycle is supported by ICT services for whole life decision-making by users, owners and the society.

Source: Hannus et al, 2003

10.4 Appendix 4

Change management steps (Kotter, 1995)



10.5 Appendix 5

Preparing The Business Case

Typical IT Benefits

Construction Business Process	Typical Efficiency Benefits	Typical Effectiveness Benefits	Typical Performance Benefits
Business Planning	Reduced planning times Better project definition	Increased Sales Minimizing business risk Strategic competitive advantage Increased business flexibility Maintaining competitive capacity Reduced risk in new business Ventures	Providing space and capacity for Business growth Safeguarding future flexibility Overcoming obsolescence Increasing responsiveness of senior management to business problems
Marketing	Reduced marketing costs Ability to handle more enquiries	Improved company image Generating new business Increased market share	Improved strategic intelligence for new markets Improved public relations targeting and delivery
Information Management	Reduced communications costs Reduced paperwork Reduced IT costs	Easier international links Fewer information bottlenecks Improved quality of output Sustaining market share Document production Document Quality Control	Improved information version control Ease of capture of meaningful information More relevant and reliable data Improved filtering of information
Procurement	Reduced storage requirements Reduced transaction times Reduced transaction costs Improved delivery scheduling Resource Assessment	Better options and sustainability analysis Faster response to supplier quotations Ability to provide instant price quotations to clients	Improving external access to stock levels and price information More effective identification and assessment of new suppliers Improved competitive capacity
Finance	Faster invoicing Reduced transaction costs More accurate cost estimating Better funding calibration and execution	Minimizing business risk Better control of cash flow Reduced lead times for financial reporting	Improved/new transaction methods Improved forecasting and control Greater integration with other functions
Client Management	Quicker response to client enquiries Quicker response on current project progress	Improved quality of output Faster delivery of services Improved focus on client requirements	Improved information exchange with clients Increased client satisfaction Strategic competitive advantage
Design and Engineering	Reduced lead times for design Reduced rework	Improved quality of output Reduced technology risks More responsive ability to	Improved idea sharing among project teams Integrated Project delivery

	Increased information exchange Better visualization Conflict Identification / Problem Identification	arrange meetings Increased speed of new design development Scenario Analysis (Feasability & ROI)	Improved overall building performance Decision/Knowledge/Data aggregation Accelerated decision making Impact exposure Accountability & auditability
Project Assurance	Quality control Predictability Delivery optimization Visibility Cost & Risk avoidance Information control	Improving competitive advantage Improved quality of output	Winning more bids Improved overall building performance Increased client satisfaction
Construction	Better construction planning Better field positioning Reduced construction times Improved productivity Reduced waste Better site logistics Better Phasing and 4D scheduling	Improved quality of output Reduced technology risks Ability to exchange data Claims analysis	Improved idea sharing among project teams Improved integration Improved project relationships with strategic partners
Operation and Maintenance	Reduced operating costs Quicker access to operation and maintenance data	Improved quality of output Ability to refer back to data	Improved capture of design and construction decisions Improved full life-cycle information management
Human Resources	Reduced staff requirement Reduced training Requirements	Improved record of staff skills Improved ability to select appropriate team members	More effective assembly of project Teams. Enabling of cross-functional teams. Improved human relations. Regularized working arrangements

Appemdix 5 Cont.

Measuring Efficiency Benefits (adapted from Andresen et al, 2000)

					Expected Benefits			Measured Benefits	
Business Process	Specific Benefits	Implication to this benefit of not making the innovation	Means by which benefit will be measured	Person responsible for achieving and measuring this benefit	Monetary Value (JD)	Likelihood of benefit occurring (%)	Expected benefit (JD) Col 6 * Col 7	Specific Benefit Resulting	Monetary value (JD)
Business Planning									
Marketing									
Information Management									
Procurement									
Finance									
Client Management									
Design									
Project Assurance									
Construction									
Operation and Maintenance									
Human Resources									
						TOTAL	JD		JD

Appemdix 5 Cont.

Measuring Effectiveness Benefits (adapted from Andresen et al, 2000)

					Expected Benefits			Measured Benefits	
Construction Business Process	Specific Benefits	Implication to this benefit of not making the innovation	Means by which benefit will be measured	Person responsible for achieving and measuring this benefit	Likelihood of benefit occurring (%)	Weighting (column total = 100)	Predicted Benefit (Col 6/100)*Col 7 (max = 100)	Specific Benefit Resulting	Measured benefit (max = 100)
Business Planning									
Marketing									
Information Management									
Procurement									
Finance									
Client Management									
Design									
Project Assurance									
Construction									
Operation and Maintenance									
Human Resources									

TOTAL			

Appemdix 5 Cont.

Measuring Performance Benefits (adapted from Andresen et al, 2000)

					Expected Benefits		Measured Benefits	
Business Process	Specific Benefits	Implication to this benefit of not making the innovation	Means by which benefit will be measured	Person responsible for achieving and measuring this benefit	Likelihood of benefit occurring (%)	Qualitative rating and description of the impact of the expected benefit. A = Very significant B = Significant C = Moderate D = Low	Specific Benefit Resulting	Qualitative rating and description of the impact of the measured benefit. A = Very significant B = Significant C = Moderate D = Low
Business Planning								
Marketing								
Information Management								
Procurement								
Finance								
Client Management								
Design								
Project Assurance								
Construction								
Operation and								

Maintenance								
Human Resources								

Overall Business Benefits (adapted from Andresen et al, 2000)

Types of Benefits	Expected benefits	Measured Benefits
Efficiency Benefits - Quantifiable and Valuable	Total forecast monetary value JD	Total realized monetary value JD
Effectiveness Benefits - Quantifiable but non-valuable	Total forecast score /100	Total realized score /100
Business Performance Benefits - Non-quantifiable and non-valuable		

10.6 Appendix 6

Title: Note taking during interview session

Name	xxxxxxx
Age	49
Years of experience	25 years
Questions	Answers
Q1: Do you use BIM?	No
Q2: Why do you not use BIM?	Because it is very expensive for me to change from our system to another and I don't have time to do that on my own. Also there are no experts in BIM here in Jordan to tell us what we have to do in order to adopt BIM. No training courses, no orientation, no seminars etc.
Q3: Do you know the specifications of BIM and what benefits it brings?	I don't know that much about them but I think the problem is not just my company or me, it is the whole situation in Jordan because there is no general knowledge about BIM here in Jordan.
Q4: What do you think are the main barriers for you to adopt BIM in your company?	For me, the financial issue is the most important thing; I can't afford spending a lot of money to adopt BIM. Then the time of changing and training my staff to work on BIM it is going to effect my work, this is about me.
Q5: Who should drive the adoption of BIM?	I think the government should force the contractors to start thinking of improving themselves and use advance IT otherwise it is going to take a long time for them to even think about it. The government should also provide facilities in order to make it easy for us to start using BIM.

Title: Note taking during interview session

Name	XXXXXX
Age	53
Years of experience	30 years
Questions	Answers
Q1: Do you use BIM?	NO
Q2: Why do you not use BIM?	Basically, because it is not a standard or rule yet in Jordan.
Q3: Do you know the specifications of BIM and what benefits it brings?	Not really. I heard about it when I went to the UK 2 years ago I met one of my friends he is in the construction industry over there and he was talking about BIM and it is going to be compulsory in the UK. Something like that. I asked him few questions about BIM and he was kind enough to answer me. After that he sent me some links by emails to read about BIM but unfortunately I was too busy and I wasn't interested to keep reading.
Q4: What do you think are the main barriers for you to adopt BIM in your company?	The awareness of BIM in the Jordanian construction industry in general, and the culture of the people particularly, You have to make a huge effort to convince them to change to something new. Of course this is cannot be done in a short term.
Q5: Who should drive the adoption of BIM?	Very simple, the government should do that like England, if they make it compulsory then we have to switch to BIM.

Title: Note taking during interview session

Name	xxxxxxxx
Age	63
Years of experience	40 years
Questions	Answers
Q1: Do you use BIM?	No
Q2: Why do you not use BIM?	I have no idea what BIM is.
Q3: Do you know the specifications of BIM and what benefits it brings?	Just my desktop to check and send emails.
Q4: What do you think are the main barriers for you to adopt BIM in your company?	The staff knowledge and age. I don't think they are open-minded to learn something new at this stage and age because most of them old. So I think they will refuse the idea from the beginning.
Q5: Who should drive the adoption of BIM?	The young people and the new generations. We are too old for this.

Title: Notes taking during interview session

Name	xxxxxxx
Age	35
Years of experience	10
Questions	Answers
Q1: Do you use BIM?	No
Q2: Why do you not use BIM?	Because the company owner is not willing to invest in such things. For me I would love to improve my skills by learning something new. As you know it is not an easy thing to find a new job, so that’s why I have to be silent and do what the owner want me to do, otherwise you know.
Q3: Do you know the specifications of BIM and what benefits it brings?	Not much. Very little,
Q4: What do you think are the main barriers for you to adopt BIM in your company?	General managers and owners
Q5: Who should drive the adoption of BIM?	The Jordanian Construction associations, they should force the managers and owners to adopt BIM for example, otherwise it will stay like that.

Title: Notes taking during interview session

Name	xxxxxxxxx
Age	30
Years of experience	7 years
Questions	Answers
Q1: Do you use BIM?	No
Q2: Why do you not use BIM?	No body in the Jordanian SMEs are using BIM and we are one of these SMEs so why should we use it.
Q3: Do you know the specifications of BIM and what benefits it brings?	No
Q4: What do you think are the main barriers for you to adopt BIM in your company?	It is not known or familiar in Jordan, I think the awareness of it is the first barrier. When I know what is BIM I will be able to discuss it with you and tell you why we cannot use it or what the obstacles of using BIM are.
Q5: Who should drive the adoption of BIM?	Jordanian Construction associations should do seminars about the new things or distribute monthly awareness leaflets for example.

Title: Notes taking during interview session

Name	xxxxxxx
Age	56
Years of experience	32 years
Questions	Answers
Q1: Do you use BIM?	No
Q2: Why do you not use BIM?	I don’t know what BIM is. First I should know what is it then I will decide if it is useful for my work or not.
Q3: Do you know the specifications of BIM and what benefits it brings?	I use 2d (paper) computer for general use
Q4: What do you think are the main barriers for you to adopt BIM in your company?	I can’t afford spending a lot of money. And I am happy for the way I work and I don’t think using advance IT is going to add something to my work or make more profit to my company because of the nature of my clients they don’t care about what I use to finish the work. All what they care about is to save money. So from that point I think there is no need for me to even thing about it.
Q5: Who should drive the adoption of BIM?	I don’t know but maybe the government.

Title: Notes taking during interview session

Name	xxxxxxxx
Age	36
Years of experience	12
Questions	Answers
Q1: Do you use BIM?	No
Q2: Why do you not use BIM?	When I start working as a contractor, we started like this and that's how we are doing our work since that time. So we don't have time to change our system or find out what is new. As long as we are able to do our work and compete in the domestic market, we don't need to waste our time and money to adopt something new. If we find that we start losing our name or credibility in the eyes of our clients because of that then definitely we will do our best to survive in the market by adopting any technology regardless of the cost.
Q3: Do you know the specifications of BIM and what benefits it brings?	No
Q4: What do you think are the main barriers for you to adopt BIM in your company?	As I told you, for us there are no barriers as long as we can still fight with what we have right now, we are fine. If we have to adopt something new we don't care about how much we are going to spend, maybe the time could be a problem but at that time we have only one choice, which is to wait.
Q5: Who should drive the adoption of BIM?	The Market.

Title: Notes taking during interview session

Name	xxxxxxxxx
Age	47
Years of experience	22
Questions	Answers
Q1: Do you use BIM?	No
Q2: Why do you not use BIM?	My employees are happy with what they are using at the moment and they are doing very well so there is no need
Q3: Do you know the specifications of BIM and what benefits it brings?	No I don't know but I think it is advanced and it could be helpful.
Q4: What do you think are the main barriers for you to adopt BIM in your company?	Awareness and the culture, and capital of the company. If we don't have enough money to invest in such IT, it will be big problem, as you know.
Q5: Who should drive the adoption of BIM?	The government should help us to improve our business to be at standard level also the Jordanian construction association plays a big role in this matter.

Title: Notes taking during interview session

Name	xxxxxxxx
Age	51
Years of experience	26
Questions	Answers
Q1: Do you use BIM?	No
Q2: Why do you not use BIM?	I don’t know what BIM is. this is the first time I’m hearing about it.
Q3: Do you know the specifications of BIM and what benefits it brings?	I use AutoCAD,
Q4: What do you think are the main barriers for you to adopt BIM in your company?	Too many things could be the barriers like money the language, culture, the way we work in Jordan, the awareness, law, etc.
Q5: Who should drive the adoption of BIM?	The private sector and large companies

Title: Notes taking during interview session

Name	xxxxxxx
Age	48
Years of experience	23
Questions	Answers
Q1: Do you use BIM?	No
Q2: Why do you not use BIM?	As you know in Jordan, it is very flexible here. No one is forcing us to use any thing. It is our choice to do our work as we like or as we prefer. If it compulsory then it is different story.
Q3: Do you know the specifications of BIM and what benefits it brings?	Nothing at all
Q4: What do you think are the main barriers for you to adopt BIM in your company?	No barrier until it becomes compulsory, then we start talking about the barriers.
Q5: Who should drive the adoption of BIM?	Of course the government

10.7 Appendix 7

University Of Salford
School of the Built Environment
Crescent, Salford, Lancashir M54WT, U.K.
+44 161 295 5000

Participant Consent Form (Interview)

TO:

Date:

Full Project Title: The uptake of advanced IT with specific emphasis on BIM by SMEs in the Jordanian Construction Industry

Principal Researcher: Omar Al Awad

Hello,

The purpose of my PhD research is to develop a framework for the uptake of advanced IT by SMEs in the Jordanian construction industry.

The SMEs in the Jordanian construction industry are facing many challenges including the competition from regional and international contractors. The SMEs needs to change and modernise, especially in terms of using IT as it can enable them to perform better and increase their ability to reach a high standard and have more credibility in the eyes of clients. An extensive study into this subject matter of information technology (IT) will enables the proper uptake of such technologies. IT in construction could include but not limited to; BIM, 3D/4D/ND, virtual reality, visualisation techniques, simulation and visualisation models to support the proper integration of design and construction information.

I am looking for construction practitioners who are willing to participate in recorded interviews. Your participation in the interview is entirely voluntary and you may refuse to complete the study at any point during the interview, or refuse to answer any questions with which you are uncomfortable. In case you refuse to carry on with the interview, answers you have given until that stage will be disposed and you will not be considered as a respondent. You may also stop at any time to ask any questions you may have. The interviews will be privately audio-recorded and would usually last around 60 minutes. The recordings will be encrypted and only accessible to the principal researcher, i.e. me - Omar Al Awad, and my supervisor, Dr. Yusuf Arayici.

I will transcribe the interviews. After transcription, you will receive a copy transcript of your interview that you can check for accuracy, or information that might unintentionally identify you. You can contact me to request amendment of the transcript up to 14 days after the transcript was sent to you. After 14 days, the transcript will be de-identified and encrypted.

The recordings and transcripts (data) will be used for analysis. Data will be encrypted and securely stored in accordance with University of Salford's data retention requirements.

You have the right to withdraw from further participation at any stage without implications. You may withdraw your data at any time until the end of the 14-day transcript checking period.

Contacts and Questions:
At this time you may ask any questions you may have regarding this study. If you have questions later, you may contact Omar Al Awad on 00962797030058 or O.s.alawad@edu.salford.ac.uk. If you have any concerns or complains about the conducted interview you may contact his faculty supervisor, Dr. Yusuf Arayici on 0044 777627566 or Y.arayici@salford.ac.uk.

Statement of Consent

I freely agree to participate in this project according to the conditions in the study. I have been given a copy of the Consent Form to keep. The researcher has agreed not to reveal my identity and personal details. I understand my interview will be audio-recorded and transcribed. Only the principal researcher and the supervisor will have access to the recording. The recording and transcription will be retained for a period of at least six years after completion of the project, and then disposed of in a secure manner, and the recording and transcription cannot be used for any other purpose without my prior consent.

I understand a transcript of my interview will be provided to me for checking and I will have 14 days in which to request amendments to the transcript by email to the student researcher.

Participant's Name (printed): ………………………………………………………

Date:………………………………….

If returning by email, please 'sign' by typing your name at the signature field:

Signature: …………………………………..

University Of Salford
School of the Built Environment
Crescent, Salford, Lancashir M54WT, U.K.
+44 161 295 5000

Withdrawal of Consent Form
(To be used for participants who wish to withdraw from the project)

To:
Date:

Full Project Title: The uptake of advanced IT with specific emphasis on BIM by SMEs in the Jordanian Construction Industry

I hereby wish to WITHDRAW my consent to participate in the above research project and understand that such withdrawal WILL NOT jeopardise my relationship with Omar Al Awad or the University of Salford.

Participant's Name (printed) ………………………………………………………………………
Date …………………………
Signature

Please mail or email this form to:

Omar Al Awad
University Of Salford
School of the Built Environment
Crescent, Salford, Lancashir M54WT, U.K.
+44 161 295 5000
O.s.alawad@edu.salford.ac.uk

10.8 Appendix 8

INTERVIEW QUESTIONS

1. What is your role in the company?
2. How many years have you been with the company?
3. How do you use information technology to support your day-to-day company activity?
4. How has your company used IT to monitor and improve performance?
5. How are stakeholder (clients, subcontractors, consultants, planning authorities, users, etcetera) inputs collected through the lifecycle of projects (from inception to completion)?
6. How is information shared? What's the dominant structure of information exchange? Paper based or computer based?
7. What is your company's ideology with regards to the use of IT?
8. What benefits have you enjoyed since the adoption of IT?
9. What were the challenges you faced when your company adopted IT for the first time and those it is facing now in the use of IT?
10. Are there monies set aside specific for investment in IT, e.g., BIM?
11. How would you categorize your understanding of BIM?
12. Does you company use BIM?
13. If yes, what are the benefits you've enjoyed using the software?
14. What is the rate of BIM adoption in Jordan?
15. Are there factors impacting your company's adoption of advanced IT such as BIM?
16. What is the way forward for your company with regards BIM?
17. What are the fears of adopting BIM? Barriers?
18. Who is responsible for driving the adoption of BIM in Jordan? For example, government, industry, and/or construction professionals
19. What are your recommendations for BIM adoption in Jordan?

QUESTIONNAIRE QUESTIONS

1. Do you use CAD?
    - No CAD
    - 2D only (paper)
    - 2D and 3D CAD
    - 3D
2. You aware or using BIM
    - Aware and currently using BIM
    - Just aware of BIM
    - Neither aware nor using
3. What is your perceived benefit of BIM to your company?
    - Positive, it will improve our business
    - Maybe, it will improve our business
    - Negative, it will not improve our business
4. How open are you to adopting BIM
    - Willing to adopt BIM
    - Not willing to adopt BIM
    - Undecided
5. Who should drive the adoption of BIM
    - Government
    - Construction associations
    - Large construction companies
    - Clients