ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

INITIATIVES FOR BIM ADOPTION IN THE LEADING COUNTRIES

M.Sc. THESIS

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Department of Civil Engineering

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JUNE 2018

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

ÖNDE GELEN ÜLKELERDE BIM ADAPTASYONU IÇİN GIRIŞIMLER

YÜKSEK LİSANS TEZİ

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İnşaat Mühendisliği Anabilim Dalı

Yapı İşletmesi Programı

Tez Danışmanı: Doç. Dr. Esin Ergen PEHLEVAN

HAZİRAN 2018

Panga Benjamin Yatich, a M.Sc. student of İTU Graduate School of Science Engineering and Technology student ID 501141114, successfully defended the thesis entitled "**INITIATIVES FOR BIM IN THE LEADING COUNTRIES**", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 04 May 2018
Date of Defense : 12 June 2018

FOREWORD

This master thesis research was inspired by the current wave of technological advancement in the building and construction industry. Building information modelling has been embraced by developed countries to sort out perennial problems that had gripped the industry. This review study presented initiatives undertaken by leading countries to facilitate BIM implementation. In addition it also presented examples of case studies that benefited for BIM processes.

I would most sincerely like to thank my supervisor Ass. Prof. Dr. Esin Ergen PEHLEVAN for guiding me every step of the way, without her support it would have not been possible.

Lastly, I would like to thank my professors for their wisdom and classmates who we always helped each other throughout my entire masters studies. I would like to dedicate my thesis to my family who have sucrificed a lot for me and are always praying for my success.

May 2018

Panga Benjamin YATICH
Civil Engineer

TABLE OF CONTENTS

Page

ABBREVIATIONS

AEC	**:**Architecture, Engineering and Construction
BEP	:BIM Execution Plan
BIM	**:**Building Information Modelling
BSI	:British Standard Institution
CAD	**:**Computer-aided design
CCIT	**:**Centre for Construction Information Technology
CDE	**:**Common data Environment
CIC	:Construction Industry Council
COBie	**:**Construction Operation Building Information Exchange
ECPIP	**:**Engineering and Construction Project Information Platform
GCC	:Gulf Cooperation Council
GDP	**:**Gross Domestic product
GSL	: Government Soft Landings
DM	:Dubai Municipality
FM	:Facility Management
GDP	:Gross Domestic Products
ICT	**:**Information Communication and Technology
IFC	:Industry Foundation Classes
IMF	:International Monetary Fund
IPD	:Integrated Project Delivery
IPR	:Intellectual Property Rights
IT	**:**InformationTechnology
LOD	**:**level of Development
MEP	:Mechanical, Electrical and Plumbing
NBIMS	:National Building Information Modeling Standards
NIBS	:National Institute Of Building Sciences
O&M	:Operation and Maintenance
ROI	:Return of Investment
R&D	: Research and Development

VR :Virtual Reality

3D **:** Three dimension

LIST OF TABLES

page

LIST OF FIGURES

page

INITIATIVES FOR BIM ADOPTION IN LEADING COUNTRIES

SUMMARY

Construction industry in recent years has been experiencing new wave of change with regard to technology, project procedures and even organizational structures. Building Information Modelling (BIM) is an emerging technological and procedural shift within the AEC industry. Its leveraging in project enables a level of collaboration that not only improves efficiency and reduces errors, but also raises productivity. Many developed countries have adopted BIM in their respective construction industries due to its benefits and hence making them the leading countries on its implementation and expertise. The goal of the research was to review BIM mandates and support in the leading countries and the initiatives that encourage its implementation. In addition, case studies of successful BIM usage in a projects of some countries under review were discussed and presented. Research findings indicate that most of the leading countries made it mandatory for BIM to be used in public projects. UK, Singapore, Finland, Norway and Denmark have developed a national BIM mandate while USA and UAE have BIM requirements by agencies and Dubai municipality respectively. Government through its agencies was found to be the major driver of BIM implementation by introducing various initiatives. It formed regulations and policies that made industry players restructure and come up with new ways to align themselves towards implementation of BIM in their projects. These efforts have resulted in tangible benefits like projects teams being more efficient through increased collaboration as well as improved productivity in the industry. Four case studies were also presented from three different countries. Most of these large scale projects that started within the period of 2014 to 2017 are still ongoing but clearly shows how BIM was implemented and its related challenges faced and subsequent benefits. In conclusion, this research indicate that despite the challenges of implementing BIM, governments and private sector including all the industry players worked coherently

towards successful BIM adoption in leading countries. In addition, those countries that had elaborate BIM strategy and BIM policies that were enforced by the government like the UK have come ahead of the rest as its industry is now BIM level 2 compliant.

INITIATIVES FOR BIM ADOPTION IN THE LEADING COUNTRIES

ÖZET

Son yıllarda inşaat sektörü, teknoloji, proje prosedürleri ve hatta organizasyonel yapılar açısından yeni bir değişim dalgası yaşamaktadır. Bina Bilgi Modellemesi (BIM), AEC endüstrisinde gelişen bir teknolojik ve prosedürel değişimdir. Projeden faydalanılması, sadece verimliliği artırmakla kalmayıp hataları azaltan, aynı zamanda üretkenliği artıran bir işbirliği seviyesi sağlar. Pek çok gelişmiş ülke BIM'i kendi inşaat endüstrilerindeki faydaları nedeniyle benimsemiştir ve bu nedenle uygulama ve uzmanlığı konusunda öncü ülkeler haline gelmiştir. Araştırmanın amacı, BIM görevlilerini ve önde gelen ülkelerde desteği ve uygulamayı teşvik eden girişimleri gözden geçirmekti. Ayrıca, incelenen bazı ülkelerin projelerinde başarılı BIM kullanımı ile ilgili vaka çalışmaları tartışılmış ve sunulmuştur. Araştırma bulguları, önde gelen ülkelerin çoğunun BIM'in kamu projelerinde kullanılmasını zorunlu kıldığını göstermektedir. Birleşik Krallık, Singapur, Finlandiya, Norveç ve Danimarka ulusal bir BIM yetkisi geliştirirken, ABD ve BAE sırasıyla ajanslar ve Dubai belediyesi tarafından BIM şartlarına sahiptir. Hükümet, kurumları aracılığıyla çeşitli girişimleri sunarak BIM uygulamasının başlıca itici gücü olarak görülmüştür. Sektör oyuncularını yeniden yapılandırıp, projelerinde BIM'in uygulanmasına yönelik yeni yollar geliştiren düzenlemeler ve politikalar oluşturdu. ABD, BIM'i kendi sektöründe benimseyen ilk ülkeler arasındadır. Son bulgular, en fazla BIM ürünü ürettiğini ve en çok tüketici olduğunu göstermektedir (Wong A.K ve ark, 2011). Genel Hizmetler İdaresi (GSA), ABD'de 8 milyar ABD Doları tutarındaki varlıkları yönetmesi nedeniyle GSA'yı çalışma kriterlerini değiştirmeye zorlayan teknolojinin öneminin artması nedeniyle ABD'de BIM tanıtımı ile görevli başlıca hükümet kuruluşudur (Hardy, 2006). Birleşik Krallık hükümeti, net bir strateji sağlayarak endüstrinin BIM

uyumluluğuna doğru ilerlemesinde önemli bir rol oynadı. Hükümetin büyük bir adımı, tüm kamu projelerinin 2016 yılında tam işbirliği 3D BIM'i benimsemesiydi. Buna ek olarak, her yıl sonunda ölçülebilir ilerleme gösteren zorunlu kilometre taşları içeren aşamalı bir plan yayınlandı. Bireysel Organizasyonlar, BIM Devleti'nin oluşturduğu BIM Görev Grubu'na geçiş dönemini destekleme ve yardımcı olma sözü veren Hükümet ile Seviye 2 BIM üzerinde kıyaslama yapmak zorundadır. Bu hükümetler, beklenmedik BIM hedeflerini gerçekleştirmek için eğitim için fon sağlayarak, ilgili vaka çalışmalarını yürüterek ve BIM temelli müfredat eğitimini formüle ederek inşaat endüstrisinde küresel inovasyonun geri kalanını ve ihracat fazlası becerilerini sektörel olarak ön planda tutuyor. fark edilmeden önce zaman ayırmak (BuildSMART, 2011). Üç ülke arasındaki (Finlandiya, Norveç ve Danimarka) temel benzerlikler, açık etkin BIM standartlarının benimsenmesini teşvik etmeleridir. Ayrıca, BIM'in benimsenmesini teşvik eden ana kurumlara sahip olmasına rağmen, özel sektör katılımı, kamuya açık olma oranının daha yüksek olduğu ve mülklerin daha çok yüzdesinin özel mülkiyete ait olduğu ve bu ülkelerdeki BIM'in benimsenmesinin başarısında büyük rol oynadıkları için kamuoyundan daha yüksek olduğu görülmüştür. Tek açık fark, her ülkenin kendi ulusal BIM yönergelerini geliştirdiği ve yayınladığıdır. Singapur'un inşaat sektörünün en önemli inisiyatifi ve dünyanın her yerinde tanınması, türünün ilk örneği olan CORENET aracılığıyla BIM e-teslim sistemidir. BCA'nın BIM elektronik gönderim sistemi, inşaat işletmelerinde dönüşümün Singapur'daki inşaat şirketleri tarafından yürütülmesinden sorumlu olarak kabul edilir. Sistem, proje ekiplerinin, düzenleyici kurum ofisi tarafından talep edilen tüm ilgili bilgileri içeren bir binanın tek bir BIM modelini göndermesini kolaylaştırır (BCA, 2011). Dubai bölgesel hükümeti (Belediye), AEC endüstrisinde BIM'i kullanmak için zorunlu hale getirerek diğer önde gelen ülkelere katıldı. Zorunlu şart sadece Dubai Belediyesine özgüdür. BIM gereksinimi, Ocak 2014'ten bu yana 18 Kasım 2013 tarihinde çıkarılan "196 No'lu Genelge" ile tüm sektördeki paydaşlara, 2015 yılında ise sirküler (207) ile başarılı olan özel bina projeleri için yapılmıştır. Ancak bu yönerge BIM'i kabul etmemiştir. Emirliklerin diğer bölgelerinde kullanmak (Mehran, D., 2016). Katar, sektöründe BIM'i görevlendirmemişti, belirgin BIM inisiyatifleri vardı. Katar'ın inşaat sektöründeki projelerin ihalesi, daha önce üstlenilen projelerden elde edilen faydalar nedeniyle, giderek artan bir şekilde, belirli BIM gerekliliklerıyle desteklendi.Teklif vermek için ihale belgelerini gönderirken BIM

kapsaması, teklif sahiplerinin bir şansa sahip olmak için uymaları gereken ortak bir uygulama haline gelmektedir (BIM merkezi, 2016).

Bu çabalar, proje ekiplerinin artan işbirliğiyle daha verimli olmaları ve endüstride verimlilik artışı gibi somut faydalar sağladı. Üç farklı ülkeden dört vaka çalışması da sunuldu. 2014-2017 döneminde başlayan bu büyük ölçekli projelerin çoğu halen devam etmekte olup, BIM'in nasıl uygulandığını ve bununla ilgili zorlukların nasıl karşılandığını ve sonraki faydalarını açıkça göstermektedir. Sonuç olarak, bu araştırma, BIM'in uygulanmasındaki zorluklara rağmen, hükümetlerin ve tüm sektör oyuncularının dahil olduğu özel sektörün, önde gelen ülkelerde başarılı BIM'in benimsenmesine yönelik olarak tutarlı bir şekilde çalıştığını göstermektedir. Buna ek olarak, İngiltere gibi hükümet tarafından uygulanan BIM stratejisi ve BIM politikaları geliştiren ülkeler, endüstri artık BIM seviye 2 uyumlu olduğu için geri kalanı daha geride kalmıştır.

1. INTRODUCTION

Construction industry is among the major contributors of any country's GDP. According to 2014, PricewaterhouseCoopers (PWC) report, the construction sector worldwide accounts for more than 11 percent of global GDP and the report predicted that it would account for 13.2 percent of world GDP by 2020. The other major competing industry is manufacturing and production industry. Unfortunately, construction industry has been lagging behind in areas of technological advancement, profitability, increasing in productivity, efficiency and optimization of processes to enable projects delivered in estimated time and within budget. Unlike the other industries, construction projects are individually unique and is dealt with uniquely as opposed to repetitive process applied in the other processing and manufacturing industries.

More importantly any given project requires participation of many parties right from the owner who is the financier, consultants who are the technical experts including; architect, engineers etc. and finally the contractors and suppliers just to name a few. These factors dictates that high collaboration of the various project participants is required in completing the project on time, which is never the case most of the time. Construction manager's primary role is to become the link to all the parties. Despite Construction Managers (CM) coordinating all the other participants in the effort of delivering projects to clients as planned, cost overruns have been the order of the day over the years due to unavoidable inefficiencies.

Further, the complexity of client's requests in conjunction with the expanding complexity of building, infrastructure and mechanical building and other development work especially as a result of advancement in technology over the a long time come about to expanding specialization inside the construction industry. As a result specialized construction specialist emerged in form of subcontractors further complicating managing of these projects. There was need to find a way to organize and coordinate all this players effectively. (walker, 2015).

In effort to try to solve the inefficiencies, profitability and productivity, researchers and players in the industry identified perhaps the most important aspect as the project delivery method. The determination of a framework on how project is to be conducted sets the terms for how players associate, which can have solid cost, planning and efficiency repercussions, beside other impacts like client fulfillment. (McGraw Hill Construction, 2014)

McGraw Hill Construction described Design-bid-build, design-build and construction management at-risk (CM-at-risk) delivery methods as the most dominant models as early as 1990s and that were well established. However, integrated project delivery (IPD) and design-build-operate/maintain (DBO/M) model emerged later on resulting into drastic shift. Integrated project Delivery (IPD) main strength is that it enhances collaboration between project teams. Despite the new integrated approach usage, there still existed complexities in correlational interdependence between the project team and therefore faced its fair share of challenges in addition to construction projects becoming bigger and capital intensive.

As a response of construction complexities, information Technology (IT) also has been growing and advancing tremendously because of major resources allocation to research and innovation of construction-related technologies. With increase in application of IT in almost all the industries, construction industry was not left behind.

One of the robust promising practical answers which has proved over the last decade of its capacity to triumph over challenges of the AEC issues is building information modeling (BIM) which has revolutionized the way processes are conducted.

Despite the fact that the driving forces for digital engineering and building information modeling for construction are obtrusive globally, national level adoption range significantly. As an example, nations like Singapore, the UK, America and Finland are leading in adoption, whilst coverage and adoption in nations such as those in middle east are still sluggish and have not developed country-specific BIM Guidelines .

Implementation of such a technology in an organization or in the entire construction industry can not be carried overnight or in an instant, this implies that an country willing to mandate BIM in its projects must learn from the pioneering countries that have already adopted BIM. Their experiences can prove to facilitate the paradigm shift expected with adoption of building information modeling. This research study

investigated the current BIM mandate and support in leading countries. It further explores the various initiatives undertaken to support adoption of BIM in the leading countries selected under the study.

1.1 Problem Statement

Most developing countries are experiencing economic growth which creates pressures on its AEC industry. Therefore, there is attempt to quickly adopt latest technologies and management tools to do away with perennial problems and to improve the performance of the AEC industry. Unfortunately, many of developing countries still face lack of commitments from the decision makers for the implementation of BIM. Leading countries have embraced BIM adoption in their respective construction industries. In fact, developing countries want to emulate the leading countries who have already pioneered in BIM adoption and are enjoying benefits from the minimization of the recognized construction performance gaps. Its anticipated that this thesis will be useful for developing countries like Turkey that are still at early stages of BIM adoption and are planning in future to mandate use of BIM in its construction sector. Policy makers and large government agencies that are exploring BIM implementation at project and program level can also benefit from this study.

1.2 Aim of the Study

The main aim is to review the current BIM mandate and supports in leading countries and the initiatives that encourage its implementation. To help achieve this goal, the following objectives were set:

1. To identify the main agencies/organizations and the roles they play in supporting BIM adoption in leading countries.
2. To identify public and private initiatives that encourage BIM adoption in the leading countries.
3. To point out the difference in the BIM implementation strategies employed by the leading countries under the study.
4. To explore a few case studies to demonstrate uses of BIM in Construction projects

1.3 Research Methodology

A qualitative research methodology was used. Literature review was conducted including the web pages of the BIM mandate and initiatives to support BIM implementation in various leading countries. The literature revealed that there are countries that were leading the way with BIM implementation, namely; United States (USA), United Kingdom (UK), Scandinavian Countries (Finland, Norway & Denmark), Singapore and middle Eastern countries (United Arab Emirates and Qatar). In order to structure the information presented in this research, firstly the countries under the scope of this study were grouped into groups with same geographical locations i.e. continents. Secondly, general BIM status, key players that supported BIM implementation, guidelines and standards and the various initiatives by the government and private sector were explained in details from respective countries.

Finally outstanding case studies that applied BIM between the year 2013-2017 were presented and discussed to further illustrate successful use of BIM in a project and demonstrating its outcomes from some of the selected countries under this study. The purpose of the case studies was to provide real example of BIM uses in aprojects and how it impacts it. These two parts will form the entirety of this explanatory study.

The following figure 1.1 present the overviewof the methodology

Figure 1.1: Sequence of the methodology of the thesis.

1.4 Gaps in the literature

Various studies have been done with respect to initiatives of BIM in various countries but the most notable ones are; Wong et al (2010), Smith (2014) and Mustaffa et al (2017) that talked about the attributes of BIM implementation in various countries. However it doesn't cover middle east countries neither does it tell the current situation of the BIM adoption in the leading country. The thesis research therefore explain in detail the key players, initiatives introduced both by private and public entities. Its then proposes a general roadmap for BIM adoption in Turkey.

1.5 Limitations

1. The entire research is based on literature review and any data used is from already documented sources.
2. The leading countries presented is limited to eight representing three continents.
3. Due to scarce availability of recent documented BIM case studies, only four cases were discussed from three different countries.

2. BUILDING INFORMATION MODELLING (BIM)

2.1 Brief History

Building information modeling has recently been creating a significant impression in entire construction industry. It may be new or may seem new to most industry players but in actual sense it has been evolving for more than fifty years (APROPLAN blog on history of BIM).

An article of "History of BIM" from exactal website in their issue of (10th February 2017) indicate that concept of BIM has been around since 1950's and was first documented in the paper 'Augmenting Human Intellect' Douglas C. Englebart (1962).

Figure 2.1 shows summary of the BIM historical evolution.

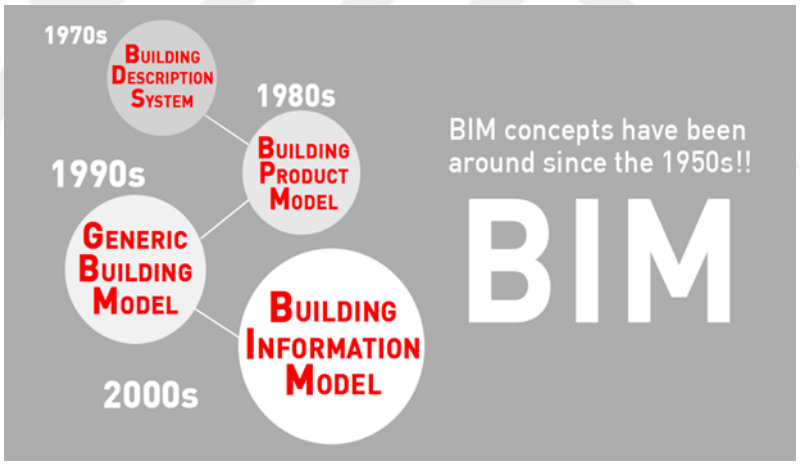

Figure 2.1: BIM historical evolution (Sourse: Exactal website, 2017).

Dr. Jonathan Ingram is documented to have given a fascinating talk on his work development of early CAD systems in which it was the foundation to BIM systems of today. Consistent to above exactal article, he stated that intelligent AEC modelling started with BDS (the Building Design System) which evolved over time leading to Dr. Ingram creating true 3D modelling environment and is recognized as being the first true system. (AEC Magazine, 2017)

Although BIM concept was presented around 40 years ago, its usability was isolated due to technological constraints. However, last 10 years has seen systematic removal of these technological constraints resulting to increase use of BIM worldwide. As

expected first world countries are leading in its use as will be discussed in later chapter. (Abbasnejad and Moud 2013).

2.2 BIM definition: What is BIM?

Building Information Modelling (BIM) is an emerging techology that is creating change in the Architecture, Engineering and Operations (AECO) field **(**Succar, 2009). Many definitions have been documented about BIM that depicts the suitable or the Ideal definition. The term BIM has been popularized by software developers as they seek to market the capabilities of their products further subjecting definition of BIM technology to variations and confusions, (Eastman, C. et al 2011).

Succar (2009) defined Building Information Modelling (BIM) as a "*set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle*"

Succar (2009) went further to breakdown the three components of his definition of BIM, namely; technologies, policies and processes with two subfields which are players and deliverables which was aimed at dissecting the process of implementation forming the BIM framework of successful implementation.

Digital, machine readable documentation, planning, designing, construction and facility managment are the components that facilitate BIM which can be further described as tools, processes and technologies (Wang et al 2015).

According to Wang et al (2015) BIM is data-rich, object-oriented, intelligent and parametric digital representation. Object intelligence characteristic depicts that it has many data that can be applied to them for example; material, material properties, 4D link (schedule), 5D data etc.

"*Building Information Modeling consists mainly of 3D modeling concepts, in addition to information data base technology, and interoperable software in a desktop computer environment that architects, engineers, and contractors can use to design a facility and simulate construction. The technology allows members of the project team to generate a virtual model of the structure and all of its systems in 3D and to be able to share that information with the entire project team*". (Kubba, 2017)

2.3 BIM vs Tradition Construction Methods

The figure 2.2 helps understand the sharing of knowledge through various stages of the project. The Red line represent a certain knowledge loss at the end of each transition when large information is passed on. For example at end of design phase, large amount of information is inevitably lost through call for tendering/bidding as the designer cannot be able to transfer the knowledge and experienced gained for that specific project. This is usually the case for the tradition construction methods. The blue line suggest a more consistent flow of information throughout the project stages as result of better coordination between parties and reuse of information and use of information technology. Application of BIM in a projects helps transform from the red curve to the more suitable blue curve.

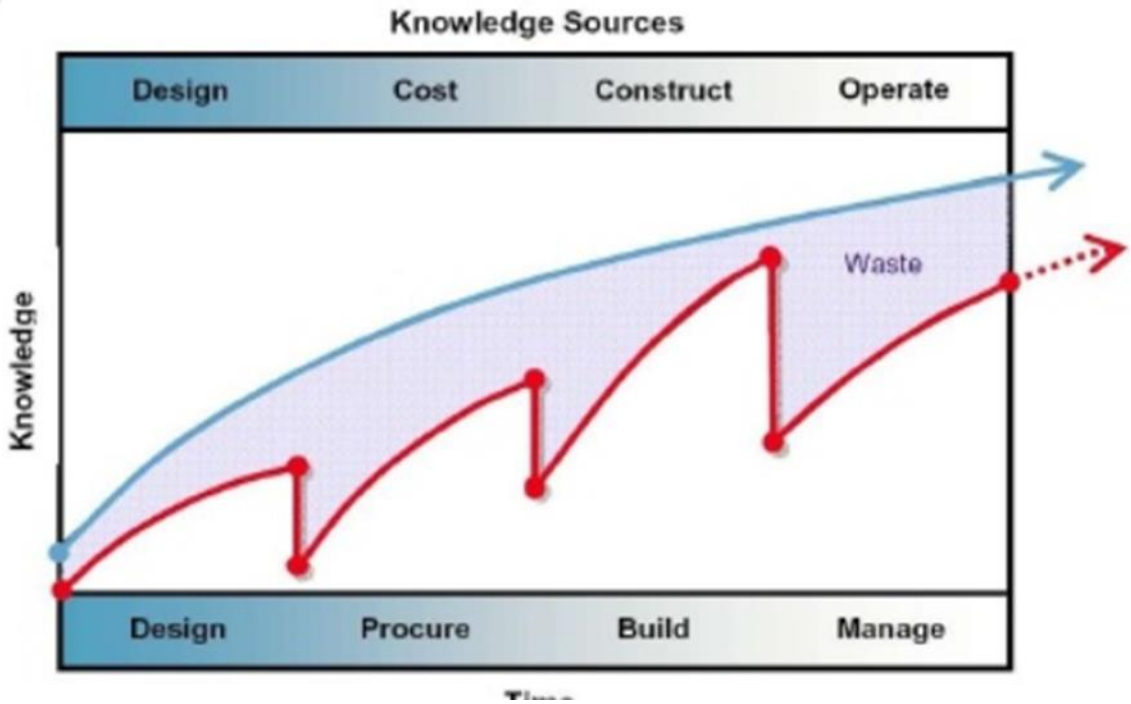

Figure 2.2: Shows knowledge accumulation of traditional approach and the one facilitated by BIM (Source: Eastman et al 2011).

2.4 BIM Uses

America buildingSMART Alliance published BIM project execution planning guide and it defined BIM Use as “A method of applying BIM during a facility’s lifecycle to achieve one or more specific objectives”. It summarized BIM Uses according to purpose of implementing BIM and in addition classified several characteristics so as

to exhaustively define BIM Use at varying levels of project lifecycle. Figure below show BIM Uses at varying levels in general.

Figure 2.3 show how BIM Uses have been defined by buildingSMART Alliance and broken down to its characteristics.

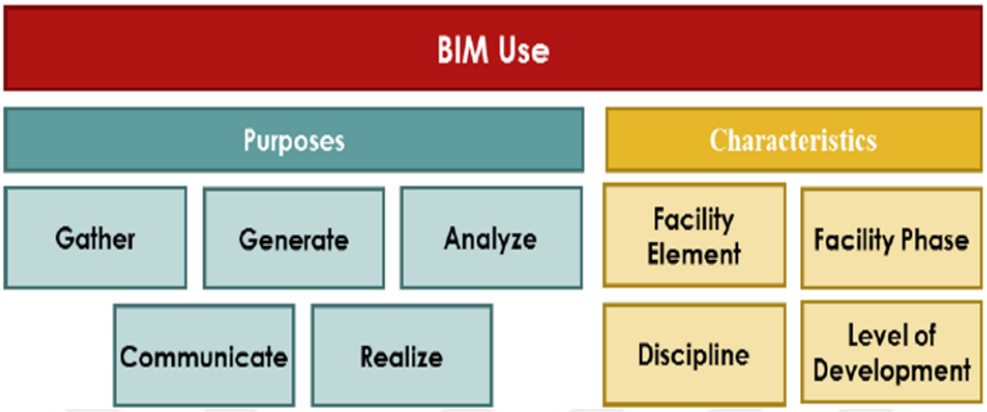

Figure 2.3: Components of BIM Use (Source: America buildingSMART alliance, 2011).

For the purpose of this specific paper it is important to define this BIM Use purposes to better understand BIM mandate in the construction industry. The definitions are as follows;

Gathering is to collect information about facility at various stages of facility's life. Collected information of facility is organized as the initial step of series of BIM processes.

Generating is to create information about the facility. This in other words means that the information you gather helps you to come up with design model. Include sizing, arranging and prescribing the elements of the facility to various Level of Development (LOD). Generation of information occurs along all phases by the different players responsible.

Analyzing is to examine the elements of the facility for a more detailed understanding. Normally after modeling period which is done by the different parties ranging from Architects to MEP design Engineers, analysis is require for purpose of coordinating, forecasting and validating. Analysis will thereafter inform decision making on how to proceed with the next BIM processes.

Communicating is to indicate all the information about the facility. After gathering the drawings and documents, vizualizing the flow of information is crucial and how it should be passed to the next user.

Realize is to make or control a physical element using the facility information. It can be found in the construction, operation and monitoring phases as it allows the manufacture, assembly, control and regulation of building elements. It greatly improves productivity of these two phases of lifecycle of the facility.

The above five categories of BIM Use Purpose are the primary objectives outlined by America buildingSMART alliance for any organization to implement the BIM Use. They can be further broken down to numerous categories for even a more specific BIM Use. When BIM Use need to be precisely defined beyond just its purpose, that's where characteristics are introduced. It include Facility element which describes facility elements which BIM Use will be applied e.g. visualization only. Facility phase on the other hand is characteristic that describe at which project stage the BIM Use will be implemented. For example, construction team may decide to do coordination analysis during the construction phase while the design team may do design coordination during Design phase. Third characteristic according this guide is discipline which describes the party responsible for the BIM Use right from initial phases to facility use. Final characteristic is Level of Development which describe the degree of detail in which BIM Use can be applied to facility element.

Table 2.1 shows results of a survey undertaken with aim determining the frequency by which organizations use each BIM Use and the benefit to the project of each Use by Ralph Kreider et al (2010). They summarized their finding on the table below that was released in 2010.

Table 2.1 : BIM Use Frequency and Benefit with Rank (Kreider et al. 2010).

BIM USE	Frequency	Rank	Benefit	Rank
	%	1 to 25	-2 to +2	1 to 25
3D Coordination	60%	1	1.60	1
Design Reviews	54%	2	1.37	2
Design Authoring	42%	3	1.03	7
Construction System Design	37%	4	1.09	6
Existing Conditions Modeling	35%	5	1.16	3
3D Control and Planning	34%	6	1.10	5
Programming	31%	7	0.97	9
Phase Planning (4D Modeling)	30%	8	1.15	4
Record Modeling	28%	9	0.89	14
Site Utilization Planning	28%	10	0.99	8
Site Analysis	28%	11	0.85	17
Structural Analysis	27%	12	0.92	13
Energy Analysis	25%	13	0.92	11
Cost Estimation	25%	14	0.92	12
Sustainability LEED Evaluation	23%	15	0.93	10
Building System Analysis	22%	16	0.86	16
Space Management / Tracking	21%	17	0.78	18
Mechanical Analysis	21%	18	0.67	21
Code Validation	19%	19	0.77	19
Lighting Analysis	17%	20	0.73	20
Other Eng. Analysis	15%	21	0.59	22
Digital Fabrication	14%	22	0.89	15
Asset Management	10%	23	0.47	23
Building Maint. Scheduling	5%	24	0.42	24
Disaster Planning	4%	25	0.26	25

Table 2.1 clearly that 3D Coordination and Design Reviews have had the most frequency of use and also had most perceived benefits. Therefore, if a certain BIM use is implemented in a project results of Kreider et al 2010 research indicate that its frequency of use corresponds to the benefits to be realized. Another clear observation from the result in the table above is that BIM Use was majorly implemented in the early stages of the project lifecycle (design and construction phases). Facility management phase is still experiencing minimal BIM Use implementation hence the benefits recorded from the result above was of lower percentage and ranked lowest in both frequency and benefits.

2.5 BIM Application in Different Stages of Construction Project

2.5.1 Design phases

Design phase can be divided into conceptual and design development. The use of BIM in the conceptual design phase can be used to set requirements, perform energy and comfort analysis, compare and contrast different design options and cost managment based on the area. Architecture, Engineering and Construction are the groups which are the bigget beneficients of BIM due to collaboration and design information sharing.

2.5.2 Procurement

BIM is utilized in procurement phase for: visualization, mass and quantity take-offs, construction schedules and production planning.

2.5.3 Construction

During the Construction phase BIM is used in many ways. The minimum level is visual support in the installation order planning. However, in some cases BIM is used for the whole construction management which includes: schedules, prefabricate design and delivery and sub-contract purchases. Renovation projects benefits from BIM as well.

2.5.4 Maintenance

Although BIM has not been widely used in operation and maintenance yet, more models and BIM based Facility Management solutions are available.

3. BIM IN LEADING COUNTRIES

3.1 General Introduction

The adoption of BIM strategies and technology is trending currently in the construction world that has been gathering momentum during the last decade, motivated by way of the need for better results. BIM initially started by individual organizations seeking to better their working formula for more gains and was generally viewed as bottom up approach. Through vast range of pilot projects conducted by architects, engineers, contractors and clients it grew and became a real game changer initially in the global building sector and later infrastructure.

3.2 Factors Driving Adoption of BIM Across Continents

The reason why USA took an early lead adopt BIM for public buildings was primarily keep in check the design and construction costs and with time clients have become more aware of the benefits that are expected if BIM if fully utilised in regard to the entire life of the facility hence shifting to lowering total lifecycle costs. Other factors that encouraged uptake of BIM is rising energy prices. USA, European Union (EU) and other regions are constantly targeting to reduce carbon emmission and how energy is used by enacting legislations which encouraged sectors like Construction market to consider to Use BIM to align with this legislations. In late 2000s there were notable introduction of new technologies that have improved the acceptance of BIM for example; cloud based data storage, better and more BIM-authoring tools etc. Another important factor is leading countries want to keep competitive edge in the global Construction market. In nations where BIM is still not yet embraced by the leaders of the industry, there is a genuine possibility of remaining behind the pack and even loose business opportunities offered by BIM in ever growing building markets, especially in the international market. (McGraw Hill Construction, 2014)

3.3 BIM Maturity Index Level

BIM levels is a concept that has become accepted formular of being regarded as BIM-compliant. It's composed of levels (0, 1, 2, 3) and indicate the stages undergone during BIM implementation process untill higher levels when it is considered to have matured also referred to as BIM maturity index (Autodesk Community forum).

The definition of the concept of BIM maturity levels is not very clear but UK BIM has defined them as follows;

3.3.1 Level 0

This the most basic level of almost non existence BIM whereby no collaboration exists at all. CAD tools is used create drawings mainly for production of information. Majority of industries is past this stage.

3.3.2 Level 1 BIM

The level refers to migration from 2D to 3D concept work. Although collaboration doesn't exist in this level, each project participant produces own data shared in a central data environment (CDE), often managed by a contractor. Many organizations are currently operating at this level.

3.3.3 Level 2 BIM

This level is what all organizations adopting BIM wants to achieve. It basically progresses from modelling to collaborating and interoperability. Collaboration is a major element of this level. Sharing of information from various designers is done through a prior agreed file format to enable parties combine the data and come up with an integrated BIM model and to carry out repeated checks on it.

3.3.4 Level 3 BIM

BIM at this level is nolonger about just sharing of information in a central storage but it forsees a a situation where fully integrated project environment is achieved. This means that access and modification of the model can be done by all parties in real time and simulteneously. Ultimate goal of BIM process which is refered to as 'Open BIM' is level 3 where worries experinced in the preceeding levels in regarding copyright and liability are expected to be overcome. At this stage focus will shift to include sustainability of facility.

Many developing and developed economies today are contemplating putting up BIM framework because of realisation that BIM adoption minimizes lifecycle building costs. The governments specifically United Kingdom (UK) have recognized that in order to move construction industry to 'full' collaborative working it has to be done in incremental steps broken down as the BIM 'levels'.

Table 3.1 shows some of the leading countries in BIM implementation according to Mustaffa (2017) in their research paper. Their findings illustrates where the leading countries lie in terms of the BIM maturity.

Table 3.1 : BIM maturity index level (Source: Mustaffa, 2017).

Country	BIM Maturity Index Level	
United States of America (USA)	BIM Level 3	• The AIA has been a driving force in promoting the Integrated Project Delivery (IPD) model which contractually bringing the client to collaborate at early stage in the delivery of a project. • The collaborative approach of the IPD model allows for increased data sharing between the design and project teams. • The AIA has produced a suite of documents which are based on the IPD model.
United Kingdom (UK)	BIM Level 2	• Mandated by the UK government in 2016 • By 2016, level 2 BIM will be mandatory on all public sector projects, including delivery of all project and asset information, documentation and data [22]; • In 2016, The UK Government has called for the wider industry to adopt BIM Level 2 [32]; • It is generally understood that current Joint Contracts Tribunal (JCT) contracts (as well the NEC contracts) are well equipped to address the requirements of Level 0 BIM and Level 1 BIM • For Level 2 BIM, the only document to be inserted is called BIM protocol as a supplement document into the main standard form contracts. • The UK Chartered Institute of Building (ClOB) in 2012 had launched its Time and Cost Management Contract 1st Edition 2013 which incorporates Level 2 BIM by way of a protocol [33]; • In future, UK has the vision for Digital Built Britain / UK BIM Level 3. The Digital Built Britain strategy takes the next step in integrating these digital technologies, transforming the approaches to infrastructure development and construction and consolidating the UK's position as a world leader in these sectors. It will based on fully computerised construction.
Finland	BIM Level 2	• Foresight the identification of needs and opportunities and the value for users, owners, and builders and development of new concepts; • Currently, no published standard form construction contracts that specifically address BIM in Finland; at present, General Services Administration (GSA) in the USA and the Association of Finnish Contractors (AFC) collaborate in establishing BIM standards [6]; • In 2012, Finland through its Building SMART collaborated with other international organizations from a few countries has developed open BIM Standards and processes to support the use of BIM implementation; • As founded [33], at present, there are no published BIM friendly contracts in the Scandinavian region (Finland, Denmark, Norway). There is very little material in the countries on how BIM is contractually integrated.
Australia	BIM Level 2	• In spite of the growing number of Australian based projects adopting BIM, thus far, Level 0 BIM to Level 2 BIM seem to be most extensively used form of BIM in the Australian construction market; • At present, there are currently no published standard form construction contracts that specifically address BIM in the Australian construction market [33]; the only provisions and requirements in implementing BIM are likely by adopting bespoke contract.
Singapore	BIM Level 1	• The Building and Construction Authority (BCA) in Singapore led a multi-agency effort in 2007/2008 to implement the world's first BIM electronic submission (e-submission). [22] through the CORONET's e-PlanCheck Automated Code Checking; • Currently Singapore does no published standard form construction contracts that specifically address in BIM. The only provisions and requirements in implementing BIM by private sectors are likely by adopting bespoke contract.
Hong Kong	BIM Level 2	• Even though Hong Kong is an active BIM practitioner [22] in construction; currently no published standard forms of contracts that specifically address BIM in Hong Kong construction projects.

3.4 United States of America (USA)

3.4.1 General introduction

USA is among the first countries to adopt BIM in its industry. Recent findings indicate that it produces the highest amount of BIM products and also is the top consumer. (Wong A.K et al, 2011)

USA being a large country, government consists of several agencies that operate in parallel or in sometimes in collaboration for promoting and developing BIM applications. General Services Administration (GSA) is the prime government agency tasked with BIM promotion in USA. Since technology became increasingly important throughout the decade it forced GSA to change its working criteria considering that it manages assets amounting to US $8 billion. (Hardy, 2006)

GSA began working on use of BIM through its office of Chief Architect as early as 2003 through 10 pilot projects which were successfully completed followed by 25 more that were expected to run through 2006 and beyond leading to establishment of "the National 3D-4D-BIM Program". This program mandated use of Building Information Technology in the design stage as a minimum requirement although at that particular time it only advocated for design phase. (GSA, 2007)

McGraw-Hill Construction (2014) indicated that the overall adoption of BIM did increase by about 45% from 2007 to 2012 in the United States of America, registering a 45% growth to over 400% between the five year period. The survey revealed also that, in the year 2012, adoption by all categories of stakeholders involved in construction sector generally increased. Positive return on investment (ROI) in implementing BIM in projects was reported i.e. contractors percentage proportion of positive ROI was (74%), owners (67%), and architects (65%) respectively.

Table 3.2 indicate how construction firms in the US was believed to be using BIM technologies on projects.

Table 3.2 : BIM contractors in the USA (Source:McGraw Hill (2014).

Year	BIM engagement Index in the USA(BIM engagement Index globally)			
	Low	Medium	High	Very High
2003	National 3D- 4D BIM program			
2007	BIM mandated			
2014	21%(36%)	36%(36%)	22%(17%)	22%(11%)

3.4.2 Organizations supporting BIM implementation in USA

There are several agencies involved in pushing for the BIM agenda in the United States as listed below;

1. General Services Administration (GSA) - main public client of the federal government tasked with BIM implementing. GSA is accredited for launching "National 3D–4D BIM program" in 2003 (GSA, 2007).
2. National Institute for Standards and Technology (NIST) - tasked to conduct research on BIM that are critical in advancing its implementation. In a nutshell it was an institution developing guidelines and building standards (NIBS, 2007).
3. CAD/BIM Technology Center - research branch of the US Army Corps of Engineers (USACE), for providing technical and professional services for BIM implementations across their projects and also ensures acceptable ROIs.
4. Construction Engineering Research Laboratory (CERL**)** is also of the USACE and like CAD/BIM center it's a research institution. It came up with tranformatory products in BIM world such as COBIE (Construction Operations Building Information Exchange).
5. International Code Council (ICC) **–** its main responsibilies are related to compliance with reulations and standards within US and beyond. Through NBIMS-US Project, consensus-based open BIM standards was formulated to act as a catalyst for innovation in processes and infrastructure. (NIBS, 2007)
6. US Department of Veterans Affairs (VA) advocates for the use of BIM in its construction and renovation projects. IT also came up with elaborate BIM guide to be used during design and the construction by all the project participants including the contractors specifically hired by the VA.
7. American Institute of Architects (AIA) concerns with deployment of computer technology and related topics in the Architecture, engineering and construction practice .
8. Several US states, universities and private organizations were actively involved in supporting the adoption of higher BIM standards. Here are few notable examples; Indiana University released "Indiana University BIM Standards and Project Delivery Requirements" in 2009, Penn State University came up with use of BIM by facility managers in 2009 and finally Wisconsin state mandated BIM in all its public projects in 2010.(Requirement: total

project cost of over $5 Million and all future new construction projects with a budget of $2.5 million or more to implement BIM).

3.4.3 BIM guidelines in USA

GSA developed BIM guidelines after undertaking several pilot projects which were later adopted across the US construction industry. They are also refered to as GSA BIM guidelines. (GSA website)

3.4.3.1 BIM guide 01-overview

The Guide focuses on how BIM technology and specifically, GSA's National 3D-4D-BIM Program can be used in support of better design and construction. It specifically targets GSA's employees and consultants who are getting started with BIM and trying to find appropriate BIM applications for specific GSA projects. This guide was published in 14th may 2007.

3.4.3.2 BIM guide 02 - Spatial Program Validation

This guide defines how BIM is used to design for and validate spatial program requirements for GSA properties. All major projects that receive design funding in Financial Year 2014 and beyond are required to use BIM for all phases of design and as the source for spatial program reviews and spatial data management submissions. This guide was published 21st May 2015.

3.4.3.3 BIM guide 03 - 3D Imaging

This guide is concerned with acquiring building spatial data in three dimensions with high degree of accuracy within a short time. The rapid collection of 3D information serves several purposes across GSA business lines, including: historical documentation, facility condition documentation and audits, construction as-built development and BIM development. Laser scanning is the common tool used to collect this type of data. It was published in 1st January 2009

3.4.3.4 BIM guide 04 - 4D Phasing

This guide is concerned with 4D models (combining 3D model with time). It allows project teams to evaluate various time-dependent project activities in an efficient and quick way. GSA implement use of 4D modelling in project-by-project basis. This guide was published 25th September 2009.

3.4.3.5 BIM guide 05 - Energy Performance

This guide is concerned with energy analysis and operational practices. GSA is using building information modeling (BIM) for energy modeling to strengthen the reliability, consistency, and usability of predicted energy use and energy cost results to be able to define sustainability goals that federal agencies are required to meet each year. Energy modelling is done by frequent energy simulations throughout design, construction, and building operations. This guide was published 2nd June 2015.

3.4.3.6 BIM guide 06 - Circulation and Security Validation

BIM Guide 06 focuses on how BIM can be used to facilitate design decisions to ensure that a proposed design meets circulation requirements. It specifically uses US Courts Design Guide as its primary example to show a complex set of circulation requirements.

3.4.3.7 BIM guide 07 - Building Elements

This guideline explains different forms of building information and provides guidance on how it was to be used by multiple downstream business processes. This guide was published 30th September 2016.

3.4.3.8 BIM guide 08 - Facility Management

This guides is on how BIM genarated from all phases of construction can be if valuable importance in facility management phase. GSA intended to use and update this data throughout the facility lifecycle. This guide was published 25th January 2012.

3.4.4 BIM initiatives and supports in USA

GSA being the prime agency pushing for BIM advancement initiated most the initiatives and top being national 3D-4D BIM Program in the year 2003. The original intention was to control cost along with increasing project quality, productivity and efficiency throughout project lifecycle. GSA National 3D, 4D-BIM program focused attention on the following;

i. First and the most important was to publish the BIM Guide Series that comprised of eight guides.

ii. Established mandatory requirement of using BIM for all major GSA projects.

iii. It approached the software vendor companies like Autodesk and Bentley to create technology products that are interoperable. Since interoperable work proved to be the key to higher productivity and efficiency.

iv. Extending use BIM data in facility management.

v. Providing continuous supervision and always check how the industry reacts to introduction technological solutionsby partnering with academic/research institutions.

vi. Developed special contracts for specific projects that will incooperate 3D-4D-BIM.

vii. Finally it built a group of BIM experts within GSA and published them in their website for the industry to consult them. (GSA, 2007 and McGraw Hill Construction, 2014)

GSA published BIM Guide in collaboration with other development partners which helped produce consistent project outcomes as there was clear way of performing BIM related processes and predictable outcome. (Hardy, 2006).

U.S. Army Corps of Engineers (USACE) another major agency advocating for BIM in its projects. In the year 2006 it mandated all its projects to use BIM specifically for architecture and as-built data. The main reason for the mandate was to lower cost of designing prototypes of "standard facilities" which constitute the bulk of its projects . They are currently making plans to go a notch higher in its BIM implementation and focus on business process transformation and future adding an extra requirement of submitting a COBie data sheet for use in project lifecycle. (USACE, 2007)

Naval Facilities Engineering Command (NAVFAC) also embarked on Building data Information Management and Modeling (BIM) Phased Implementation Plan. This policy initiative was targeting new building with capital cost of over 750000 thousand dollars, major renovations costing over 25 million dollars and those plants that are equal or greater than replacement value. Their ultimate aim is that by using BIM they can be able to have data of the entire project lifecycle by ensuring that in future projects, data will be submitted as electronically. (McGraw Hill, 2014)

3.5 Europe

Europe has always remain among the world leaders in all fronts which is majorly attributted towards a strong Union body. As BIM and use of technology in general grew globally, countries under European Union were not left behind. European Parliament came up with incentives in form of policy formulation in an attempt to encourage its member states embrace and adopt BIM with the ultimate target of cost overrun reduction in construction project.

3.5.1 United Kingdom (UK)

In 2011 the United Kingdom government developed strategy to revolutionize construction sector. The goals were reduction of public capital expenditure by 20% and reaching the United Kingdom carbon reduction commitments of down 50% in 2019. The document highlighted some of aspects to accomplishing those objectives and using BIM was singled out as one of the key components in the approach. These reasons lead to establishment of BIM Task Group which immediately started working hence producing several reports, forming other task specific working groups and conducted pilot projects . from these efforts and the seriousness of government, UK therefore embarked on an ambitious plan to be BIM level 2 compliant by the year 2016.

"*This Government's four year strategy for BIM implementation will change the dynamics and behaviors of the construction supply chain, unlocking new, more efficient and collaborative ways of working. This whole sector adoption of BIM will put us at the vanguard of a new digital construction era and position the UK to become the world leaders in BIM*" (Francis Maude- minister for the Cabinet office)

3.5.1.1 Organizations formed to support BIM adoption in UK

The Regional BIM Hubs, now known as the BIM Regions, BIM Task Group and the Construction Industry Council (CIC) were the major organizations that lead in BIM implementations in the UK with their maiden tasks were to come up with BIM initiatives to enable rapid adoption in the industry. (Cabinet Office, 2011)

3.5.1.2 UK BIM guidelines

According to BIM Regions, BIM is unforgiving since it demands proper following of processes while being guided by prescribed standards.

British Standard Institution (BSI) produced a standard code of practice known as BS1192:2007 which introduced eight Level 2 documents or 8 pillars of UK level 2 BIM as shown in figure 3.1.

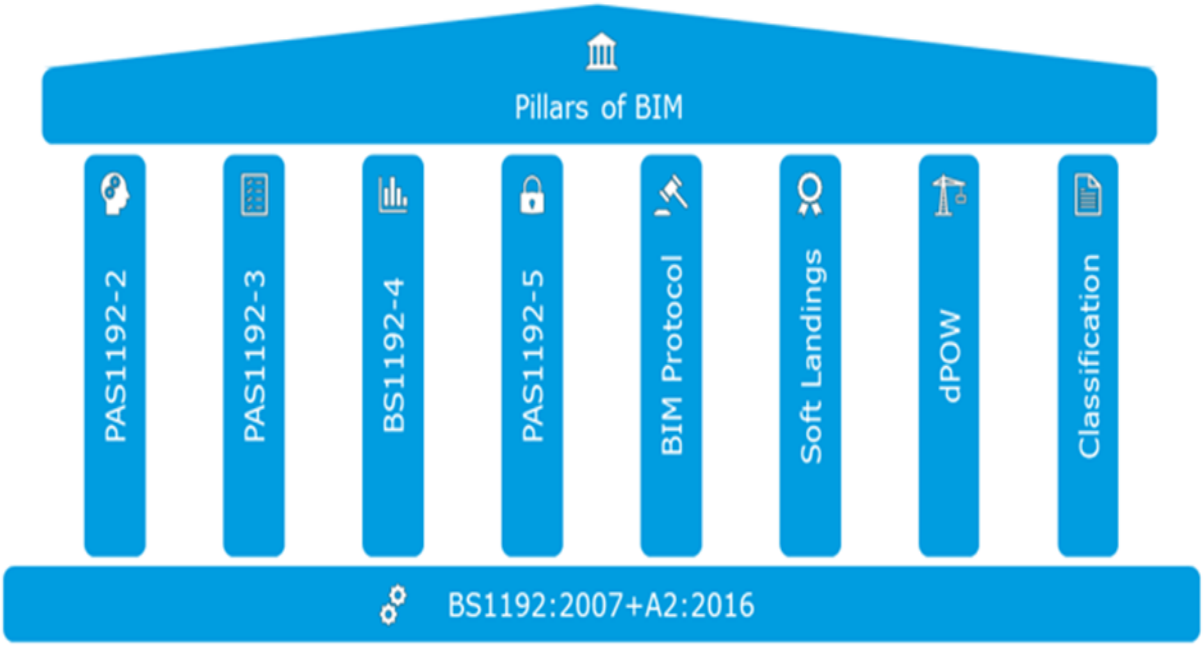

Figure 3.1: Pillars of UK Level 2 BIM (Source: BSI, 2013).

"*The purpose of the PAS is to support the objective to achieve BIM maturity Level 2 by specifying requirements for this level, setting set out the framework for collaborative working on BIM enabled projects and providing specific guidance for the information management requirements associated with projects delivered using BIM*" (Task Group, 2011)

3.5.1.2.1 Pillar 1 - PAS 1192 Part 2

Specifies how information is managed at the conception of the project. This include; Clients information requirements, BIM execution plan, capabilities and roles of all the teams, co-ordination strategy etc.

3.5.1.2.2 Pillar 2 - PAS 1192 Part 3

Stipulates how information will be managed and exchanged during operation and maintenance period. This phase begin right from handover to the end facilities life.

3.5.1.2.3 Pillar 3 - BS 1192 Part 4

Concerns mainly the COBie requirements. There should be COBie outputs at every phase of the project during modelling process which mostly occur inform of a spreadsheets.

3.5.1.2.4 Pillar 4 - PAS 1192 Part 5

Specifies how BIM working environment can be made secure as it operate in digital environment which is susceptible attacks. Generally, Relates to cyber and digital security which is important given that BIM is pull of digital information.

3.5.1.2.5 Pillar 5 – CIC BIM Protocol

It is solely for contracting purposes. It's a form of an addendum that specifies appointments made by contract clients and contractor client. Its designed to work with all main UK contract formats.

3.5.1.2.6 Pillar 6 – Government Soft Landings (GSL)

GSL encourages involvement of the project end users right from the start of design for any completed project. Commissioning, handover, end user training and post occupation analysis is emphasized. GSL is also a 2016 target since for every Public Sector Project there will be a GSL Champion appointed from the start.

"**BIM + GSL = Better outcomes" –** Task Group Website

3.5.1.2.7 Pillar 7 – Digital Plan of Work

It talks about how model matures in terms of Information and design. Provides a central structure that will act as the base for all other plans of work.

3.5.1.2.8 Pillar 8- Uniclass2

BIM being a digital information environment, needed to have a digital classification system refered as Uniclass 2. However, developments are ongoing to accommodate the growing data maturity of a model and changes over the asset lifecycle.

According to BIM Regions, the challenge after the 2016 deadline was to ensure that the UK industry operates at Level 2 precisely, deliver intended benefits from organization and project performance. Adhering to above 8 pillars will render an organization UK Level 2 BIM-compliant.

3.5.1.3 BIM initiatives and support in UK

Government plays an important role to develop policies, standards, guidelines with help of technological adoption to ease whole process as well as help in legal difficulties arising from BIM implementation (Mustaffa, N., et al, 2017).

The UK government played an important role to drive the industry towards BIM compliance by providing a clear strategy. (BIM Task Group website)

Major step by government was the requirement that all public projects were to adopt fully collaborative 3D BIM in the year 2016. In addition it published a staged plan with mandated milestones showing measurable progress at end of each year. Organizations have to benchmark on Level 2 BIM with government pledging to support and assist in the transition period to BIM

Government formed BIM Task Group which was multidiscipline team that made a lot of efforts and in the end it led to publishing of UK Level 2 BIM documents that are used as the guidelines and standards for BIM compliance since 2016.

The government together with all also issued a policy about the sharing medium of information (COBie) which will streamline the industry and eliminate interoperability problems. It created CAD and BIM unified standards in the UK AEC industry.

3.6 Scandinavian Countries

Scandinavia is reagarded as a front runner in BIM adoption. It consist of small to medium-size nations Norway, Finland and Finland respectively. Sweden is also among these countries but due to availability of literature, it was excluded from the research and therefore was not presented along the other three notable countries. They mandated BIM in their public projects (Norway in 2005 while both Finland and Denmark in 2007). These governments invested a lot in innovation in the areas of technology specific emphasy was on using BIM to produce buidings with better performance and lower energy costs as there was need to control initial costs . These governments have shown interests in being ahead of the rest in global innovation in the building industry and export surplus skills intarnationally. Similar to other countries with national BIM requirements, Scandinavian countries have provided funds for training, conducting relevant case studies and formulating BIM-based curriculum education in order to accomplish its BIM goals which were expected to

take time before they were realised. Part of the funding also covered creation of BIM guidelines and manuals that are country specific. (BuildSMART, 2011)

3.6.1 Finland

Finland is a relatively small country with a population of 5.4 million people and a GDP of 218 billion dollars (construction manager magazine). Once the industry players agreed that BIM implementation was the main focus in the strategy of technologicalinnovation in early 2000s , it did not require contractual changes unlike the huge markets because small market forces you to work in a reliable way and also contracts are more important for bigger markets since several entities are involved. BIM's importance grew quickly which was due to the increase in the number of owners demanding BIM to be used in their projects.

Following the unanimous decision to working towards BIM direction, its usage was estimated to be about 33% in 2007 in Finnish construction sector. Further observation also revealed that 93% of the architectural firms were using BIM in their projects whereas the engineers percentage was slightly lower at around 60%. (Kiviniemi, 2007)

Senate Properties like the GSA in the united states was the government's expert on the matters relating to BIM in Finland. Private sector was also actively involved as several companies were in the fore front in coming up with BIM related initiatives and in particular research and development. Just to name a few of organizations are; Skanska Oy, Tekes and The Association of Finnish Contractors

3.6.1.1 Organizations promoting BIM in Finland

1. Senate Properties of Finnish Government is owner in charge of all public projects using BIM and Industry Foundation Classes (IFC). In general it is the overall regulator and the guidelines developer.
2. Skanska Oy is a prime contractor in Finnish private sector that uses BIM processes in its project. It also makes its contributions in the areaof research and development.
3. Tekes and Association of Finnish Contractors partners with senate properties in BIM implementation.

4. Helsinki University of Technology and Tampere University of Technology are the government educational institutions primarily conducting research and development in BIM related areas.
5. VTT is also another major research organization in Finland for BIM.

3.6.1.2 Finnish BIM guidelines

(COBIM, 2012)

Common BIM Requirement 2012, COBIM, was an update from the initially published BIM guidelines in the year 2007 by Senate Properties in collaboration with industry partners. The result was a 13 series guidelines that were released in Finnish on March 27th 2012. (BuildingSMART Finland, 2012)

The series of 13 guidelines was released and is described briefly as follows;

3.6.1.2.1 Series 1: General part

This document only describes in general the basic requirements of the use of Building Information Modeling (BIM) in architectural projects.

3.6.1.2.2 Series 2: Modeling of the starting situation

The definition of the content and accuracy level of the starting situation modeling is done using this guideline which lays foundation to the next series.

3.6.1.2.3 Series 3: Architectural design

The architect's model is mandatory in all design phases therefore forms foundation for all other models and is a critical part of many analyzes and simulations. This requirement is essential as it enables make architect’s model technically correct in all phases of the project.

3.6.1.2.4 Series 4: MEP design

Specification of how to model mechanical, electrical and plumbing (MEP). This will help capture relevant information and the information produced from MEP design to be used for making decisions that are well informed besides assisting information exchanged between designers and the client.

3.6.1.2.5 Series 5: Structural design

This guideline covers the BIM structural model. The structural model develops and becomes more specific as the design process progresses.

3.6.1.2.6 Series 6: Quality assurance

The main goals of Quality Assurance are firstly, to ensure the quality of each designers own design work shall be checked and secondly, the integrity of information exchange between the parties. This guideline is therefore focused on checking the quality of building designs according to what BIM-based design currently enables.

3.6.1.2.7 Series 7: Quantity take-off

The purpose of these guidelines is to address the take-off of quantities procedures from a BIM model. This document does not stipulate step by step way on how quantities must be taken off from a BIM neither does the document mention preferred tools to be used.

3.6.1.2.8 Series 8: Use of models for visualization

This guideline defines how BIM models will be used for visualization in order to analyze and compare different design solutions. Environmental impact assessment can be able to be analsed also whenever possible which is achieved through comparison simulations.

3.6.1.2.9 Series 9: Use of models in MEP analyses

This series guides the desisgner on how to best utilize the data available from the building information models and make sense ofit.

3.6.1.2.10 Series 10: Energy analysis

This document defines the requirements of how BIM models are used in energy analyses during design, construction and operationin order to achieve energy efficiency. By doing analysis you are able to compare different permutations in the persue to realise more efficient ways. However, the most important benefit from utilizing BIM is the ability to extract correct information for important calculations.

3.6.1.2.11 Series 11: Management of a BIM project

The use of modeling requires special approach from the management of the project from its organizational structure, advanced cooperation, active flow of information

between the project parties working on the BIM project which is provided by this guideline.

3.6.1.2.12 Series 12: Use of models in facility management

Despite the relatively new concept in facility management applications and are still under development, this guideline defines use of BIM in facility management phase. Industry Foundation Class (IFC) and COBie are the main information transfer standards in facility management.

3.6.1.2.13 Series 13: Use of models in construction

This particular series guides general contractors and subcontractors on how use BIM models for construction planning and construction phases and most importantly deliver As-built model data.

3.6.1.3 BIM Initiatives in Finland

3.6.1.3.1 Public sector

Senate Properties which is the main BIM regulator in Finland under the ministry of finance mandated the use of BIM models meeting the IFC standard in its projects (Wong et al, 2010).

In 2012 it became common national requirement to use BIM in all public projects with goal to reduce unwarranted errors, improve communications and coordination, decrease inefficiencies and use research and emerging technologies to improve the construction processes (McGraw Hill Construction, 2014).

Finland's commitment towards BIM implementation in the industry was drafting of BIM guidelines with with industry-wide support. These guidelines were presented in the Finnish language and covered general principles of modeling any product in construction projects. (Kubba, 2017)

The Infrastructure BIM (YIV) requirements were published in 2015 by buildingSMART Finland, which deals with specification of BIM projects of infrastructural nature. (Finnish Transport Agency, 2015).

3.6.1.3.2 Private sector

BIM received support inform of conducting intense Research and Development from private sector in Finland and higher learning institutions. This efforts helped senate properties publish the BIM guidelines .

Tekes and Skanka Oy are the major private organizations that promotes extensive usage of BIM in Finland. Association of Finnish contractors is also active in promoting BIM in the enterprise in affiliation with the state client (senate properties) whose focus is similar, in respect to the need for open standards

research organizations and universities in Finland rolled out several programs concerning the implementation of BIM. As an example Helsinki and Tempere university had several programs associated with BIM implementaion that were funded by VTT engineering. This efforts resulted to creation of notable Information platform such as ECPIP. VTT as an enterprise was like the other mentioned orginazitions an entity that was mainly in research field of BIM since the Eighties. VTT developed a prototype we services known as CS collaborator which a software that attempted to create a BIM system that is web-based.

3.6.2 Norway

Norway has a Population 5.1 million people with GDP estimated to be about of 328 billion dollars. Evolution of BIM use in Norway can be traced back to 2000 when Norwegian Building Authority and the Map Authority of Norway worked together to come up with digital electronic submissions. This collaboration gave Norwegian Building Authority a strong impression that BIM would play an important role in the future of Bulding processes. Specifically, the focus was mainly on open IFC standard that would later proof be crucial in the information exchange between the project teams which underwent extension in 2005. (McGraw Hill Construction, 2014)

All the industry-based organizations and contractors in Norwey fully supported BIM implementation and in addition used it in their projects. The main key players included; civil state client (Statsbygg) and the Norwegian Homebuilders Association (NHBA). (Kubba, 2017)

Generally, architecture, engineering, construction and facilities management (AEC/FM) companies that have implemented BIM (IFC-enabled BIM) and used it in regular basis to deliver their projects was about 22% in 2010. Besides Statsbygg and Norwegian Home builders being main champions of BIM adoption in the industry,

many contractors implemented BIM by channeling funds in systems aquisition of Information and Communication Technologies (ICT) and intergrating with their business of construction in order to have competitive edge. (Wong et al 2010).

3.6.2.1 Organizations supporting BIM implementation in Norway

1. Statsbygg – is the the department that manages the Public Construction and Property on behalf of the Government and is the main public agency championing for the Building Information Modelling.
2. Norwegian Homebuilders Association is working actively to bild capacity of technology and knowledge development that will be critical when BIM has totally rolled out in the industry therefore avoiding technical know- how demand gap .
3. Forsvarsbygg is the Norwegian Defense Estates Agency mandating use of BIM in its project.
4. SINTEF is the leading organization conducting research in BIM.
5. Norwegian University of Science and Technology (NTNU) encourages student to dwell on BIM related research topics.

3.6.2.2 BIM manuals in Norway

3.6.2.2.1 Statsbygg BIM manual (SBM 1.2.1)

This document contains Statsbygg's general requirements for Building Information Modelling (BIM) in projects and at facility level. The manual is based on the previous versions of that were earlier developed. Compilation of the manual and the experiences were derived from actual pilot projects undertaken by Statsbygg.

The main aim of SBM 1.2.1 is to stipulate Statsbygg's requirements when using or implementing Building Information Modeling (BIM) in the open IFC format applicable for both general use and more specialized use. The requirements may be supplemented or altered during operational projects. The manual targets all project participants involved in BIM processes right from the design consultants to the facility end user. The manual is considered to be best possible guide to be used by the AEC industry in Norway incase they don't have individual guide. (Statsbygg, 2013)

3.6.2.2.2 Norwegian Home Builders' Association BIM user manual

Norwegian Home Builders' Association came up with manual to disseminate practical knowledge to its member companies that will eventually switch to a BIM enabled processes. The manual summarizes general modelling methodology, independently of the software. It focuses mainly on areas like calculations, roof trusses, energy calculation and ventilation. It seeks to give practical advice associated with the processes, modelling and utilization of the model itself.

The main goal of the manual is to provide overall assistance on how BIM processes works and to give references to the member companies on issues that require specific assistance and where it can be obtained. It also recommend where to find specific software. The target groups for this manual are those who are starting BIM processes in their respective companies that deal with residential dwellings (Norwegian Home Builders' BIM user manual, 2012).

3.6.2.3 BIM initiatives in Norway

The main public agency advocating for BIM use on all new and renovation projects was Statsbygg. It started gaining momentum around 2006 after the release of its first version of BIM manual and by 2007 five projects had implemented BIM already. By 2010 is when it became a requirement that all the projects will be required to use IFC-based BIM (Statsbygg, 2013)

Forsvarsbygg also known as The Norwegian Defense Estates Agency (NDEA), is the millitary agency responsible for real estate. It came up with a BIM strategy in year 2012 with goal of improving the efficiency of buildings throughout their entire lifecycle.

According to the Norwegian Building Authority buildingSMART has membership amounting to 75% of the construction market. BIM use gained momentum in the entire industry indicated by varying project types that were able to implement BIM in the public and private sector. BuildingSMART worked with SINTEF to to develop BIM guidelines and manual besides collaborating on all building and implementation projects. Example of the collaboration efforts was converting over 800 design sheets to acceptable format recommended under buildingSMART guidelines. The BIM design consultants have also helped spread use of BIM across building types. (buildingSMART Norway, 2010)

Another important initiative is the Norway's BIM guidelines. Based on experiences from Statsbygg's pilot construction project, it produced the first version at the end of 2007, which was later updated to version (1.1) of the guidelines released in February 2009 and finally updated to third and the latest version (1.2.1) in 2013. Despite being developed by Statsbygg, it's now being used by other groups in the industry. (Statsbygg, 2013)

3.6.3 Denmark

According to International Monetary Fund (IMF) global financial report of 2016, Denmark recorded a GDP of 302.571 billion dollars with gross population of 5.683 million people which is almost similar to the other Scandinavian countries.

"Will to grow" a competitiveness package was launched early 2000s in Denmark by the government. The main aim of this so-called package was to increase productivity and competitiveness in the construction industry through enhanced use of information technology (Jensen et al, 2013). This package included digital construction initiative which had a vision all parties involved in a building project could work collaboratively and contribute to the overall data of the project. The strategy was to form universal IT standards and guidelines for the industry and putting them up as requirements in public building projects, and to generate "best practice" examples from pilot projects in order to gain experience and document the benefits.

Similar to Finland, the Danish government mandated BIM to be used in all public projects in 2007 which lead to continuous increase in BIM's use in Denmark. Despite the mandatory demands on BIM from Danish state clients being the prime promoter of BIM in Denmark, there were also private organizations which strongly influenced to a great extent implementation of Information Technology in Danish industry, main example is 'Bips'. Surveys conducted in 2006 showed that approximately 50% of architects and 40% of engineers were already using BIM in some parts of their projects in Denmark (Kubba, 2017).

3.6.3.1 Organizations supporting BIM implementation in Denmark

1. Public owners which included; Palaces and Property Agency, Defense Construction Service and the Danish University that were initiators of BIM. Privately owned properties forms the bigger chunk as compared to government property which represents small percentage but in terms of policy formulation

that can significantly impact the industry, there is no question therefore putting emphasis on importanced of government in creating IFC-based BIM requirements .

"*The Palaces and Properties Agency is responsible for providing the Danish state with office buildings of 550,000 m2 floor area, worth a total of DKK4.3 billion (US$0.72 billion) and additional 450,000 m2 are leased and administered by the agency on behalf of the state. The Danish University and Property Agency had a portfolio of 1,640,773 m2 buildings in 2006. The third governmental agency, Defense Construction Service's portfolio consisted of 2,900,000 m2 of buildings in 2007"* (Wong et al, 2009)

2. Gentofte, Municipalities and KPL Ejendomme are some of the Danish government agencies that have embraced the Digital Construction Project requirements in their projects.
3. Danish Enterprise and Construction Authority initiated Digital Construction Project program that led to creation of 3D CAD guidelines.
4. Education Institutions contributed a lot in BIM adoption in general. For example, Aalborg University focused mainly on IFC model servers and whereas Aarhus School of Architecture focused on product configuration, design intent and IFC model servers. Interoperability was handled by Technical University of Denmark.
5. Private organizations like BIPS and Rambøll developed BIM guidelines and worked on its web-based system for O&M of buildings called Rambyg which is compliant with IFC requirements respectively. (Wong et al, 2010)

3.6.3.2 The Danish BIM guidelines (Friborg, G. 2012)

The Danish BIM guidelines is composed of the ICT-notification from Danish Construction Authority with its five digital clients demands combined with the Bips ICT specifications and bips manuals, tools and instructions. The five digital client demand include; Use of classifications, Use of project web, use of 3D BIM models, electronic tendering and delivery of digital as-built and FM-data.

The BIPS ICT specifications consist ICT specifications for construction which is focused on project specifics and the client's basic specification and ICT Technical

Specification is focused on areas of communications, CAD, tendering and handover specification, and project organization.

i. *Communication* Specification is mainly focused on Party responsible, Data structure, Document Management, Metadata, Classification, Projectweb, E-mail and Data format.

ii. *CAD Specification* is focused on Model coordinator, Model production, Model use, Drawing production, Simulations, Consistency control, Visualization, Data extract, Common and Skill model, Model coordination and exchange, IFC-model and Data format.

iii. *Tendering Specification* is focused on Tendering platform, Electronic tendering manager, bill of quantities and Structure of the tender documents and Specifications.

iv. *Handover Specification* is focused on Scope of digital Operation and Maintenance documentation, Digital handover manager, (Purpose, format, method and time) of digital handover, Data structure, Operation and Maintenance documentation, Data model, Digital snagging lists and IFC-model.

v. *Project Organization* is focused Project ICT participants, their roles and IT systems.

3.6.3.3 BIM initiatives in Denmark

Use of open BIM started as early as 2007 for state projects. This requirement demanded that the gorvernmental projects were to start working with technology based tools which later was officially made to be BIM. The new working way was called "the Digital Construction". BIM would later become mandatory in state, regional, municipality, and social housing projects in the year 2013. This mandate was mandatory for projects having estimated cost of above 5.5 million Euros is required that 3D models in the design have to satisfy certain requirements and in addition, the models were explicitly recommended to be exchanged using the IFC format.

Guidelines in Danish published by the Danish Building & Property Agency and Ministry of Housing, Urban and Rural Affairs Guidelines developed targeted social housing projects in Danish published by the organization making a register of

construction faults. The guidelines purposed to set up and fulfil requirements in BIM applications across projects. (Wong et al 2010)

BIPS which is part of the private sector collaborated by adopting the results from the Digital Construction Program and encouraged all companies in the Danish construction industry to implement new working ways in their businesses and projects they undertake following '3D Working Method' guidelines.

Rambøll and the Danish Enterprise and Construction Authority also came up with initiatives by supporting the Research and Development (R&D) work in BIM. Other initiatives by learning institutions were mainly undertaking in various R&D work in BIM related fields.

3.7 Singapore

3.7.1 General introduction

According to UN report of 2012 about global population, Singapore is one of the most densely populated country in the world. With just a 716 km2 land area, Singapore's population is almost 5.61 million people at the end of June 2017. This is requires enormous construction developments in regards to housing, commercial spaces and infrastructure to cater for its population demands. Since residential development make up bulk of the construction work, 700,000 new homes have to be delivered to meet the said demand which will cost the state approximately $11 billion. (Department of Statistics, 2017)

According to Land Transport Authority, Singapore government was in focusing on extending its rail network as entailed in its vision 2030 both underground and above-ground. The sector of Construction contributes a lot to the national ecomomy and therefore eliminating notorious challenges such as low productivity rates is of major importance. In "The Intelligent Nation (iN2015)" which is a 10 year masterplan the Singapore crafted, recognized construction sector as having potential to contribute more to the economy if ICT could be leveraged to improve productivity.

Ministry for National Development along with Building and Construction Authority (BCA) were tasked on improving productivity in collaboration of sector's experts. In 2010, they came up with roadmap strategy for realizing productivity gains which was fully endorsed by the government. This strategy was to be facilitated by three

important factors which were focus on improving technical knowhow of labour by creating incentives to promote career development, embracing technology and capacity building. (Ho & Rajabifard, 2016)

BIM adoption was also proposed as part and puzzle of the roadmap. Singapore set forth a five year plan known as 'Roadmap 2010' to supply the industry with the requirements needed to adopt BIM, with a target of eighty percent to have used BIM by the end of the five year period startegy which was 2015 (McGraw Hill Construction, 2014)

Establishment of Construction and Real Estate Network (CORENET) project back in 1995 as part of their Information Technology masterplan as the country entered 3rd millenium can be considered as the foundation of BIM in Singapore. CORENET provided Electronic Information Systems such as eNPQS, e-Catalog, e-Submission and Integrated Plan Checking Systems to its clients. At this period, Singapore relied on the guidelines of International Alliance for Interoperability for its IT developments in its construction Industry. (buildingSMART and Kubba, 2017)

At the same time, Singapore formulated some BIM regulatory requirements for approvals as follows;

i. It was required to avail BIM electronic submissions for all new building projects over 20,000 m^2 in order to receive architectural approvals in the year 2013.

ii. In the following year of 2014, for any engineering approvals to be done, e-submissions were required for all new building projects over 20,000 m^2.

iii. Finally in order to get both architectural and engineering approvals for new building of larger than 5,000 m^2, electronic submission of BIM was mandatory.

Currently, Singapore has made it industry wide requirement to implement BIM for approvals ranging from building plan approvals to fire safety certificationsjust to name a few.

3.7.2 Organizations involved with BIM implementation in Singapore

1. Building Construction Authority (BCA**)** is responsible for 2010 BIM roadmap five-year plan. Tasked to improve productivity in the construction industry.

BCA's also worked with Technical institutions to enable produce required technical knowledge in the industry. (BCA, 2011)

2. Construction and Real Estate Network (CORENET**) -** is a program that gave base to the popularity and subsequent implementation of BIM for government projects. It is a regarded as one of its kind information technology (IT) initiative.
3. Arup and WSP are construction companies in the private sector that have contributed to adoption of BIM in Singapore. Arup Singapore adopted BIM processes successfully in all its projects while WSP applied BIM process during the design stage and effectively produce the structural design.
4. National University of Singapore (NUS) Many Singapore universities and polytechnics offer education and training related to BIM but NUS stood out by publishing the first of NUS BIM in 2015 to be in cooperated with Singapore BIM Guide.

3.7.2.1 Singapore BIM guidelines

The Building and Construction Authority (BCA) and other collaborated with industry players to come upwith BIM guidelines to apply specifically for Singapore construction industry. According to BCA Chair Dr. John Keung "*Singapore BIM Guide Version 2 is part of the industry's efforts to give clarity on the requirement of BIM usage at different stages of a project*". (buildSMART Magazine, 2011)

The BIM guide was published so that the industry BIM users can realize the full advantages of integrating BIM processes it into the projects they undertake from the beginning to the end. When developing a BIM Execution Plan (BEP) as would be agreed by all parties, the guide acts as the main reference which will determine degree of success of implementing a BIM project. (CoreNet website, 2013)

The specific guides are documented under the following titles;

3.7.2.1.1 Guide on deliverables, process and personnel

Singapore BIM Guide Version 2 works towards outlining the possible alternatives in regards to processes, milestones to be achieved and relevant personnel when BIM is implemented in a construction project. Roles and responsibilities are clearly spelt out

and all the project members can refer to it when BIM construction project is undertaken. (BCA, 2013)

BIM deliverable refers to specific task carried out by project members at any stage of project life targeted to meet objectives set out in the begining o a BIM project. These agreed upon deliverables are outlined in t "*BIM Objective and Responsibility Matrix".* Some of these deliverables include; (Site, Architectural, structural, MEP) models, Scheduling, fabrication models, As-built model and data for facility management. BIM process is the pathway to delivering BIM objectives taken to create along the project phases. Deliverables can be set in form of measurable milestones at different stages of the project and how project members collaborate is also provided. BIM professionals refers to who is responsible to what task? for example, BIM manager and BIM Coordinator are the typical new professionals incharge of BIM Execution Plan (BEP).

3.7.2.1.2 Guide on BEP

Importance of developing a BIM Execution Plan lead by the BIM manager and coordinator can not be overemphesised as it introduces BIM effectively into the the heart of the project right from the early stages. BEP entails the vision and the details on how implementation of BIM procedures by the project teams will happen throughout the project. It is the reference point for meeting the deliverables at different milestones of the project period.

The guide provides a BIM Execution Plan template that can be used by the project. Updates to the BIM Execution Plan should be made with the permission of the Employer or his appointed BIM Manager (BCA, 2013).

3.7.2.1.3 Guide on BIM modelling and collaboration procedures

This guide is about sharing of project information of any BIM project. It outlines steps of model making process from creating the model, to the next step which is coordination it and how the exchange of data is. Finally the resulting model is frozen and is ready to be used.

This guide also provide guidance on documentation procedures. For example BIM Exchange formats. It indicate that the adopted format must be written down in BIM execution Plan (BEP). The format could can be choosen from the available open standards. It also cater for data security and saving to enable model integrity stand. In

addition, it requires BIM Manager to arrange for a way to check quality of the BIM models and mantain it to guarantee that data and information is extremely accurate. BIM can be incooperated in a project as a service under a principle agreement inform of an addendum provided in the guide called *BIM Particular Conditions Version 2*.

3.7.2.2 BIM initiatives and supports in Singapore

Adoption and progressive advancement of BIM in Singapore is contributed mainly by top-down government approach, tradition of embracing technology and the fact that Singapore has notably a small population hence faces insufficient labour. To date, any initiative introduced to its construction industry is focused on making issuance of permits simple and streamlined. (BCA, 2011)

The main organization that was tasked to come up with roadmap for BIM adoption was Building Construction Authority (BCA). And it focused on a sole main agenda which was to escalate the use of BIM in the building and construction industry targeting upto 80% usage by end of year 2015 which was alligned with Singapore's government plan of productivity improvement by up to 25% by 2020 in the construction sector.

The five year Roadmap of BCA was made up of initiatives and strategies to enable smooth transition from traditional 2D building drawings to 3D models by the industry (construction firms and various professionals). First step that BCA took was to identify challenges faced by firms and introduced initiatives and strategies that was aimed at helping BIM adopters to overcome them. Among the major challenges firms faced were; *non-existence of demand for BIM due to deep-rooted traditional methods, large gap of experts in BIM* and *after implementating BIM in the industry there was shortage of skilled labour to propel the wagon*. BCA came up with the following initiatives to help overcome these challenges:

i. To counter the challenge of lack of BIM demand, BCA had tasked public sector and government procurement entities (GPEs) to ensure that all its projects to use BIM by the year 2012. In that respect, BCA had to develop new requirements to support the BIM mandate. Another initiative by BCA was to establish the centre for Construction Information Technology (CCIT) as a BIM

support base and guide the industry as a whole towards its implementation by caring out conferences, trainings and seminars.

ii. To counter the challenge of deep rooted 2D drafting practices, BCA came up with ways of removing impediments and simplifying processes by developing BIM submission templates and sets of guidelines to facilitate the understanding the new regulation of submission processes by professionals. BCA worked with Government Procurement Entities, Singapore's buildingSMART and professional organizations in developing guide for project collaboration and a library of object standard.

iii. To counter the challenge of the build up enough BIM experts, BCA embarked on initiatives of building BIM capability and capacity by launching courses that fast tracks learning and the a Diploma in BIM specialist at the BCA Academy. In partnership with tertiary institutions, BCA introduced BIM training in their curriculum. As a short term initiative, BCA provided experts to support organizations who are doing project submissions for the first time using the new requirements and are facing challenges

iv. To counter the challenge of lack of ready-skilled labour related to BIM, BCA came up with incentives for BIM adopters by making available a $20 million Fund specifically for BIM under the Construction Productivity & Capability Fund (CPCF) to help companies mitigate training cost, consultancy cost and software or hardware related purchases. Thousands of companies have benefited and have been helping in documentation so as demonstrate BIM's value.

v. Establishment of Singapore's BIM Steering Committee was another initiative to lead in development of country's BIM Standards and guidelines, starting Centres of Excellence (COE) in BIM to provide the needed BIM solutions for the industry. In addition, the committee is tasked to creat awareness about BIM and encourage the best practices through competitions. Lastly , the committee brought together more than 40 BIM Manager in a Forum aimed to discuss issues related with processes during BIM implementation.

The most notable initiative by Singapore's construction industry and recognized all over the world is the BIM e-submission system via CORENET which was first of its

kind. BCA's BIM electronic submission system is considered to be responsible for the transformation in the construction businesses is carried out by construction companies in Singapore. The system makes it easy by project teams to submit just a single BIM model of a building containing all of the relevant information required by the regulatory agency office.

Singapore's BIM e-submission system has distinct features. First, it is easy and smooth to make Submission following BIM guidelines provided which has clear instructions on how to prepare the BIM models for submission as required by the regulatory agencies. Secondly, it has been made a standard Template which makes the usage easy for companies and professionals to during the transition period. In addition, the template improves work flow among project teams hence fast-tracking BIM benefits realization by professionals. The final feature is that the system is equipped with value-added automation (BCA, 2011). Through collaboration with software developers and industry professionals, BCA was able to customize BIM tools. An example is an adds-on module that can compute the Buildability score from created models when launched automatically. (buildSMART Magazine, 2011)

Private sector major contractors have contributed to BIM adoption in Singapore by ensuring that they use BIM in their projects. The main examples include, Arup and WSP companies whichsuccessfully adopted BIM process in all its construction projects but WSP specifically applied BIM in design phase. (Wong et al, 2010)

3.8 Middle East

3.8.1 General introduction

The Middle East region is famously know for its rich countries located in the gulf region forming the Gulf Cooperation Council (GCC). Although in reality North Africa and some Asian countries are also part of it. Middle East's construction industry is rapidly growing due demand for buildings and infrastructure projects to cater for the growing population. According to research project conducted by EC Harris (2014) titled "Middle East Major Construction Programs Mitigating The delivery Risk" Countries in GCC, have ambitious plans for development to achieve robust all round economies and reduce over reliance on oil and gas therefore competing internationally. Consequently, a huge number of construction and infrastructure projects will continue to be undertaken in the this and coming decades. Major

programs and projects that cost more than staggering $1 billion dollars and need to be delivered with fixed deadlines, form the backbone of these development plans (Harris, 2014).

These major projects have attracted multi-national companies from UK and USA who have close ties with the Middle East countries and have capacity to deliver these construction projects on time. Most of the advanced countries where these multi-national firms originate from have already mandated use of BIM in their major public projects resulting in transmission of BIM adoption especially in the Middle East. Spreading of BIM use in the Middle East is ona constant rise. (Gerges et al 2017)

3.8.2 United Arab Emirates (UAE)

The United Arab Emirates (UAE) is a union of seven states which are: Abu Dhabi, Dubai, Ajman, Sharjah, Fujairah, Ras al Khaimah, and Umm al Qawain, located in the Middle East region. The UAE has been experiencing "extremely rapid economic growth and urbanization". Construction sector in the UAE like all the other countries is a key sector in this respect as it shows how a country is prospering (Mehran, 2016).

In 2013 UAE's construction and building sectors contribute 12.5% of the Gross Domestic Product (GDP). In addition, 22.1% of the total workforce in UAE comes from the building sector. During the The mid 1990s it realised that they needed to diversify their economy and move away from over reliance in oil industry to more robust economy which include key areas like; industrialization, financial services and tourism. (UAE Economic report, 2013)

UAE boasts of construction projects that are very unique technically and engineering wise. These projects pose a lot of challenges when executing them. Famous examples include; Burj Khalifa the world's tallest building and Burj Al Arab world's only seven-star hotel.

With these kind of projects comes enormous challenges like serious delays and cost overruns. Many organizations as well as pilot studies have agreed that the usage of BIM is very important in the countries experiencing a big construction growth to help increase construction performance (Eastman et al. 2011). UAE's construction sector like other governments around the world recognized these inefficiencies that were crippling the sector and sought for strategies to address the declining productivity. Building information Modelling was found as a practice that will remedy these

challenges. This led to government mandating BIM in Dubai state which was mainly influenced by BIM survey in Middle East as well as BIM adoption in the UK since both countries were close allies and most of the multi-international construction companies from UK had set up offices in the entire Middle East.

3.8.2.1 Organization/Agencies supporting BIM use in UAE

Most organization or agencies that are supporting adoption of BIM are mostly UAE government-owned developers such as;

1. *Masdar* (Abu Dhabi Future Energy Company) was founded in 2006 by Abu Dhabi leadership. The company provides renewable energy development services and sustainable procurement and supply chain consulting. It also operates a graduate-level university that focuses on advanced energy and sustainable technologies (Bloomberg website)
2. *Tourism Development and Investment Company (TDIC)* is in charge of tourism developing and managing tourism department of the Abu Dhabi Tourism and Culture Authority (TCA), with aim to revamp the tourism sector by introducing many projects which are high profile in nature. (TDIC website)
3. *Mubadala* an investment company is incharge of driving the country towards industrialization as we as managing diverse financial institutions. Its total assets value is a whopping 126.7 billion dollars. (Mubadala website)

3.8.2.2 BIM mandate/initiatives in UAE

Dubai regional government (Municipality) joined the the other leading countries by making it mandatory to use BIM in the AEC industry. The mandatory requirement was specific to only Dubai Municipality. BIM requirement was for specific building projects which took effect since January 2014 through "Circular No. 196" issued on 18th November 2013 to the stakeholders in the entire industry. However this directive did not impose BIM use in the other regions of the Emirates. (Mehran, D., 2016 & Khaleej Times, 2015).

In November 2013, an announcement was made by Dubai Municipality making Building Information Modeling use a requirement for specified architecture and MEP works in a *"Dubai Municipality's 2013 mandate – circular (196)".* This circular stated that:

"Pertained to the application of the first stage of BIM in the construction and mechanical (parts) on buildings and the following facilities;

1. Buildings that are above 40 floors.
2. Building with area's larger than 300 000 sq^2.
3. Specialized buildings such as hospitals, universities, and all that is similar to that.
4. All buildings requested on behalf of a foreign office".

Two years later (in 2015) another circular (207) titled "*Regarding the expansion of applying the (BIM) on buildings and facilities in the emirate of Dubai"* was issued by the Dubai municipality to succeed circular 196 as part of the municipality's efforts to keep in toes with latest construction trends especially concerning BIM processes from all over the world. (The BIM hub, 2015)

Circular 207 (2015) BIM requirement was an expansion of the previous circular 196 as follows;

1. Building's Architectural and mechanical works for;
    - Buildings that are above 20 floors.
    - Buildings that are over 200,000 $ft^{2.}$
    - Special buildings such as Hospitals, universities etc.
    - All major government projects.
    - Foreign office-based projects
2. Structural works for ;
    - Buildings that are above 40 floors.
    - Buildings exceeding 300,000 ft^2
    - Special buildings such as hospitals, universities etc.
    - All building Projects requested on behalf of foreign offices.

To promote this requirements introduced by the municipality, the local construction companies as well as the major stakeholders were requested to whole heartedly support the initiative. (Abdalla, 2016).

UAE's main problem in implementing BIM was that it lacked any published BIM standards and protocols specific for the country. Despite that, there was immense nee by clients to have BIM implemented in their projects due to their well known benefits without a clear understanding of its impact and practical implications to the project and industry in general. (Mehran, 2016)

Croft (2017) noted that the progress that is being witnessed in UAE with regard to BIM implementation has not been made standard across the construction industry. Projects in the UAE most of the time use BIM standards from countries like UK and US who form the bulk of multi-national companies that run the mega project, which may not always be appropriate to the unique nature of the UAE construction market. Croft also added that the use of BIM still not well spelt out in the contractual agreement and rarely aligned with the approach being taken by the project team. As a result, uncertainty occurs in real issues including employer's right to access or use BIM information.

3.8.3 Qatar

Among the gulf countries, Qatar is the fastest growing economy especially in construction and infrastructure industry with projects value estimation of $200 billion by the year 2021. There is strong awareness of BIM technology in Qatar and Middle East in General but industry-wide adoption strategy is still lagging behind. (STRUMIS, 2017)

There has been considerable usage of BIM in many modern and recent projects in Qatar not withstanding the fact that country's construction history regarding to technology and its application in construction is of recent years making this a giant step. (Qatar Construction news, 2015)

Qatar National Vision 2030 (QNV 2030) is the major program or roadmap strategy that had spurred growth by laying milestones and deliverables along the way to achieve its aims. Qatar Rail Development Program (QRDP) and National Tourism Sector Strategy 2030 are also other major flagship initiatives expected to support the industry's expansion over the forecast period and in line with vision 2030. Recent years have indicated that Qatar has experienced rapid growth in the usage of BIM and has proved its readiness with more implementers reporting benefits from their BIM projects. Large cooperations associated with government in Qatar that run multi-

billion dollar projects such as Lusail City, Qatar Rail, Ashghal's Doha Expressways, Qatar Foundation, Qatar Economic Zones and the Supreme Committee have been in the fore front in demanding use of BIM in their respective projects. These projects are enomous in size and challenging technically with very ambitious deadlines of almost unreal has lead Qatar turn to Building Information Modelling (BIM) to facilitate delivering of these projects. (BIMhub, 2017 & reportlinker, 2017)

Qatar will undergo transformation over the next 10 years as these various works progresses that the country is witnessing are undertaken and completed. In addition, in quest to realize Qatar's vision for 2030, more BIM advancements is expected to happen.

"*Over the past few years, Qatar's construction sector has seen a significant increase in the usage of building information modelling (BIM), but the lack of national standards and local capabilities of consultants pose new challenges for supply chain*" **(** Christoph Weber, MD Hochtief Vicon Qatar**)**

3.8.3.1 BIM drivers in Qatar

1. Q-BIM is a voluntary group engaged in popularising building information modelling (BIM) in Qatar and beyond through organizing local and international forums that bring forth BIM discussions. Q-BIM performs its mission through alliances, networking, lobbying, continuous education and recognizing excellence in BIM. (Qatar-BIM, 2017).
2. The Supreme Committee for Delivery & Legacy was a committee formed to oversee the delivery of the required infrastructure, planning and operations for Qatar as it was mandated to host historic FIFA World Cup in the year 2022.
3. Lusail Real Estate Development Company is a private owned firm which is a subsidiary of Qatari Diar Infrastructure responsible for developing, promoting, construction and ongoing management of Lusail City development.
4. Qatar Rail also known as Qatar Railways Company that's state-owned responsible for all rail transport operations in Qatar.
5. Qatar Foundation is a semi privately owned non-profit organization established in mid 1990s to support transition of Qatar from a carbon economy to one based on knowledge development

6. Qatar University (QU) is working in collaboration with Hochtief Vicon and Teeside University from UK to support BIM education and research and also in establishing BIM standards in Qatar.

3.8.3.2 BIM initiatives in Qatar

In Qatar's construction industry, tendering of projects has increasingly been accompanied by specific BIM requirements due to the benefits realization from the earlier undertaken projects. BIM inclusion when submitting tendering documents for bidding is becoming a common practise that bidders have to comply with in order to stand a chance. (The BIM hub, 2016)

Another initiative that encourage BIM use in Qatar is a specialized conference named "*The annual Future BIM Implementation Qatar*" which is specifically designed to talk about the increase in use of BIM technologies in Qatar. In doing so, major construction projects being undertaken that apply BIM will be delivered to design specified, on time and budget. This conferences are held yearly at Doha, Qatar. The most recent edition was held in March 2017 (Qatar project management, 2017).

Qatar University, Hochtief Vicon and Teesside University have been Organizing BIM related events that is accessed freely by the public example is BIM User Day series, organized each year since 2011. These approach brings together industry experts, academia and the government so as to come up with a common standpoint in matters BIM related. Such efforts allows Qatar to be viewed as a leading promoter of BIM in the region by building a strong professional network as well. (The BIM Hub, 2017)

Qatar is undoubtedly putting in significant efforts to integrate BIM on its industry but lacks regulatory body formulated to draft national standards and guidelines nor that does it have BIM specific educational programs and sufficient consultants who are experts on BIM to meet the growing demand. However, at present, in absence of Qatar's BIM guidelines, there exist UniFormat commonly used BIM format found in the USA or an equivalent of level 2 that is mandated in the UK. (Qatar Construction News, 2015)

Government-based organizations and mega projects undertaken in Qatar are promoting BIM adoption requiring use of BIM. Lusail City is one of the BIM pioneer projects in Qatar as many of its processes have been based on robust infrastructure BIM model including acquiring building permits, marketing the products through the

model and during design and construction. Ashghal is another prominent organization that has made it a requirement to use detailed BIM on their projects such as Doha Expressway which include highways and tunneling.

The Supreme Committee for Delivery & Legacy (SCDL) has taken advantage of implementing BIM in their numerous projects required for the 2022 world cup like the new stadiums in order to beat deadlines and achieve the required quality. Through "*SC BIM Implementation Master Plan*" it was obvious that any interested parties be it consultants or contractors had to possess strong BIM capabilities. Qatar Foundation/Education City is implementing BIM for a slected types of projects and also is demanding the teams involved tohave technical know-how of BIM since it is encouraged to be used across design, construction and operations phases of the project.

Due to the growing demand for BIM in Qatar, there is evidence of a few private entities and government institutes taking initiatives to train and develop a skilled workforce though its still on need to need basis. Hochtief ViCon Qatar is a good example of organizations that posses ability to offer training and certification programs for BIM managers to help them successfully deliver projects that they are involved in. (Qatar construction news, 2015).

Table 3.3 shows the the summary of countries with BIM National mandate and table 3.4 shows summary of countries with policies by agency or municipalities. The details included are; the organizations involved, name of the mandate, data required, size/budget of the projects requiring BIM implementation and reasons behind it. The between the two is that a national mandate means that all public projects within the nations are required to use BIM while the agency requirement means that the requirements are specifi to projects related to specific institutions with with terms and rules unique to individual organization/ agency.

Table 3.3 : Countries with national mandate.

Country	Organization Responsible	Name of BIM strategy	BIM data Required	Building size/Budget requiring BIM	Reasons for establishing this Policy
United Kingdom (UK)	The UK Government, Cabinet office	Government Construction Strategy (2011)	Project lifecycle data as defined by BIM UK Level 2	All national public Projects Beginning year 2016	• Reduce construction cost • Help UK meet carbon reduction targets for buildings • Reduce project delivery time • Enable UK's design and construction industry be more competitive globally.
Singapore	Building and Construction Authority (BCA)	BIM Road map and e-submission requirements (2012)	Architectural and Engineering data	All new buildings over 20,000m2 in 2012 but improved in 2015 to All new buildings over 5,000m2	• Realized a highly skilled and technologically advanced construction industry by 2020 • Achieve BIM Usage of 80% in Singapore by 2015 • Increase construction industry productivity by 20% by 2025

Table 3.3 : (Continued)

Country	Organizations responsibe	Name of BIM strategy	BIM data Required	Building size/Budget requiring BIM	Reasons for establishing this Policy
Finland	Senate Properties	Common BIM Requirement 2012 (COBIM)	Project lifecycle	All national public projects	• To support making design and construction lifecycle process safe and compliant with sustainable development • To utilize models for facility management.
Norway	Statsbygg	Statsbygg BIM Manual 1.2.1 (2005/2013)	Architecture and handover data	All national public projects	• Improve coordination and communication • Increase energy efficiency • Reduce errors and omissions • Use cutting edge research, technologies and processes to improve the built environment.
Denmark	Danish Building & Property Agency	Executive Order No.118 2007/2013	Project lifecycle	Above 5 million Kroner for national projects and above 20 million	• Reduce energy consumption in buildings • Improve productivity • Improve coordination

Table 3.4 : Countries with BIM requirements by Agencies or Municipality.

Country	Agency or Municipality	Name of the policy	BIM data required	Building size/Budget requiring BIM	Reasons for establishing this Policy
United States of America (USA)	General service Administration (GSA)	National 3D-4D-BIM Program (2003)	Architecture and design	All national public projects under GSA	The initial intent was to control cost but later focus shifted achieving energy efficiency and lowering long-term operation cost The other reasons include increasing project quality, productivity and efficiency throughout project lifecycle.
	U.S. Army Corps of Engineers (USACE)	BIM Requirement on USACE Projects (2006)	Architecture and As-built data	All its projects	Initially adopted to streamline and lower cost of designing prototypes of standard facilities but later it transformed to focus BIM implementation on business process transformation.
United Arab Emirates (UAE)	Dubai Municipality	BIM Requirement for specific Buildings (Circular 196-2013 succeeded by Circular 207-2015)	Architecture and MEP data	Buildings over 40 stories high, buildings that are over 300,000 sq. ft., All hospitals, Universities and other specialized buildings.	Due to the construction boom experienced in the country the adopted BIM to overcome challenges like serious delays and cost overruns Like most of the other pioneers they wanted to reduce inefficiencies and improve productivity in the industry.

Table 3.5 summarises BIM initiatives and support in the leading countries under this research. It also state the BIM guide being used if available.

Table 3.5 : BIM initiatives and supports in leading countries.

Country	organization	Initiatives/policy initiative	BIM guideline
United States of America (USA)	U.S. General Administration (GSA)	• National 3D-4D-BIM Program in 2003 and encouraged in all GSA project • BIM requirement in all major projects for approval since 2007 • Established BIM Guidelines and Standards Development	GSA BIM Guide Series
	National Institute for Building Science (NIBS)	• National Building Information Modelling Standard (NBIMS) on Building Energy Performance(BEP)	
United Kingdom (UK)	UK Government	• BIM UK level 2 mandated (Model-based) on all public sector projects since 2016	UK Level 2 BIM standards
	BM Task Group	• Provided Support and assistance in transitioning to BIM and electronic delivery. • Information sharing environment (COBie)	
	British Standards Institute (BSI)	• Created information sharing standards (PAS 1192:2)	
	AEC (UK) committee	• Combined standard for the AEC industry CAD & BIM in the UK	
Singapore	Building and Construction Authority (BCA)	• BIM e-submission system mandated for regulatory submissions since 2015 • Offered incentives those are willing to adopt full BIM submissions beginning 2015 • Established Singapore BIM guidelines	Singapore BIM Guide (1st Version in 2012 and 2nd Version in 2013)

Table 3.5 : (continued).

Country	organization	Initiatives/policy initiative	BIM guideline
Denmark	Palaces and Property Agency, Defense Construction Service and the Danish University	• Mandated BIM to be used for the whole lifecycle of buildings. Complete implementation began on 2010. • Danish Parliament extended the mandatory adoption of BIM to all local and regional projects worth over 2.7 million Euros and government projects for over 667,000 Euros.	3D working Method and layer and object structures guidelines 3D CAD manual And
	Byggeri informationsteknologi Produktivitet Samarbejde (BIPS)	• Developing BIM guidelines and promoting new working methods to all companies in Danish Construction sector adopted from 'Digital Construction Project'.	
	Rambøll	• The main organization in Denmark that performs research on BIM.	
	Universities	• They perform Research and Development work in BIM related areas. For example Aalborg University focused on IFC model servers and 3D Models, Aarhus School of Architecture focused on product configuration Technical University of Denmark works on interoperability.	
Norway	Statsbygg	• Mandated BIM to be used for whole lifecycle of building since 2010 (IFC/IFD based BIM) • Developed BIM guidelines called BIM manual	Statbygg BIM manual
	SINTEF	• Developed IFC enabled BIM and ICT solutions based on BIM by conducting research.	
	Norwegian University of Science and Technology NUST	• Student projects and thesis proposals are focused on buildingSMART technology and to develop student courses.	

Table 3.5 : (continued).

Country	organization	Initiatives/policy initiative	BIM guideline
Finland	Senate Properties	• Mandated that models should meet IFC standards in all public projects since 2007 • Established BIM Guide called Common BIM Requirement (COBIM, 2012) • With BuildingSMART Finland, it published Infra BIM requirements used as general technical references and modelling guidelines during procurement and construction	Common BIM Requirements, COBIM (2012) Infra BIM requirements (Vol. 1-7) 2015
	Skanka Oy	• Integrated specified BIM models into industrialized building process	
	Helsinki University and Tempere University	• Develop the Engineering and Construction Project Information Platform (ECPIP) • Study industrial processes incorporating IFC-based BIM respectively.	
	VTT Engineering	• Developed a prototype web services called CS Collaborator program which was one of the first attempts to build a BIM- based Web service for the construction industry	
United Arab Emirates (UAE)	Dubai Municipality (DM)	• Imposed BIM as a compulsory requirement for specific buildings in Dubai city as on 1st January 2014 via the Circular No. 196 issued on 18th November 2013 to all the developers, contractors and consultants. This directive was later succeeded by Circular 206 in 2015. • Municipality also called on local construction companies to fully support BIM adoption by providing data to develop a national databank for research and development (R&D).	N/A
Qatar	Qatar government Agencies	• In line with vision 2030, BIM is becoming a pre-qualification requirement in the tenders and a standard that bidders must comply with to win megaprojects undertaken by various Qatar government agencies.	N/A
		•	

Table 3.5 : (continued).

Country	organization	Initiatives/policy initiative	BIM guideline
	Q BIM	• Provides a platform for the development of BIM in Qatar through lobbying, mentoring, networking, strategic alliances, and developing industry standards.	
	Qatar University, Teesside University and Hochtief Vicon Qatar	• Organizes BIM specific events which are free and open to the public. (For example *BIM User Day series* organized annually since 2011).	

3.9 Successful BIM Projects from the Leading Countries

3.10 Introduction

This section presents overview of case construction projects from 2014 to date in which BIM was implemented in some of the leading countries and played a significant role. It represents experiences of project teams in the application of BIM and benefits. Each demonstrates a diverse use of BIM tools and processes by organizations in their projects.

3.11 Case 1: 39 Victoria Street, London

(Source: Chattered institute of Building, 2017)

3.11.1 Project overview

Project type: Category B fit-out of existing 11-storey building

Client: Department of Health

Lead Contractor:Willmott Dixon Interiors (WDI)

Completion: September 2017

Value: £12.5 Million

Contract type: Design Build Contract

Award: Best Overall BIM Project at BIM4SME awards for delivering successful BIM projects and initiatives.

The building comprised of 11 floors of multi-use, from meeting rooms, restaurant, customer service area and office spaces. Client required to be done by WDI in-house

design team, implementing BIM Level 2 in accordance with the UK government mandate that began 2016. The contractor was able delivered the project on time and budget using BIM and virtual reality (VR).

3.11.2 Processes undertaken during the project

WDI became proactive right from the beginning so as to effectively advice the client of the most relevant asset information needed so as to capture and be used during maintainance period which included equipment information as part of the lifecycle of the building resulting to more collaboration exercise. This led to an appropriate level of information to develop the BIM Execution Plan(BEP) and allowed the design team to proceed to modelling. However, most of the operation and mantainance (O&M) information was unavailable or was incorrect of the existing building which was a major challenge. It led WDI to undertake a point cloud survey of the existing building to verify the dimensions of the site as well as researching information for elements that would not be replaced in the project. The outcome of the point cloud survey was a 3D model that reflected the correct dimensions for the architectural and structural visible components, but lacked complete mechanical and electrical services information. In order to stay on schedule (12-week preconstruction period) WDI could not wait for the point cloud survey consultant to scan the entire building and produce the 3D model of the existing site, rather they provided weekly floor-by-floor update of the survey to the archtect to allow them to develop the design with verified site information.

All stakeholders having agreed on Employer's Information Requirements and asset information requirements to be captured, WDI set up a Common Data Environment (CDE) for exchanging all the project information. The CDE allows for the right workflow so that information can be managed and traced accurately.

Subcontractors with design responsibility had to provide BIM models while the majority of the supply chain in the project had to provide data captured using the partially completed COBie template that was only requested by the client for incorporation in the model. Figure 3.2 shows model of cloud survey

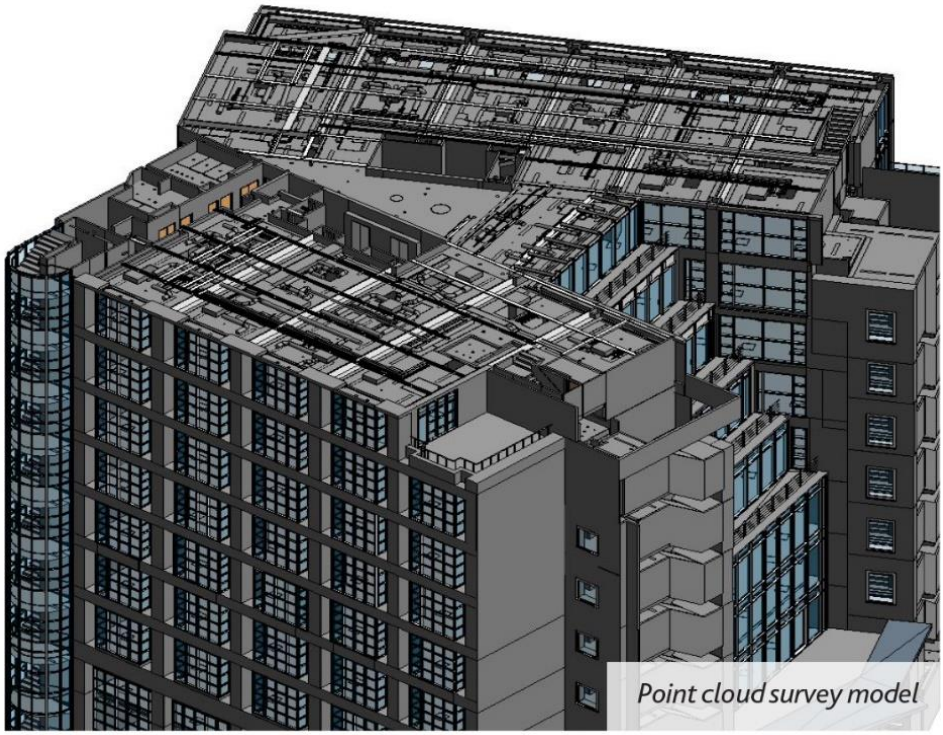

Figure 3.2: The point cloud survey model.

3.11.3 BIM uses in the project

Among the BIM applications on this project was the production of visualisations, animations and VR presentations to support the client's understanding of the project. This ensured that any additional information or any ommission done was able to be rectified for example modification of material finishes. WDI senior estimator was able to utilise 5D quantities take-off which was considered to be a remarkable achievement since a number of benefits were discovered. Despite limited limited information of existing MEP installation, early engagement with the MEP subcontractor was critical in developing a BIM model for design coordination. Coordination reviews using the BIM model were carried out every two weeks between the architect and the MEP subcontractor and if any relevant issues were detected, Architect provided a clash report which was discussed and resolved during design team meetings. Most importantly, asset information model was delivered to client for better for supporting better management of the building.

3.11.4 Challenges faced

The main challenge experienced by WDI of implementing BIM on this existing building with existing services was that data of any objects above the ceiling were not captured when performing point cloud survey, only the visible objects. This meant

that they they just got dimentions of architectural and engineering elements but incomplete MEP information.

The other challenge WDI experienced was mainly with the project participants. The client was not aware of the asset information required to support the operations and maintenance (O&M) of the building, subcontractors were had major challenges engaging with BIM because they lacked of experience and on the other hand it was the first time supply chain had to open a COBie file. However, it improved throughout the project.

3.11.5 Lesson learnt

In order to achieve valuable outcome, BIM processes must be Client-driven from onset of the project. Also, the ability to update the model during the project duration by defining and documenting the entire information needed for each component is essential to successfully handing over BIM to Facility Management (FM) team. Its critical for FM to continue mantaining it during the lifecycle of the building to avoid the model becoming outdated. Finally, since most of the subcontractors and suppliers might not be adequate in terms of skill to deliver BIM in a project, its important to provide continous support throughout the project life.

3.12 Case 2: Slussen Lock, Stockholm

(Source: SKANSKA, 2017)

3.12.1 Project overview

Client: City of Stockholm

Lead Contractor: SKANSKA AB

Designer: Foster + Partners

BIM Project Manager: Tikab

BIM Tools: BIMEye, Autodesk Navisworks, Revit

Start-completion date: 2016-2022

Cost of the project: €1.2 billion

Project status: Ongoing

Slussen was built in the 1930s but was getting worn out, undergoing problems of the foundations, crumbling cement and rusting reinforcements leading the owner to decision that it must be demolished and reconstructed from scratch. Skanska was one of the construction companies that was tasked by City of Stockholm with this project. The project was divided into 25 sub-projects, with Skanska assigned two largest tasks and three others. The main concept of the new Slussen is to provide more meeting places, More space for pedestrians, cyclists and public transport and clean drinking water. Figure 3.3 shows visual model for the entire proposed project.

Figure 3.3: model indicating the scale of masteplan (source: Foster + Partners).

3.12.2 Processes undertaken

BIM manager defined all BIM working methods and all aspects of information delivery. All the design information of this project was digitally produced during the design phase, with no paper drawings and is believed to be first of its kind.

Skanka construction was in charge of the foundation which will require a total installation of 3,600 steel piles with unique dimensions and detailing, each one driven down 70m to hit bedrock on the sea floor as shown in figure . The piling operation accounts for around 20% of the total project budget, each pile costs about €20,000 to produce.

Skanka realised that producing 3,600 sets of drawings was going to be inefficient, resulted to modelling the piles as “coarse” geometric items in Revit and Navisworks, with simple unique information for the individual pile (pile number, location coordinates, direction and length) as shown in figure 3.4.

Figure 3.4: model slussen showing 3600 stell piles to be installed.

In order to plan and manage the complex piling operation, Skanka came up with ssolution by using the cloud-based BIM data management platform (BIMEye). Data linked from over 50 Revit models of the steel piles was synced to BIMeye, where foundation contractor, Skanska, supplies the project with detailed text information on each pile's needed parameters. As each batch of 50 piles is installed, Skanka fill as-built data into the management system to eneable checking of the structure against the design model.

BIMeye then syncs the data back to the Revit and Navisworks models to give users real time access to all BIMeye information. Finally, BIMeye will get deliveries of information in information models, stakeout data and other types of information withdrawals from the BIM models guaranteeing the quality of the information in all models.

3.13 Case 3: 1 Merchant Square, London

(BIMplus, 2018)

3.13.1 Project overview

Project type: Highrise building

Client: European Land and Property

Lead Contractor: Robin Partington and Partners (RPP) (Architect)

Structural Engineer: WSP Group (design consultant)

MEP Engineer: Hoare Lea (design consultant)

BIM Tools used: AECOsim Building Designer, Bentley Navigator, MicroStation®, GenerativeComponents®

Cost of the project: £500 million

Start date: 2015

Status: ongoing (expected to finish 2018)

Merchant Square development brings together four buildings and their unique setting as one coherent piece of urban infrastructure with the 1 Merchant Square being the tallest comprising of 42 -storey mixed use tower having curved form with vertical structural fins clad. When completed, it will be the tallest building in the City of Westminster, with a hotel and 222 apartments. Figure 3.5 present the design data of the storey building.

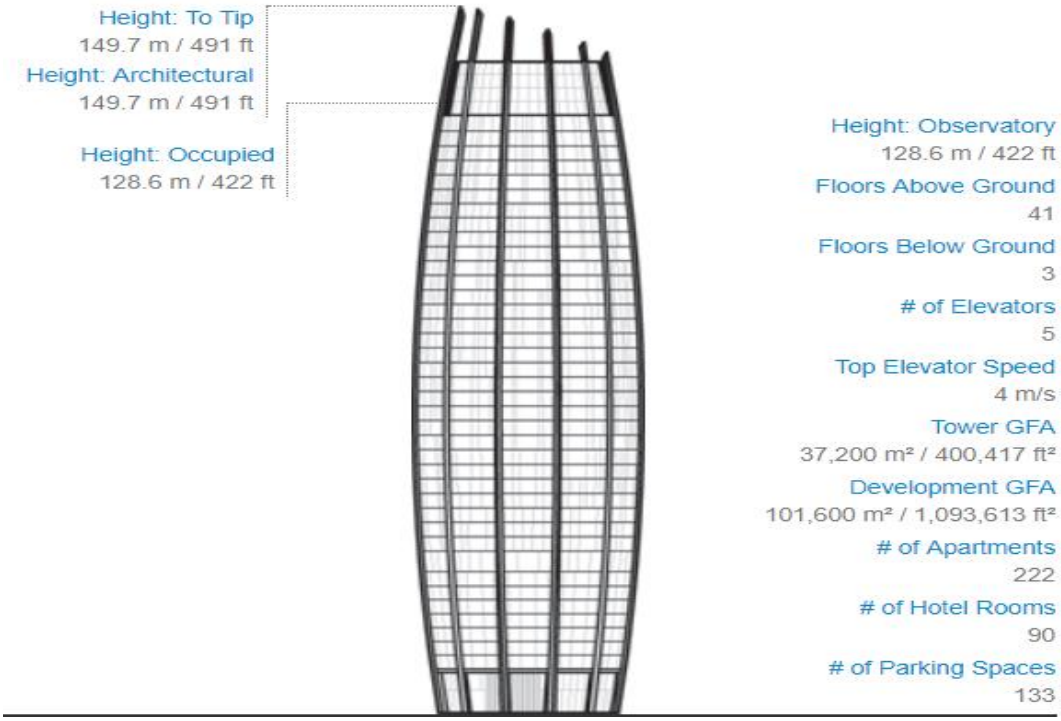

Figure 3.5: Design data of the storey building (source: RPP website).

3.13.2 Processes undertaken

AECOsim Building Designer software was used to develop the form of the building which was in a shape of cucumber and went through a series of iterations trying to

develop the most elegant form whilst optimising the client's vision in terms of area and at the top, vertical crown-like structural fins completed the elegance.

Modelling these unique 150 m structure with frames of trapezodal shapes will result to many scenarios and tremendous amount of time will be taken. GenerativeComponents provided an efficient method to model the varying cladding system without building a detailed design model for each scenario. RPP also built a computational model of one panel type using 3D design software from Bentley and applied it across the bays throughout the building.

There was extensive amount of modelling data coupled with complex variables, RPP leveraged Bentley's BIM software solutions to manage the extreme quantity and potentially oversized computer files to resolve the internal modelling challenges faced from the varied floor plans and different apartment types.

RPP delivered an innovative, iconic building design with an integrated approach that optimized productivity and saved resources powered by various BIM tools.

3.13.3 Benefits of using BIM in the project

i. RPP was able to organize its design data to generate production drawings by using AECOsim Building Designer model.

ii. BIM coordination optimised data, enhanced the workflow, and facilitated accurate communication of design intent to the client and construction team. Bentley Navigator was used to coordinate the entire basement model with structural, MEP installations and architecture models all referenced together

iii. Clash detection was ran through the isolated model parts to faster and more precise analysis of problems detected. This process was more efficient due to the use of interoperable Bentley BIM tools that waere used by designer to instantly generate design reviews as part of regular coordination meetings with the wider project team.

iv. RPP implemented a federated BIM strategy using Bentley's integrated 3D design software to streamline the workflow and optimise Return of Investment (ROI).

3.14 Case 4: Doha Expressway, Project 26

(source: Autodesk University, 2015)

3.14.1 Project overview

Project type: Infrastructure

Client: Ashghal (Public Works Authority)

Lead contractor: CH2M HILL Halcrow (supervising engineer and design consultant)

Program Management consultant: KBR

Project time frame: Ongoing (2015 still on design stage)

Budget: the entire project is US $20 billion (project 26 section is US $1 billion)

Project 26 consist of 10km, dual 5 lane carriageways will be built as well as various grade separated interchanges, footways and cycleways that is aimed to ease the traffic in the city and most importantly during the 2022 FIFA world cup tournament. Majority of the new highway will be constructed in the middle of the desert therefore will pose challenges as its far from the capital. The project will consist of Dual highway each five lanes with separate truck lane. It will be equiped with Utilities, stormwater tunnel, streetlights and landscaping as shown in figure 3.6.

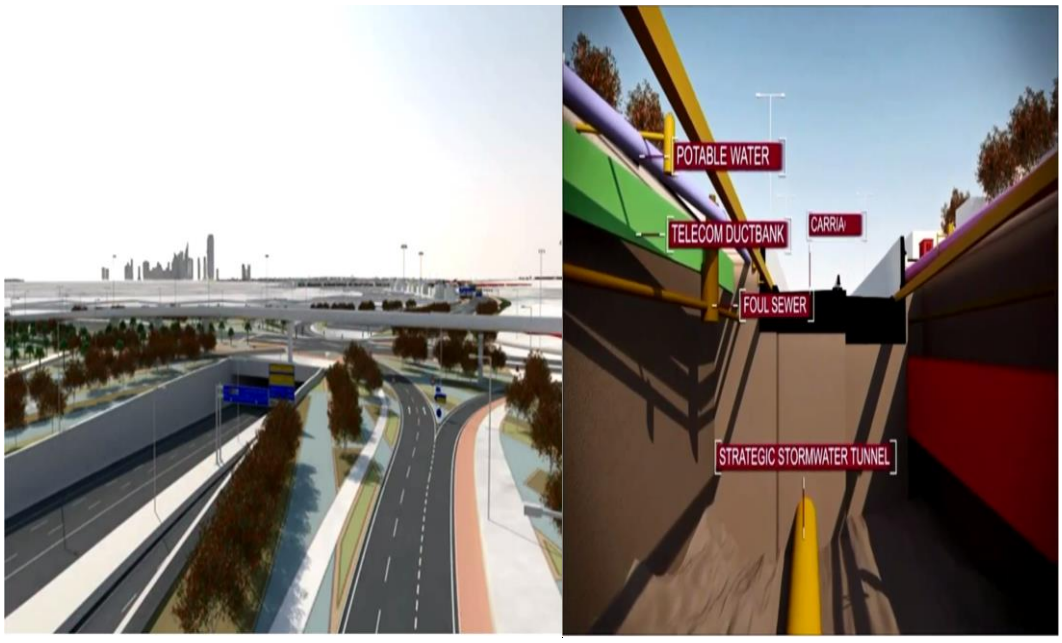

Figure 3.6: Design model of Doha expressway (Autodesk, 2015).

3.14.2 Design process using BIM

The conceptual design was developed by a UK based firm which therefore meant that the project had to implement BIM and specifically BIM level 2. The conceptual design was presented in Bentley mx software. Preliminary and detailed design were done on Civil 3D autodesk softwares which presented major challeng in form of interoperability.

During model designing, robust management of the process had to be agreed upon since large teams of designers in different locations on the globe were working on the various aspect of design and therefore required effective collaboration. As shown in figure 3.7, the project hub was in Doha while other satelight offices of designers were located in UK, Germany, Manilla (Philipines), Australia and India. It was agreed that Microsoft Office 365 will be used as the central data repository tool which ensured that all the teams in different region were in sync and able to access same information and data.

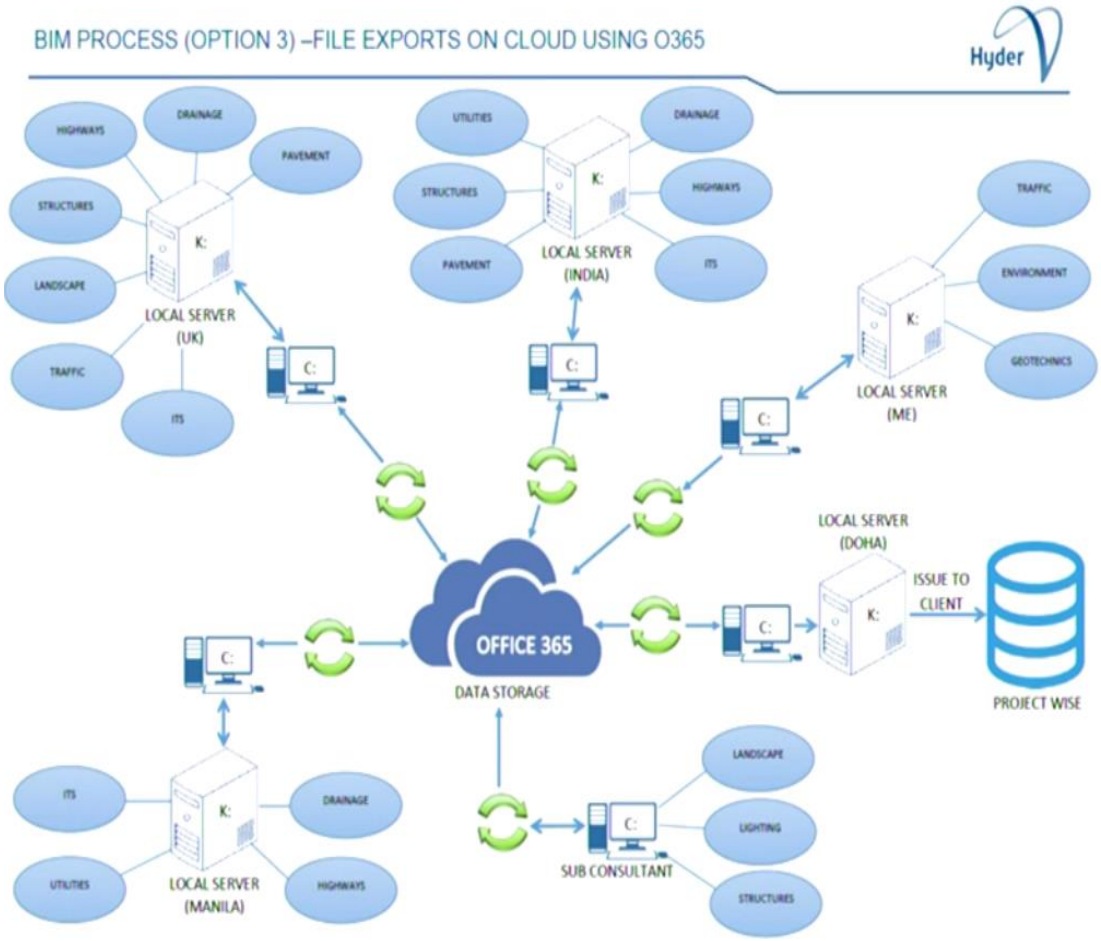

Figure 3.7: Project team collaboration using Office 365 (source:Autodest University, 2015).

Since the project was big with a lot of detailed requirements from the client, it seemed ambigous initially but improved as the project progressed and became more clear. The project was divided into specific pieces that can be worked by multiple design teams in order to be efficient and deliver quickly i.e. there were twenty designers working on highway at the same time while twelve designers worked on utilities also at the same time. Design convention was also agreed upon so that every team will work coherently.

Each teams updated their designs to the main/central data point so that other users can work according to the updated data. 3D model check of the detailed design was done using an integrated model of relevant design elements for space allocation issues and conflict analysis to ensure that there is no conflict below and above the gro0und. Its done by exporting the detailed design from civil 3D to Naviswork visual for clash detection because naviswork can detect clashes between any type of surfaces and any 3D objects. Conflict analysis report also know as clash report is sent to all the designers and solution to the clashes is deliberated. For example, the Initial analysis report resulted in more than 3000 clash detected and after two months of solving, it reduced down to 200 clashes.

The table 3.6 summarises the case studies under these reasearch that BIM was implementated indicating type of project, phase of the project, responsible party for BIM implementation, contract type if available and BIM use

Table 3.6 : Details of the selected construction project cases (2014- 2018).

Case	Type of project	Phase of the project	contract type	party responsible for BIM implementation	BIM uses	Challenges faced	Lesson learnt
39 Victoria street, London	Building	Plan, design, construction and facility management	Design Build Contract worth £12.5 Million	Client required implementing BIM Level 2 in accordance with the UK government	5D quantity take off 3D models Coordination Visualization Clash detection COBie data presented to client for FM	Contractors lacked experience of usibg BIM O&M information/data was unavailable Working with existing services Suppliers had difficulty filling COBie files	Client should drive BIM process from start to end Update of BIM model should be continous througout the project to avoid being outdated Support should be accorded to consultants, subcontractors and suppliers toimprove their skill for successful delivery of BIM.
Slussen Lock, Stockholm	Building and infrastructure.	Design and construction	Design- Build contract worth €1.2 billion	Client driven. appointed BIM project manager (Tikab)	Revit models Navisworks simulation 3D models Integrated Project delivery Coordination	Challenge in planning and managing the pilling operation when building the foundation.	Use of cloud-based syatems was important to this prroject where many variables were involved so as to be accessible to all relevant teams and importantly to create one source of data.

Table 3.6: (Continued).

Case	Type of project	Phase of the project	contract type	party responsible for BIM implementation	BIM uses	Challenges faced	Lesson learnt
1 Merchant Square, London	Building	Design, construction	Design build contract worth £500 million	Client requirement in accordance to Government BIM level 2	3D models MEP Coordination Clash detection Integrated project delivery	Design challenges due to curved tower varying cladding systems and floor plans Inteoperability problems Extensive modelling data with cplex data resulted to oversized computer files.	Need to use integrated approach incase of huge data to streamline processes Creation of federated environment for storage of data. When developing BEP choice of inteoperable software is important
Doha Expressway , Project 26	Infrastructure	Design	N/A Total budget for project 26 US $1 billion	Client requirement through the appointed consultant	3D design model Information exchange Teams collaboration Conflict analysis of the elements	Clients unclear project vision hence underwentalot of changes Interoperability problems Challenges as multiple users worked on the project from different location	Enabled creation of central data repository hence better collaboration The process were automated hence

4. DISCUSSIONS

This section summarises comparisons and contrasts between the BIM initiatives and supports in the leading countries presented earlier. United States being pioneer of most of technological advancement in construction and specifically BIM has the most initiatives. Its BIM maturity level is considered to be high (level 3) however, its uniqueness as compared to the other leading adopters is that at the top level which is the federal government, agencies like GSA which is the major agency pushing for BIM develop their owns requirements for their projects while the state government have their devolved mandates with completely unique BIM requirement. Therefore, there is no common BIM guide for the entire nation but by agency. United Arab Emirates has a similar approach as Dubai municipality has mandated use of BIM for specific projects despite lacking BIM standards and guidelines which are made specific for the country.

United Kingdom is urguably the current leader in BIM interms of the whole industry embracing it, having come up with a four year strategy of 2011 leading to mandating total collaborative BIM in 2016 commonly referred to as BIM level 2. These means that both public and private sector players have to be BIM-compliant in order to conduct any projects and stay on competetive business. Some also urgue that its BIM adoption model is very comprehensive and countries with a desire to develop BIM roadmaps may benchmark on UK's model.

The Scandinavian countries have national mandates too but mostly based on open standard IFC. Technology initiatives were introduced to its industries more than a decade ago making BIM processes deeply entrenched in their constructionindustries.

Singapore on the other hand took a top down approach as the government took charge by developing a clear five-year roadmap towards BIM adoption. But the distinct initiative that is unique to singapore and recognized world-wide is the BIM electronic-submission system of models inorder to get permits from their projects. This system was made streamline submissions to the regulatory agency and on top of it it was easy

to use it. This initiative transformed processes in the sector and is been louded world over.

As for Qatar, its BIM usage in its mega projects is unquestionable despite not having any documented mandate for BIM to be used in its projects neither does it have country-specific BIM guide. Its however worth noting the funding and the numerous initiatives that the government is involved in currently will yield to it breaking the new grounds and joining the rest.

4.1 Roadmap for BIM Adoption in Turkey

The review study has shown various initiatives and steps taken by the leading countries for successful BIM adoption in the industry. Several lessons can be drawn from the findings and a roadmap of BIM adoption for Turkey and any other developing country that wishes embrace BIM in full length to its industry can be proposed. BIM roadmap can be defined as a strategic plan by government throught its relevant authorities to ensure that BIM adoption spread widely across the construction sector and all players embraces its use.

Turkey is in a critical position in its history due to its economic strength and is ready to embrace BIM in its industry. In addition many Tukish major contractors are also working internationally and inorder to become more competitive, adoption of BIM is inevitable. Some mega projects like the Istanbul 3rd Airport project which is projected to be the biggest in the world implemented BIM throughout its lifecycle and also some of the underground rail constructions just to name a few. This shows that the industry is already embrasing BIM but lack of a national roadmap that can guide the industry to wide penetration of the new working ways is lacking. Findings from the leading countries above has shown that the success that is enjoyed across the sector is characteristic of a clear strategic plan by collaboration of the public and private sector to drive their country towards BIM direction through the steps that culminated to series of initiatives that promoted wide BIM implementation.

According to "*Turkey vision 2023"* various projects worth USD 100 billion in total which include highways, bridges, airports, power plants etc. shows how important is it to anchor BIM to this vision for timely delivery of these mega projects and to successfully deliver the vision of becoming among top 10 economies in the world. For these reason government should adopt a strategy to popularize BIM by developing a

clear roadmap for a certain timeline which will inturn trigger initiatives that will lead to widespread of BIM uptake in the country.

Proposed roadmap must make clear what construction industry has to accomplish with time i.e. incremental progress and most importantly draw lessons from leading countries who have walked the path. Borrowing from the already developed BIM roadmaps from countries like UK and Singapore, This study proposes 'BIM roadmap strategy for Turkey' and can be divided into three broad parts; initial stage, consultative phase and finally the implementation phase.

4.1.1 Initiation phase

The initial stage of the proposed BIM Roadmap can be anchored on the following pillars;

4.1.1.1 Leadership

Its very important for government to take lead in this process by establishing a BIM task group . Its main mandate will be to coordinate the processes taken towards BIM implementation and provide an overall national support. The first task of the committee is to bring everyone in sector together and encourage the organizations to embrace BIM so as to be competitive nationally and internationally insisting on making them understand business value that comes with it to avoid disjointed approaches. By doing so there is will be a higher percentage of success since everyone will understand the mission. Government should always take active approach for successful outcomes.

4.1.1.2 Promoting success stories

Turkish industry at the moment can be classified to be at BIM level one interms of maturity which translates that a lot of companies still use traditional methods and therefore

will be resistant to significant changes that will arise from introduction to BIM processes. Therefore, the authorities charged with BIM popularization must tell success stories that have happened in the industry and the benefits that comes with it. This will help change the mindsets and soften the resistance that usually comes with introduction of new working ways.

4.1.2 Consultations phase

At this stage it would be clear across the industry that the government and the sector in general is serious about introduction of BIM in the entire industry. Consultations with will focus on the following pillars;

4.1.2.1 Standards

Next step is to identify the major stakeholders ranging from professional organizations, Private sector clients, association of contractors, Learning institutions and relevant regulatory bodies to form executive committee for drafting BIM guidelines that will add to the existing building standards and codes. The standards should incorporate existing international standards inorder to allow for accreditation, the most suitable or to be recommended is open BIM standards. It should be developed comprehensively to cover every aspect so as to avoid gaps which may lead to confusion in future

4.1.2.2 Procurement

There are existing tendering laws and procedures at the moment but introduction of BIM will require special considerations either as a totally newly developed requirement or an additional section interms of an addendum that will adress BIM related issues. Requirements should therefore be drafted that BIM contracts is required to fullfill. The major issues to be adressed are data ownership, and how to solve disputes arising from faulty BIM data/information and who to take responsibilities.

4.1.2.3 Education and training

The industry is definitely lacking skilled- labour related to BIM for the extensive market, as a result there is great importance in building BIM capacity and awareness. National education taskforce can introduce short training courses to the professionals already practising in the industry from top management that will lead to certification. There should be introduction of BIM courses in the higher learning insitutions that will enable graduants be BIM experts which will be of great importance to the overall long term success of BIM in Turkey.

Another important aspect is how to measure BIM progress. Collaboration between authorities, professionals and Higher learning institutions is necessary inorder to come upwith ‘BIM assessment tools’. This measuring mechanism will tell weather organizations and the entire market is stagnating or moving forward or declining. This

is important as to have uniformity in the implementation process and also for accrediting those who are compliant.

4.1.3 Implementation phase

This stage is the actual roll out of the BIM implementation and experience tangible results. It should be anchored on the following pillars;

4.1.3.1 Pilot project programs

Its important to test new working ways so as to identify the shortcoming and correcting them before making it as an enforceable requirement for specific projects that can be endorsed by everyone in the building and construction sector. Therefore, potential pilot projects should be identified to test the deliverables. The experiences and data collected from this pilot projects should help establishing the final industry-specific BIM guidelines and regulations that can be used across the industry.

4.1.3.2 Mandating BIM in specific public projects

The next step is to make the use of BIM mandatory to public projects that satisfy the requirements created and government to act as enforcing agent. Its however of paramount importance that as BIM mandatory requirements are introduced, its should be gradual with continous improvements but the ultimate goal will be to make BIM a requirement for all facilities. The BIM task group should introduce the minimum requirements derived from well informed standpoint.

4.1.3.3 Provision of incentives and building BIM capacity

Building up BIM expertise in an organizations will require significant investment which has been recorded as one of the major challenges. This investments cover Hardware and software purchases and cost of training workforce to run them. Government must therefore create a fund that will incentivize early BIM adopters for example, licence exemptions or assisting to foot some percentage of their costs when buying hardware and software.

There is also need to provide support for technical issues related to BIM as a short-term solution to help the stakeholders during the transition period. There is also need to remove impediments by making processes as easy as possible.

4.1.3.4 National BIM library

There is need to establish national BIM library that may be controlled and monitored by an authority specially created. Its important that all industry players should collaborate to input sufficient data including suppliers. The library shall be made freely accessible to the entire construction industry. This will not be easy to accomplish but with time when use of BIM has become entrenched in the country its real importance and benefits will be realized.

5. CONCLUSION

This thesis reviews Building Information Modeling (BIM) mandate in the USA, UK, Finland, Denmark, Norway, Singapore, Qatar and UAE and respective initiatives and supports by the public and private sector has been presented. Its evident that changing from traditional construction approach to BIM processes require setting up suitable policy strategy and device ways to follow through it for success to be realised. In addition, Public and private entities must work together in developing a clear plan, define roles for all the players and most importantly develop guidelines to enable progressive implementation of BIM in a country.

Findings of this thesis suggests that USA is leading the rest of the countries in terms of BIM maturity as it has been implemented for many years right from national level down to various individual states most having their guidelines and initiatives. However, its important to note that USA‘s government has not enforced any unilateral requirement for the entire construction industry.

United Kingdom kingdom on the other hand has the most government- centered approach strategy for BIM compliance by the industry hence making it world leader in BIM adoption. Other countries that have national BIM mandates include: Norway, Denmark, Finland and Singapore. Among the countries under the study, Singapore is the only country that has standardized and regulated the BIM adoption by its unique BIM e-submission guidelines.

Countries with their own BIM guidelines and regulation were found to have achieved more success in BIM implementation and therefore reap more benefits than those with none. The two good examples from the study are UAE and Qatar. Although Dubai Municipality has mandated use of BIM in specific types of projects, there are no country specific guidelines developed to be followed hence those multi-national companies that work on their projects are at liberty to use project delivery method that the so wish and BIM processes from their mother countries which might pose challenges and may not optimize use of BIM technology.

Qatar on the other hand has neither specific BIM guidelines for its vibrant construction

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