Importance of BIM as a Qualitative Tool for Construction Management: Learning from the UK and understanding scope of Implementation in the Middle East

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Abstract

Building Information Modelling is now an established process in the developed countries like the regions in the UK and it has gained much attention of researchers as well in the recent years due to its potential for improving efficiencies of construction projects. UK is considered as the leader in the field of BIM with many construction projects using BIM for its entire project lifecycle. Moreover, the achievements of UK has also motivated government that has come up with a Digital Built Britain plan which aims to make all constructions in the countries use BIM level 3. However, as the gap exist and organizations are not already adopting lower levels of BIM, the government has issued a mandate for making all public construction projects adopt BIM level 2. The BIM has tremendous potential to improve construction processes which is not only experienced by UK organizations but also worldwide. Thus, countries like Middle East region are also adopting BIM. However, there is a gap in understanding, experience, and level of expertise and adoption rate of BIM between UK and Middle East countries. This research explores this gap.

Before understanding the adoption of BIM in UK and Middle East and do a comparison, the researcher uses literature study to explore the concept, uses, benefits and applications of BIM. The dissertation discusses the fundamental principles of BIM, construction strategy of UK government, Digital built Britain plan, and BIM level 2 mandate requirements as well as RIBA plan for achieving the same. Further, it explores the status of BIM in the construction industries of The UK and Middle East.

In order to understand the applications and practical aspects of BIM in construction industry, the researcher uses primary method of data collection through a survey and a secondary method by using case studied that involve critical analysis of already completed BIM projects from UK and Middle East. Further, a thematic analysis is being performed on the qualitative data obtained through survey and the information obtained in the six case studies, three each from UK and Middle East.

Objectives of this research are to understand the practical applications of BIM in UK and understand the status as well as the scope of its implementation in Middle East countries. The research would particularly useful for construction engineers and architects in understanding

the potential of BIM as well as build upon its foundational knowledge. Moreover, it would help organizations take decisions on whether BIM would be an appropriate strategy to be adopted in their case. With the case studies, the engineers and designers would be able to understand how they can best use Building Information Modelling applications in practice. Further, it would also help BIM software solution makers to understand why the adoption rate of BIM in Middle East is low so that they can use the knowledge to make modifications in their approach to reaching out to companies as well as help them in better ways through the adoption process.

This document serves as a guide to understanding BIM practice, its implementation, applications and usage as well as a source of inspiration for adoption of BIM as it is able to present the scenarios where actual benefits were achieved by real construction organizations.

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Abbreviations

BIM	Building Information Modelling
EU	European Union
AEC	Architecture/Engineering/Construction
ROI	Return on Investments
RIBA	Royal Institute of British Architects
KPI	Key Performance Index
KTP	Knowledge Transfer Partnership
LOD	Level of Development
MDS	Model Development Specification
ICT	Information Communication Tecnology
COBie	Construction Operations Building Information Exchange
PDT	Production and Delivery Table
EIR	Employers Information Requirements
ODA	Olympic Delivery Authority

1 INTRODUCTION

The construction industry throughout the world is facing a paradigm shift towards increasing value, efficiency and productivity and reducing costs, rework and lead time. Most of these benefits are achieved by BIM as it is capable of streamlining construction business processes. The modeling techniques used in BIM have replaced the traditional processes that were earlier fragmented with a consolidated environment where teams are highly collaborative. Moreover, BIM integrates various processes throughout the project lifecycle (Arayici, Khosrowshahi, Ponting, & Mihindu, 2009).

Building Information Modelling is an area of study that has taken much attention in the field of civil engineering as a result of the popularity of the practice in construction and the benefits it is capable of delivering to construction projects. The latest Mandate issued by UK government for adopting BIM level 2 implementation for all public sector construction projects has further propelled the area of study as more and more organizations are adopting the process.

However, BIM is not just popular in UK but also in other parts of the world. Developing countries like those in Middle East have started adopting BIM for managing construction projects. The lessons for best practices as well as expertise usually comes from the learning received by BIM projects in developed areas like UK. This research makes an attempt to understand the practice of BIM in practice, understand how it is used in UK and identify the scope of implementation on projects in Middle East construction.

Middle East has already adopted BIM for some big projects in the region like Dubai, but the adoption rate is still very less due to major barriers such as lack of expertise. Thus, it is important to understand how Middle East countries are actually using BIM and those not using must be explored to understand the barriers.

Building Information Modelling

Historically, the initial construction planning was being done using manually constructed models; that lacked crucial information like the efficiency of the model. These factors were uncertain and dependent on the ability of craftsmen. It was then replaced by the practice of two-dimensional (2D) designs that offered multiple views from different angles. However, it was a time consuming and work intensive task. Before the advent of computer-aided designing software like CAD, the designs required high level of skills and precision in manual drawing on behalf of the designers. The arrival of such technology offered a certain level of automation in terms of creation of orthographic projections, thereby simplifying the work of designers. However, it was still short of the virtues of three-dimensional (3D) models that replicate real life structures. As the 3D modelling technology came that used axometry, isometry, and perspectives as principles, a paradigm shift occurred in the field of construction designing (Naya, Jorge, Conesa, Contero, & Gomis, 2002).

Building Information Modelling (BIM) is the latest practice in the field that goes beyond mere 3D visualizations by integrating it with other elements of a construction project. It creates a workflow that integrates multiple elements, components and processes involved in construction such as planning, design analysis, procurement, scheduling, sequencing, facility management, information tracking, etc. A big advantage of using BIM is that it allows real time tracking of related information that gets updated instantly, and is available to all the project stakeholders and partners for monitoring. BIM makes the project seamless, and an integrated communication becomes the strength of the project (Naya, Jorge, Conesa, Contero, & Gomis, 2002).

Advantages of using BIM on construction projects are multi-fold. This study, therefore, explores in depth the usage of BIM on construction projects for the UK and the Middle East countries.

Research Background

BIM allows the making of 3D digital visual representations of both functional and physical characteristics of structures, and also offers the integration of planning, designing, construction and building management. It facilitates easy information retrieval, better coordination among team members of a project, virtualization, improved productivity, faster deliveries, linking of important information throughout the project lifecycle, and reducing the direct and indirect costs of the project significantly (Naya, Jorge, Conesa, Contero, & Gomis, 2002).

UK has many projects that have been constructed using BIM, and the benefits realized from the process has lead to a consideration by the government that has issued a mandate for a compulsory use of BIM for all construction projects in the country. The target of the British government is to achieve level-2 BIM capabilities on all central government infrastructure projects by 2016. BIM levels are the metrics of defined capacities of the implementation starting with level "0" in which only 2D CAD drafts can be prepared without any collaboration between teams to Level 3 which allows for highest level of coordination between teams and processes. The UK government has allotted a budget of over US $5 million in order to achieve its goal (MacLeamy, 2009).

BIM has transformed the construction industry of UK which employed over three million people who worked to deliver £107billion projects in 2010. The industry is going forward towards higher levels of integrations with other technologies that can further improve the construction projects. Some of the technologies that are expected to become the part of BIM processes in UK include internet of things, which is network of digital devices connected together with the internet enabling seamless communication between them and data analytics which involves inspection, processing and modelling of data to support managerial decisions. With the increasing use of BIM, the government of UK is aiming to build an infrastructure that is effective in terms of costs and operation. The objective is to build a Digital Built Britain (DBB) (Cable, Digital Built Britain: Level 3 Building Information Modelling - Strategic Plan, 2014).

Digital Built Britain

Digital Built Britain is the Vision of BIM Task group that aim to create smart cities in UK by integrating expertise of different areas including constructions, technology, operations, and risk management. Although the plan is to begin with the BIM level 2 mandate, the vision extends beyond with an objective of creating BIM level 3 buildings in the United Kingdom thereby making cities Smart. Use of big data and other intelligent systems would be utilized for delivering public health services like Healthcare with assisted living, Smart Energy Grids for renewable sources of energy, traffic and congestion management for transport convenience, Water management and wastewater treatment as well as management of all types of wastes including those including carbon (Cable, Digital Built Britain: Level 3 Building Information Modelling - Strategic Plan, 2015)..

This BIM Level 3 vision aims to facilitate growth and competitiveness of public infrastructure projects in UK through more efficient use of assets in future. New models of deliveries and engagements would be adopted for building excellence on projects. With this approach, companies would be building upon investor confidence through technological capabilities. The efforts would also strengthen small and medium enterprises as they would gain more confidence in use of technologies for their organizations. The underpinning of the success in the long run include use of highly skilled and digitally enabled workforce, building of digital infrastructure that would have a framework for security, privacy, regulation, growth, collaboration, innovation and so on. Rich data sets generated through BIM level 3 applications are expected to support further developments both internally in organizations and across the market with collaborative working and sharing of this information. Moreover, with level 3 BIM, the industry aims to build an effective change management program which would help organizations develop necessary skills faster to adapt to changing needs of consumers as well as changing phases of technologies (Cable, Digital Built Britain: Level 3 Building Information Modelling - Strategic Plan, 2015).

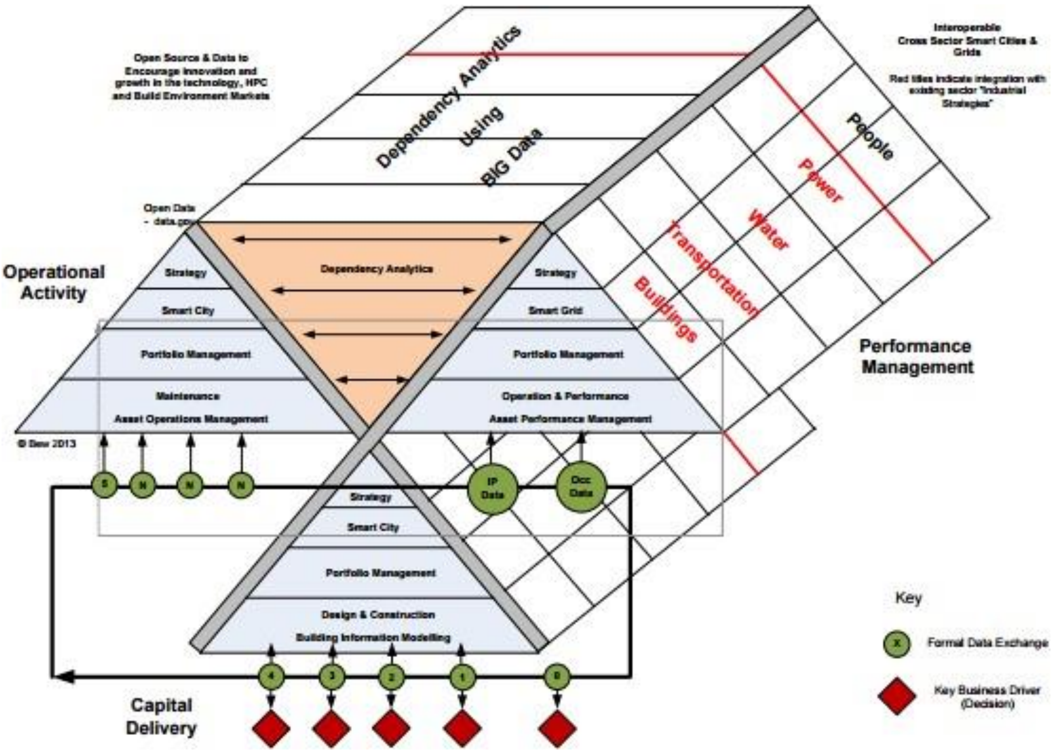


Figure 1: Digital Built Britain Operational Model (Cable, Digital Built Britain: Level 3 Building Information Modelling - Strategic Plan, 2015)

An operational model has been defined by the task group for Digital Built Britain that specifies the Level 2 BIM program which proposes to build low cost and low carbon construction services by using technologies for performing different operations such as measuring performance, comparing delivered assets with briefed requirements, using open data standards for integration design, construction and operations and building ability to analyse the data for building learning feedback loops for the industry for long-term improvements (Cable, Digital Built Britain: Level 3 Building Information Modelling - Strategic Plan, 2015).

Before achieving the BIM level 3 which is the key aim of the Digital Built Britain strategy, the construction industry needed to first adopt to Level 2 BIM and thus, UK government came up with the BIM level 2 Mandate for government construction projects.

BIM Level 2 Mandate

Government was a major client and developer of buildings in the UK but they were unable to give the required level of satisfaction to the dwellers of their projects and thus, there was a realization that government projects needed improvements in construction management practices. It was found that through BIM, government projects could be made capable of better value creation, cost improvements and achieve improvements in carbon performance. A task group was set up by the government in order to assess the possibilities of adopting BIM and assess various levels to identify the most appropriate maturity levels for public infrastructure projects. The efforts of the task group resulted into formation of a four year BIM implementation strategy that was to explore the construction supply chain for its improvement. The BIM Level 2 was declared to be adopted as a minimum requirement and organizations were given a mandate to convert all project related information and documents intro electronic information by 2016 (Philp, BIM: The UK Government Strategy, 2015).

This study is developed mainly in response to this mandate, aiming to understand the reasons behind this decision which could significantly affect the entire construction industry of the nation. Additionally, it tries to find out why BIM has not been received similarly in other places worldwide if it is really as virtuous, and efficient as UK government considers it to be.

A new McGraw-Hill study on construction has covered projects that did not use BIM, as well as those construction project representatives who have used BIM, in order to identify the benefits BIM offered to them. There were significant findings that explain UK's move to adopt BIM on all public infrastructure projects. It was found that 67 percent of the projects studied reported improved return-on-investment (ROI) with the use of BIM. 70 percent of those not using BIM were seeing the pressure for its adoption considering competition is moving towards the use of BIM. Some major benefits found were lowering of project risks, and improved predictability of the project outcomes (Cable, Digital Built Britain: Level 3 Building Information Modelling - Strategic Plan, 2014).

The government of UK, with the adoption of BIM on construction projects, is targeting 15-20 percent of cost savings on project by the end of 2015. Initial estimated saving would be £2bn per annum. Some of the other benefits of adopting BIM in the construction industry, as per the insights from the government, are greater operational efficiency, effectiveness, and creation of a forward-looking sector which is put on an impressive growth trajectory. A BIM Task group has been created by the British government for guiding the growth ambitions, and assisting projects through investments, technology, strategy and communication. This task group has worked with EU and other international organizations of the industry to understand how BIM can be used to build a collaborative business model across projects. A vision is created to have all construction projects adopting level-2 BIM by 2016, and reach level-3 by 2025 (Cable, Digital Built Britain: Level 3 Building Information Modelling - Strategic Plan, 2014).

Research Problem

In spite of the massive use of BIM by big organizations and governments like that of UK, it has still not been received as positively elsewhere. Middle East countries that have huge and growing construction industry limitedly use BIM. Nevertheless, BIM has been used in a few big projects in the region like Habtoor Aqua Theatre, National Bank of Kuwait, Bahrain International Airport, King Abdullah economic city, and more (Ventures Middle East LLC, 2012).

Thus, there is a need to understand the reasons behind the slow adoption of BIM in these countries, and at the same time identify reasons behind the UK mandate for the use of BIM. Understanding the differences can find gaps that can be addressed to expand the use of BIM and make its operations more efficient and relevant for the users.

Aims &Objectives

The aim of this dissertation is to explore the advantages of BIM when used as a tool for project management for construction industry, and to understand how it enables better collaboration between different disciplines within the process of construction considering the Western markets like UK and the emerging markets like the Middle East.

Key research objectives for this study are:

- To understand the concept of BIM, its advantages and the challenges faced by using BIM in construction projects
- To explore individual projects and case studies taken up in the target countries so as to understand the practical aspects of its use in-depth
- To study current trends in the construction industry using BIM for UK and Middle Eastern countries
- To understand best practices used by successful construction projects in developed countries, and to use the lessons to assess the performance of BIM projects in Middle East
- To identify and discuss the scope of using BIM for construction projects in Middle East as well as explore the scope for improvements in existing practices.

Value of Research

The aim of this research in terms of its use for the industry is to bring out best practices that could be employed in the construction projects that plan to use BIM for their management. Also, this document can be used as a guide for the Middle Eastern countries for the use of BIM on construction in an optimized manner while identifying potential challenges and possible ways to overcome them in using BIM in construction. This will also serve as a study guide for students of construction and BIM. For the Middle Eastern projects, it would give specific cases where the reader would be able to understand the ongoing trends, loopholes in the management using BIM, if any, and potential benefits of using BIM.

Scope and outline

This dissertation aims to understand the importance of BIM in the construction sector. It discusses its success in the developed countries by considering the example of UK. Further, it explores the scope of the implementation of BIM on construction projects in the Middle East both, for the purpose of comparison with benchmarks, and to make use of learning from its application in UK to come up with recommendations for Middle East.

The dissertation would begin with an understanding of BIM as a concept, and then its technical importance, application as well as benefits to the construction industry would be explored in detail. Building Information Modelling would be studied as a collaborative model and an integrated tool that facilitates synchronized working of planning, designing and construction on projects.

Individual chapters that this dissertation will explore the subjects which are listed below:

1. **Introduction**: This chapter will briefly outline the field of study, and will explain why is it undertaken. It will talk about key objectives of the research and outline of the dissertation. This section will also identify the need for the use of BIM on construction projects, and would discuss how this particular study will be helpful in contributing to the body of knowledge or to the industry in general.

2. **Literature Review:** With the help of existing research, this chapter will support key objectives of the research that are to understand the concepts of BIM, use of BIM in construction, considering the practical implementations on the UK, and scope of the same in the Middle East countries. It chapter will discuss main theories related to project management, BIM and use of BIM on construction. It will study the trends of BIM in constructed in the targeted countries.

3. **Research Methodology**: This section will define the approach taken by the research, and will explain how the data has been collected, analyzed and presented. It will also explain the research design, methods used for both data collection and analysis, the limitations of this study, and the ethical considerations of it.

4. **Data Analysis & Discuss**: The main approach taken in this research is the use of multiple case studies that will be discussed in detail in this section. This will include discussions and critical analysis of the BIM construction projects of UK and the Middle East. This analysis will also involve a comparison between the BIM practices used in the two regions such that best practices as well as shortcomings can be identified.

5. **Conclusions & Recommendations**: This section will summarize the key findings of this research study and will also make recommendations on the basis of the learning from the same for the Middle Eastern countries defining the best practices that can be used or the improvements that can be made to make the BIM projects successful.

6. References: This section would list down all the references to books, journals, research reports, and other documents that have been used as the part of this study using the Harvard format of referencing.

2 LITERATURE REVIEW

Principles and Characteristics of BIM

BIM is used for managing projects with higher complexities arising from the use of multiple processes that have to collaborate to achieve a common goal. Key factors that constitute the foundations of BIM are intelligent modeling and integrated collaboration. While building models using BIM processes, 3D representations of project components are created that goes beyond the visualization to add other project related information like schedules, construction plan, material costing, construction and logistics (Sebastian D. R., 2011). Further, the integrated platform enables seamless communication and collaboration between stakeholders of a construction project such that decisions are made faster thereby allowing teams to adhere to planned schedules with fewer deviations.

BIM systems also display some important characteristics that are important to explore in order to gain an understanding of the working of BIM in practice. For instance, BIM being a technological platform, the processes within it are performed using the information obtained from a digital database which is made available to all parties to contract which is why the collaborative environment can be exercised. Moreover, on construction projects, several and modifications may be required during a project lifecycle which requires corresponding teams to incorporate changes in the information database. The use of database also allows collective storage and archival of project information such that it is made reusable by future projects of similar characteristics or involving similar components (Autodesk, Inc., 2002).

BIM works on two key principles that are intelligent modeling and integrated collaboration that allows information sharing. The framework and technology are used in BIM to achieve these goals.

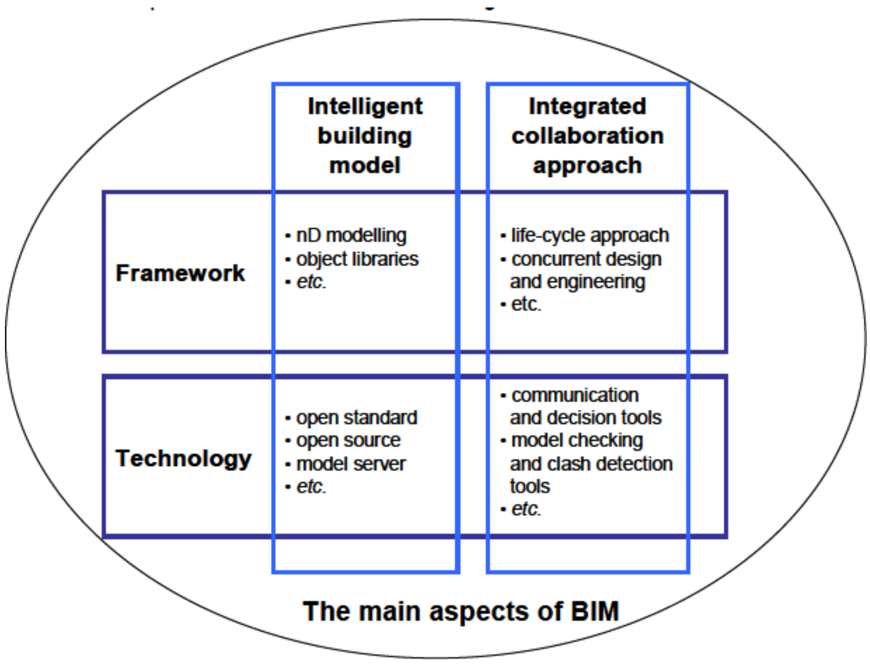


Figure 2: BIM Principles

Intelligent Building Model: Intelligence in BIM is achieved using multi-dimensional modeling, which includes 3D visualization, planning, scheduling, cost estimation, production, logistics and other types of documentation. The intelligent model use object libraries containing open standards. Despite the uniqueness of individual construction projects, there are standardized components that can be used everywhere. BIM allows creation and reuse of such components in construction designing. It can store objects in the unified open libraries from where different objects can be retrieved and used by different stakeholders and parties to contract enabling collaboration between them.

Collaboration in BIM: Stakeholders can exchange information and use the project components collaboratively. Once a design is created, it is verified against initial requirements and the performance of the construction and only after that, stakeholders take decisions. The decision-making process involves the creation of ideas, their conversion into concepts and then elaboration for documenting them through proposals.

Uses

BIM can be used differently by several parties on a construction project including architects, engineers, contractors and facility managers. Architects use BIM for creation of 3D BIM models of construction site, perform sustainability analysis, bring coordination between people working on projects within different functional departments, and to produce construction documents such as designs. Structural analysis can be performed by structural engineers while M&E engineers can use it for designing of mechanical and electrical systems as well as planning for optimizing distribution routes. Contractors use it for construction planning, establishing sequences and quantity as well as cost estimation. Facility managers use it for building maintenance, generate floor plans and creation of database (Das, et al., 2011).

BIM in practice can be used for different stages of a construction project lifecycle including designing, bidding and construction. As this research aims to understand the use of BIM majorly in designing of construction projects, only the design aspects would be covered here in depth.

BIM in Designing

While traditional construction based systems aimed at reducing construction cost, BIM takes a step ahead by focusing on maximizing benefits in addition to optimization of costs. In designing, the aim is to create a sustainable construction. The design created using a BIM software allows enough flexibility to accommodate lifecycle changes even in the long term which not possible with traditional methods. Designing stage in BIM -led construction projects consider life-cycle management requirements as well and thus, while creating design options, business strategies of the organization and the activities of the users are considered.

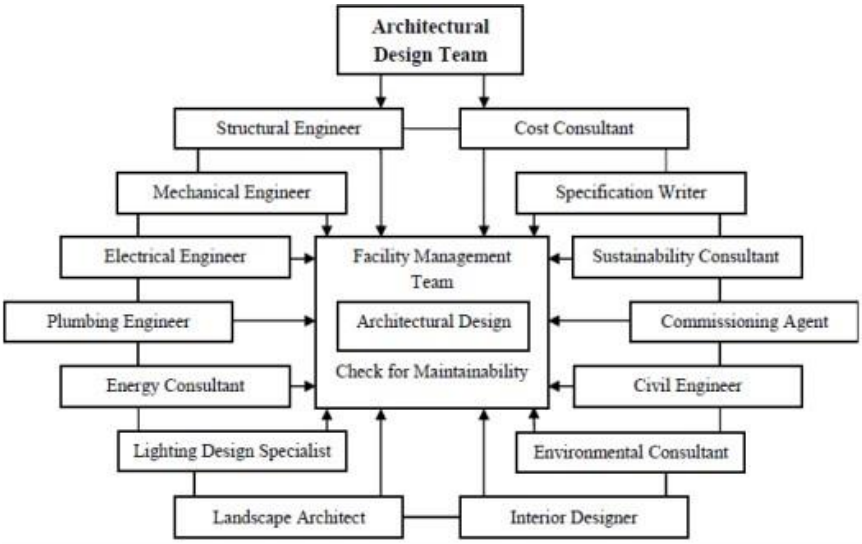


Figure 3: BIM FM design integration

The collaboration between the design teams and other disciplinary teams like owners, contractors, engineers, contractors, architects, suppliers and so on from the early design phase can quickly generate design options, create alternatives and build more efficient designs. Better decisions can be made during the design stages through presentation of information in a way that users can understand them and perform analysis such as environmental impacts assessment and thermal building performance analysis (HUNGU, 2013).

Difference between traditional CAD Models and BIM

Traditional CAD models had closed propriety approach while BIM use the open standards. While CAD only generate a 2D or 3D model, BIM defines facilities in terms of objects. There are also differences in the way information is maintained in CAD and in BIM. While CAD model contains information about geometric constraints, BIM contains information about geometric shapes as well as objects. The information is stored in the form of central object-oriented models that are embedded into a central model which is linked with the Data management System (Sebastian R. , 2010).

Benefits:

BIM has several benefits that may be worth exploring considering the objectives of this project that are to understand concepts, working, and advantages of BIM.

- **Less Wastage:** BIM enables design analysis involving all project components; materials and assembly requirements such that an optimum set of requirements can arrive at considering resource constraints and quality requirements. This can thus reduce instances of unwanted orders, mistakes and other kinds of wastages (Studio4 Consultants Pvt. Ltd, 2013).
- **Better communication**: A common platform for collaboration allows teams to have an understanding of the processes being carried out in other departments and thus, the projects teams at all levels and in all departments can keep themselves updated on the latest developments on the project (Studio4 Consultants Pvt. Ltd, 2013).
- **Processes will be faster**: A strong coordination between teams and analysis of time and material requirement in design phases reduces the time requirements of the project on different phases of its life cycle (Studio4 Consultants Pvt. Ltd, 2013).

- **Better performance**: Simulations of design outputs allow managers to make decisions related to performance such that it can be improved (Studio4 Consultants Pvt. Ltd, 2013).
- **Simplify Project Management**: BIM is a platform that contains an integrated database, which includes information on schedules, resources, costs, space considerations, and risks which were not possible to maintain with ease in traditional processes. Further, the data that is stored may come from different sources and can still be presented in combination in the form of reports that allow faster decision-making. With data consolidation and single platform reporting, the processes are simplified and data is easily accessible (Studio4 Consultants Pvt. Ltd, 2013).
- **Cost Saving**: Costs that are incurred due to delays, reworks, manual designs, and so on can be saved with the use of BIM. Further, the improved speed of information retrieval and better understanding of scope reduce uncertainties and delays on project. Thus, some extra expenditure that may be incurred in such cases is avoided (Studio4 Consultants Pvt. Ltd, 2013).
- The accuracy of the information which is flowing between teams and processes is also improved using BIM (Studio4 Consultants Pvt. Ltd, 2013)

Guidance and Standards

BIM is a practice that uses certain standards that present performance benchmarks for projects. AEC Standard is one such standard, which is used in UK. This standard, which was established by a committee of engineers, technical consultants and architects, define certain BIM procedures and protocols for construction projects. These may include resources, procedures, workflows, coordination, data structures, modeling and so on. Protocol V2.0 is an AEC (UK) protocol defined for the effective use of BIM practices in order to improve the efficiency of the construction (AEC(UK), 2012). These protocols also include descriptions of individual roles of teams involved in management, construction or strategy making.

Table 1: BIM Functions (AEC(UK), 2012).

	Strategic						Management				Production	
Role	Corporate Objectives	Research	Process + Workflow	Standards	Implementation	Training	Execution Plan	Model Audit	Model Co-ordination	Content Creation	Modelling	Drawings Production
BIM Manager	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N
Coordinator	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N
Modeller	N	N	N	N	N	N	N	N	N	Y	Y	Y

Maturity Levels

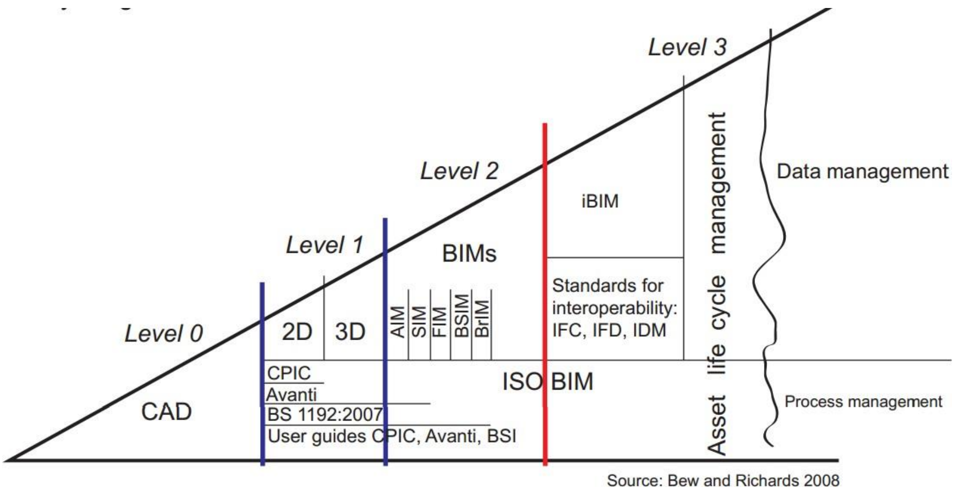


Figure 4: BIM Maturity Levels

Adoption of BIM on different projects can be differentiated based on the level of capabilities that are being incorporated in the systems. 4 key levels are defined for the use of BIM technologies from level 0 to 3 where level 0 claims the capability of designing and planning of 2D CAD files, one level up adds 3D information on these models. Level 2 includes making of 3D models, addition of information and also enables inter-team collaborations with collective access to resources. The level 3, which incorporates the highest capabilities of a BIM system which creates a collaborative model which is built upon the integration of different processes including designing, construction, asset management, maintenance, data analysis, and so on. This level makes a complete 3D BIM model which incorporates all the information about the components and assets of a project (Sinclair, BIM Overlay, 2012).

Level 0

BIM Level 0 uses 2D CAD designs and the output of the same is presented in a printed form or PDF format Sinclair, BIM Overlay, 2012). In this level 2D information and designs are exchanged electronic within teams but these drawings do not have uniform formats and there are no standardized processes or standards that are used for creation, sharing and use of these documents in practice.

Level 1

At this level, visualization of designs is done using 3D information of the structure. This level is often called 'lonely BIM' as users working separately on creation of models can exploit the benefits of the BIM solution individually. There is no collaboration involved at this stage. During early development stages, a 3D modeling software may be used as a design tool for visualization using both 2D and 3D information. A major benefit at this level is that it minimizes wastes and increases efficiencies of design and construction processes Sinclair, BIM Overlay, 2012).

At this level, both 2D and 3D are used. 2D drawings are used information collection and approval documentation while 3D is used for development of conceptual models and 3D visualization. The 3D models created at this level remain with creator and are not shared with team members.

Level 2

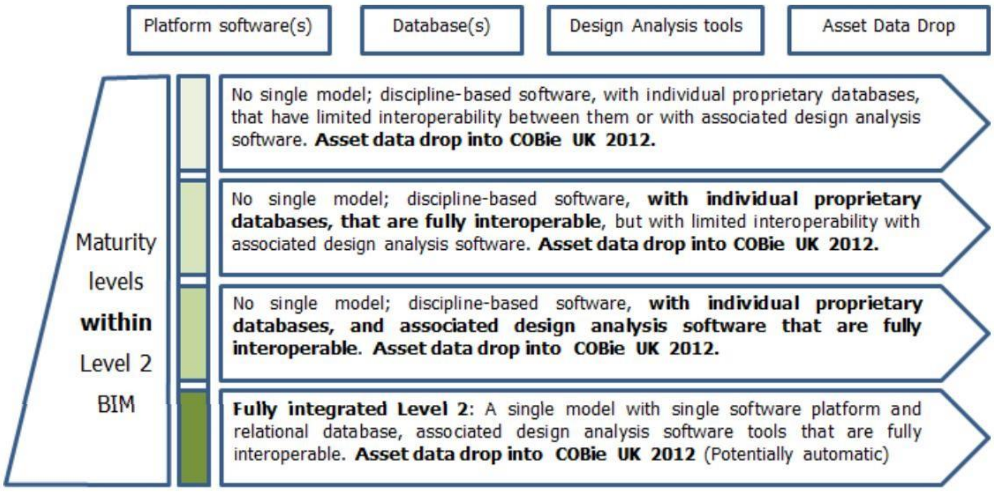


Figure 5: Maturity levels within BIM level 2 (Philp, First Steps to BIM Competence: A Guide for Specialist Contractors, 2012)

This is a managed BIM level that itself has several sub-maturity-levels of BIM. At this level, digital prototypes are created using intelligent objects for a building. Each prototype or a model needs software and an information database that adds intelligence to the model. In a fully integrated model, different users can integrate individual designs on a single platform. The models created are also interoperable with different design analysis tools such as environmental design analysis (Philp, First Steps to BIM Competence: A Guide for Specialist Contractors, 2012).

At level 2, contractual deficiencies are also exposed and performance measurement can also be done for the work of designers and contractors. This level allows collaborative work between different subcontractors such that procurement may be done using 'plug and play' methods (Philp, First Steps to BIM Competence: A Guide for Specialist Contractors, 2012).

Level 3

It includes single real-time model of a project which is created using common objects from the standard libraries and different types of collaborative information such as infrastructure problems, simulation, intepetatibility and so on. At level 3, an early rough design analysis can be done such that iterative designing time is reduced. 3D models created can also be used for deriving cost models. The analysis at this level also includes health and safety, asset management, KPI and feedback analysis for improvement. For level 3 BIM to become a success, processes have to be aligned properly and legal issues such as related to copyright have to be resolved (Philp, First Steps to BIM Competence: A Guide for Specialist Contractors, 2012).

While a project shifts from level 0 of BIM to level 3, there are certain requirements to be fulfilled. First, collaborative and integrative working methods have to be used both by designers and contractors, which requires a close communication. In order to produce a model, which is data rich, good knowledge of database is required. Other than regular communication, new working methods would also be required for procurement and other types of contracts that have to be aligned. For concurrent designing, the software used for BIM must also be interoperable. Standardization of user definition and rationalization of new terms is also required. BIM data can also be used for analyzing time (4D), cost (5D) and FM (6D) (Sinclair, BIM Overlay to the RIBA Outline Plan of Work, 2012).

Dimensions of BIM

H.J high has defined 6 different dimensions of BIM beginning with 2D to 6D. In 2D models, 2D drawing is used and any changes in the model have to be updated earlier so that time-related conflicts do not arise. In 2D models have to be updated for any changes in practice.3 D model adds clash detection and lean coordination to the project.4D models add information about the schedules and methods of construction. While 4d deals with time, 5D dimension estimate exact quantities and expected expenditure as per budget constraints. 6D is the last dimension that adds facility management to the BIM model. Such a model would contained detailed information about structural components of a construction such as room number, name and other elements (Storer, 2012).

BIM Application:

There are several software applications such as Graph iSOFT ArchiCAD, Nemetschek Vectorworks; these are Autodesk Revit and Bentley Micro station that are used on BIM projects. (Kim, Moon, Choi, Kim, & Kang, Development and Application of BIM System for Construction Project by Project Phase- Focusing on Bridge Project, 2013). This software offered different features and capabilities depending on the level of maturity of BIM. This software may be used for planning, designing, construction and operations.

Use of BIM in Construction

Key processes involved on a construction project are preliminary designing, detailed designing, documentation, raw material procurement, production and construction. Further, a need for change is a common concern on construction projects during the life cycle as this may demand a re-work, which could add both to the cost and delays of the project. BIM attempts to save on these costs and time delays by reducing rework. This is possible with the use of collective database that can be used for analysis of the model during the design phase such that required modifications are made prior to the beginning of construction such that there is less of rework required (Strafaci, 2008).

Documentation is another time-consuming process, which is minimized to a great extent with BIM. Design costs can also be optimized with BIM as it brings capability of automation of designing processes. It has been seen that, with the use of BIM, projects can incur 35% less cost for designing (Strafaci, 2008).

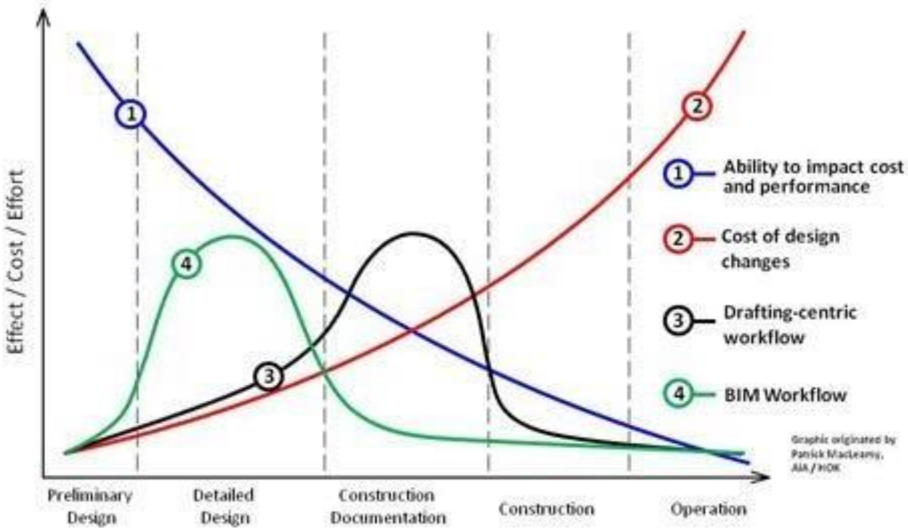


Figure 6: ***BIM in Civil Engineering Projects*** **[Source: (Strafaci, 2008)]**

Other benefits that BIM offers include cost reduction, energy efficiency, reduction in hazards, team alignment to project goals, better performance, availability of information on best practices and better decision-making capabilities (Strafaci, 2008).

BIM application can be used for performing site analysis, design authoring, design review, evaluation of building sustainability, validation of codes, detection of clashes detection, estimation of cost, planning, digital fabrication, data modeling, model assessment and so on (Strafaci, 2008).

Designing with BIM

An initial step of designing is defining forms and space to be used for construction after which the defined area and space specifications are used for planning and preparation of layout that best suit the project needs. A preliminary layout may be created first with addition of object features like wall material, assemblies, windows, lights, shades, roof form etc. Based on these specifications, quantities can be determined and costs can be estimated for the project developing (Chang & Al, 2013).

The design elements discussed above only make the preliminary design which is stored in the form of documents containing details of interiors, fixture placements, walls, ceilings, electrical systems, plumbing, and so on. This information can be used for assessing various design options considering their architectural impacts and costs such that a best-fit layout can be chosen (Chang & Al, 2013).

Thereafter, a detailed model of the actual construction involving geometric scales is created using features like call outs and section cuts that incorporate details of materials as specified by manufacturers as well as of best standards of architectural designs.

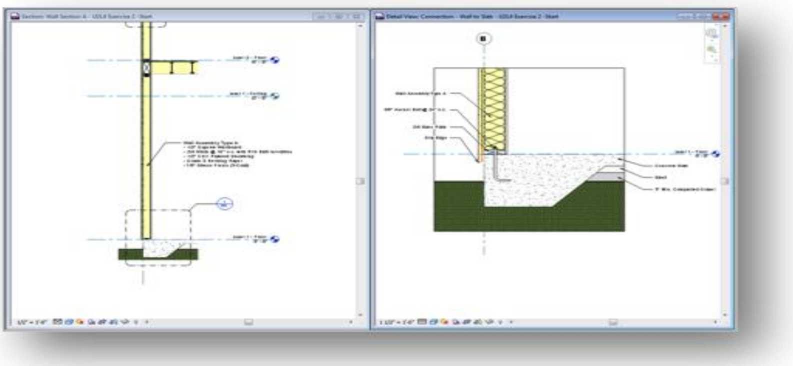


Figure 7: Calling out a detail for a wall-to-slab connection (Chang & Al, 2013).

BIM Implementation:

BIM can provide significant benefits to any organization. However, it is still not a widely adopted practice mainly due to the implementation challenges. Deployment of BIM requires a company to perform an extensive analysis of its processes as well as the impact of the adoption on management. High cost of implementation is another challenges. Further, BIM adoption requires, a deep understanding of the technologies, its environment, procedures, protocols, processes and methods such that a company can leverage on the full potential of a BIM solution.

Barriers to Implementation

Adoption of BIM is a major change process in an organization and its implementation do come with challenges that are required to be taken care of by management for smooth adoption of the BIM. These challenges are crucial to understand as they can explain the lower rate of adoption of BIM in Middle East countries as compared to UK. Also, it would particularly assist in understanding the measures taken by UK government and individual project companies to counter these challenges that include:

Lack of support from senior management: BIM requires a bottom-up approach to be followed with "learning by doing" approach which requires support from top management that may be used to top-down approach of management and thus, there is possibility of seeing resistance from senior management while making changes in the approach. Implementation of BIM not only requires installation of hardware and software but also a different way of use of processes and people and thus, Knowledge Transfer Partnership (KTP) have to be put in place with "buy-in" from top management. If there is a lack of vision on implementation purpose, ROI and benefits by top management, it can lead to failure of implementation (Jung & Joo, 2011).

Implementation cost: BIM requires purchase of software and hardware as well as training of staff on the use of software, which takes a significant cost of the organization adopting BIM. This posts a significant barrier for the construction industry because of significant expenses involved. Even after implementations, costs are incurred in updates, as the BIM packages need periodic updating of software as well as hardware in case of scale-up requirements. However, it has been argued that the implementation costs can be easily recovered after it is done with achievement of benefits like reduction in re-work and delays thereby reducing overall operational cost of construction. Contracting organization has to thus perform an accurate business case analysis to justify the costs of BIM implementation before a decision can be taken by management (Eadie, Odeyinka, Browne, McKeown, & Yohanis, 2014).

Cultural change management: Challenges in BIM implementation are not just technological but also cultural, as the organizational change has to be changed for its adoption, as people would have to become more flexible towards operations in construction. Thus, in addition to assessment of financials and physical resources, an assessment of people working in an organization is also required in order to understand their capabilities to adoption of the BIM culture (Tizani, 2010).

Competing Initiatives: UK Government construction strategy explains 13 initiatives taken by the government including BIM implementation that affect the BIM adoption as well. These include setting of targets for quality, environment, health and safety and others. This requires commitment of resources to these initiatives too, which could leave a limited number of resources to be used up for the implementation and operation of BIM strategy.

Lack of buy-in: BIM facilitates collaboration between designers, clients, fabricators and contractors and all of these have to be made BIM literature to make the most out of the BIM practice. Moreover, applications used must be interoperable such that data can be exchanged between different parties to contract seamlessly with reduction of chances of human errors (Aouad, Wu, & Lee, 2006).

Staff ITC literacy and resistance: Adoption of BIM require staff to be literate about ITC and thus, needs them to learn new systems. Often, staff would find it difficult to adapt to major changes and thus, can resist to its adoption. Further, a skill gap in terms of understanding of ITC can act as a significant barrier to adoption (Arayici, Koskela, Usher, & K., 2011).

Legal issues: Installation of ventilation duct in construction has some legal binding that requires companies to follow a specific process for construction. There are no specific legal precedents are set for construction industry in case of the use of BIM and thus, in case of commercial conflicts with BIM usage, parties have to make settlements out of court. However, there still are some legal issues that may arise while using BIM practice such as intellectual property, ownership, virtual enterprising, taxation, government policies, contract arrangements and so on (Oluwole, 2011).

Intellectual Property and Ownership: In case BIM application is used for client, the client can claim the intellectual rights on designs being sponsors while designer with the fear of losing competitive edge can also claim the rights causing conflicts. Thus, to resolve such conflicts, the UK BIM Industry Working Group has given intellectual rights to author of designer and not the party commissioning it (Oluwole, 2011).

Contact Agreements: Security issues may arise in case of e-procurements and contractual risks may be introduced if that is a lack of clarity on the security of the confidential data resulting from BIM applications. BIM solutions are used for facility management and if there is a changeover in responsibilities, it can cause confusion and uncertainty (Defining High Performance Buildings for Operations and Maintenance, 2010).

Product Liabilities: BIM model is often considered a product and thus, it also faces product liabilities. For instance, in traditional construction, designers were not liable for design defects but with the use of BIM, they can be held liable (Race, 2012).

Indemnity Insurance: Design works are required to be covered by Professional Indemnity insurance but insurers are reluctant because of inability to make an accurate prediction of liabilities and blurred delineation of responsibilities.

Authenticity: It is easy to create fake records by changing dates, metadata on paper and thus, establishing integrity can become challenging. Moreover, while sending files over an extranet, it comes difficult to prove the identity of sender in case of conflicts when they are taken to court (Christensen, McNamara, & O'Shea, 2007).

Execution Plan

A step before implementation of BIM in an organization is creation of an execution plan which involves documentation of BIM deliverables and processes including project information, members, goals, use cases for every stage and deliverables for each use case, author and users, model elements, process of creation, maintenance, release, collaboration and so on (Building and Construction Authority, 2013).

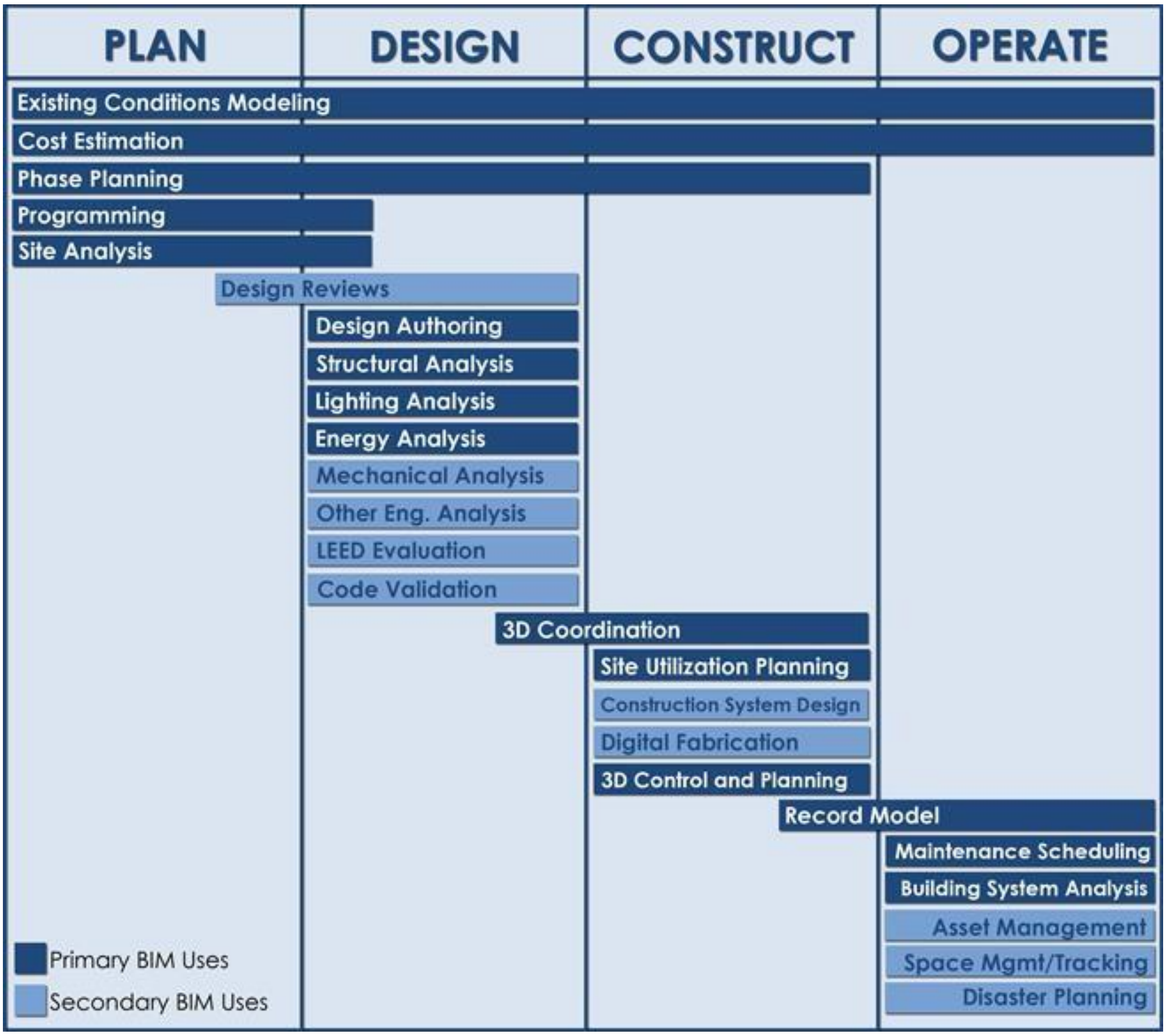


Figure 8: BIM Uses [(Kreider, Messner, & Dubler, 2010)

The identification of BIM uses for specific project is the first step to creating a BI execution plan. The benefits likely to be received from the use of BIM are recorded as BIM uses on project. The execution plan also requires an outline of project goals that should both be measurable and be improving quality of the project. A project performance may be measured by parameters like schedule, cost, and project quality. For instance, goal of a good quality may be defined by creation of an energy efficient design. A goal of achieving efficiency may include measure of the extent to which costs are saved (The Computer Integrated Construction Research Group, 2010).

After defining the uses, they are given priorities of low, medium and high based on the value they provide to the project. It would further with a selection of team involving members, their capabilities, their roles and responsibilities on the project. Once appropriate uses are selected, process maps are created for implementation using a two level approach that includes level 1 involving overview and level 2 involving details (The Computer Integrated Construction Research Group, 2010).

While working with information, a method called Model Development Specification is used for identifying amount and type of information required in modeling. MDS models use The Level Of Development (LOD) language definitions for 450 building systems and their sub-systems. MDS are used while executing any BIM plan. Use of MDS reduces the cost as well as efforts in BIM modeling. It also effectively reduces errors as well as coordination. MDS definitions also describe different components and elements of buildings and the framework is followed throughout the project process beginning from concept development, assembling to building of components.

MDS can be used for planning and tracking of the project deliveries which includes implementation of software, mapping of processes with standards of construction models, scoping, development of the baseline design and its schedule, defining of use cases and their milestones, setting milestones and determining workflow, design bridging packages, and then passing on the design to the construction stage (Bedrick, 2013).

Integrated BIM model

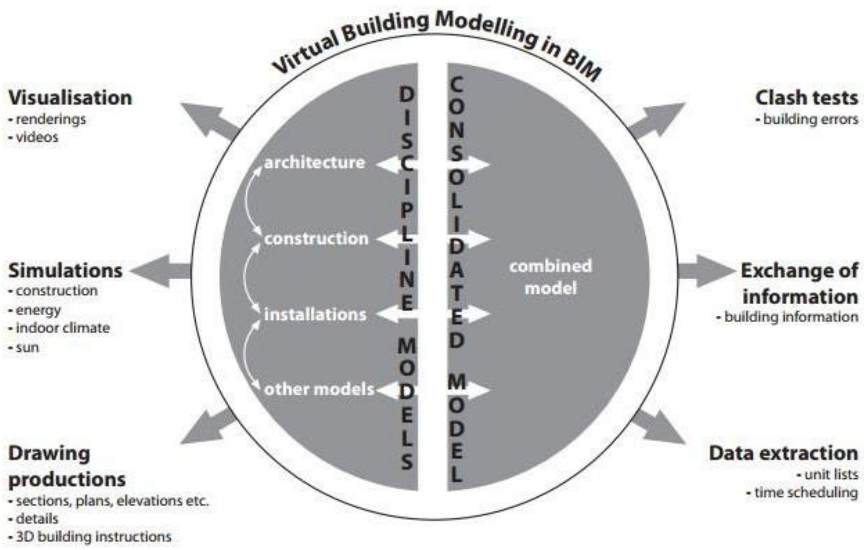


Figure 9: Integrated BIM model

The BIM processes and their vision are presented using an integrated model, which illustrates the use of Virtual BIMs that represent physical functions and characteristics of construction using parametric intelligence. BIM actually related to several disciplines that work collaboratively to form its principles and these include architecture and engineering and involve suppliers and contractors of construction process. Intelligence is built-in inside the model that contains different Levels of Details (LOD). These details are extracted automatically from the VBM to store into the database for building intelligence into the system (Thomassen, 2011). There are seven levels of information that are defined by Danish BIPS that created a guiding document for use of 3D called "3D Working Method 2006".

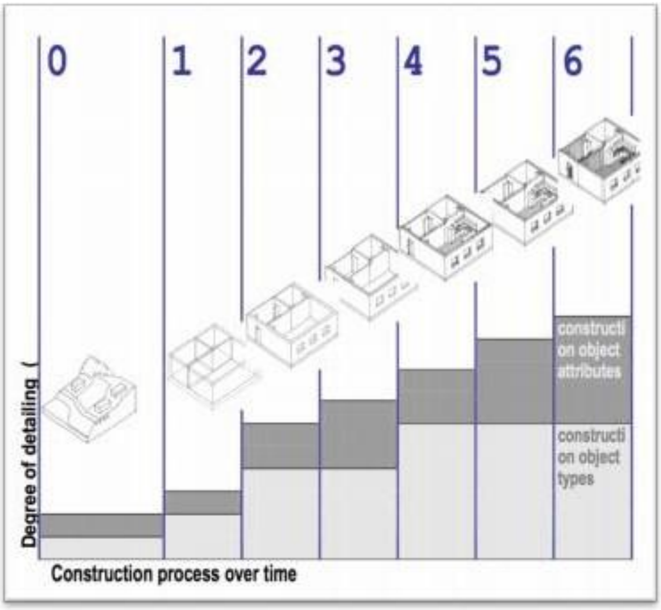


Figure 10: Danish Model of Information levels

The Danish method is based on the principle of detailing that evolves through the process as the levels are increased. At every higher level within a discipline, geometric, functional and object specific attributes are added to processes. These levels are actually detailed as per traditional phases of construction but they remain flexible for customization as per processes or methods and roles can be allocated according to the nature of tasks involved (Berlo, Bomhof, & Korpershoek, 2014).

LOD as defined by AIA has five stages on a rising scale including LOD200, LOD300, LOD350, LOD 400 and LOD 500. LOD 100 is only graphically represented BIM model but does not contain any specifications. LOD200 present a generic system that contains information about quantities, shape, size, orientation and location. Some non-graphic information can also be included in LOD200. LOD300 contains information similar to

LOD200 but it is more specific to a system. LOD350 contains specific system information like previous detail levels and also adds interfaces of the system with other building systems. LOD400 also contain other information such as detailing, assembly, fabrication, and installation. LOD500 is the final field verified representation containing all the information (Rancane, 2014).

BIM Technologies in Practice

Use of BIM technologies can render several benefits as well as pose many challenges and thus, a business case analysis would be required before an implementation is done in practice. This would involve understanding of roles of different parties on project for facility management and sharing as well as utilization of the construction information. A central repository can be used for saving information and tools can be used for enabling inter-operatibility that represents the information visually. For instance, CAD models can take information from bills, spreadsheets, and work schedules within data repository to create schematics. It is very important for data repository to contain updated information, which can be added as attributes to 3D CAD model components to facilitate coordination. The set-up cost for such a central repository is between 0.5% and 1.5% of the project value (Harty, Throssell, Jeffery, & Stagg, 2008).

With an aim to save on costs and reduce project risks, there can be several ways; various BIM actors such as virtual snagging, construction monitoring and planning, material take-off, and modular services can manage a project.

Virtual snagging: Problems in data may arise due to undocumented data causing inconsistencies that can be avoided with clash detection technique that is a result of a combination of models from different disciplines. Further, if there are new installations required on construction sites where there is a limitation of spaces, a central data model may be used for virtual snagging or troubleshooting of designs before actual installations to understanding if various design components could cause issues in actual construction such as trip hazards, inaccessibility to construction components and so on (Harty, Throssell, Jeffery, & Stagg, 2008).

Clash detection shows if any of the construction projects items and if there are clashes expected then corrections can be highlighted. Moreover, some BIM tools also allow one to set the rules for clash tests. Revit provides the feature for clash detection. However, additional features like clash reports, crash tracing, status of clashes, crash management, setting of rules, custom clash tests, clearance tests, and time-based crashing are available in Navisworks.

Construction monitoring and planning: Tracking of project progress can be done such that comparisons are made to find variations between planned activities and actual performances. In practice, separate monitoring and recording handovers are used for recording and reporting activities which include requirement printouts for posting in each construction room, customization of menu in the 3D model, linking of hand-held devices with BIM repository and so on (Harty, Throssell, Jeffery, & Stagg, 2008).

Material take-off: BIM models can provide quantities of materials required for various structural elements of construction project such as floor, ceiling, walls, partitions, doors, windows, cladding, skirtings and so on. While doing this, targets for waste reduction, checking wastages and issuing incentives for meeting targets can be incorporated into the model based on environmental considerations (Harty, Throssell, Jeffery, & Stagg, 2008).

Modular services: Module designers or manufacturers can be used with the utilization of standard modules that make modeling services faster as time otherwise taken up for re-designing or re-routing is saved thereby reducing delivery times (Harty, Throssell, Jeffery, & Stagg, 2008).

BIM solutions

Common software that are used for BIM applications includes Autodesk Revit, Graphisoft ArchiCAD, Nemetschek Allplan, Bentley architecture, IntelliCAD, and Tekla Structures, to name a few. BIM solutions available in market are categorized into the applications including architecture, sustainability, structures, MEP, facility management, and construction. On construction, BIM is used for simulation, estimation and construction analyses.

Most widely used products in BIM construction projects are Autodesk Revit and Graphisoft ArchiCAD. Revit provides decent out-of-the-box rendering similar to produce by 3DMax or Maya and ArchiCAD uses LightWorks as the rendering engine. However, Light Works initially lacked global illumination and instead Cinema4D and Artlantis as companion solutions. Later, was introduced CineRender which provided advanced materials and lightening. Autodesk on the other side added cloud rendering to its features.

The Revit solution uses credit-based system through which one needs to pay only for the use and thus, the system remains free for future modeling needs. However, it requires large rendering files. ArchiCAD provides a huge library for render-ready material presets. Overall both solutions provide comparable features for rendering, revisions, and parameter ordering, with some differences that make them unique solutions. For instance, ArchiCAD provides extensive customization of objects and space for incorporation of new workflows. Revit provides family dialog for organizing spreadsheet tables and ray tracing which was much discussed in 2015.

While making decisions about choosing software, core functionalities that are required by the project have to be explored first. This includes just 2D, both 2D and 3D and fully functional BIM. When considering 2D solutions, an organization may have cost or compatibility on priority. For instance, TurboCAD and NanoCAD are low-cost solutions while AutoCAD LT solution is compatible with more systems. If the organization needs both 2D and 3D functionalities, solutions can be chosen on the basis of project types that could be residential or commercial. Chief Architect, ProArchitect and Softplan are used for residential projects while AutoCAD is used for mix of project types. However, AutoCAD is a costly solution and thus, if cost is a concern, other solutions may be considered such as BricsCAD, ProgeCAD, Data CAD and Turbo CAD. For a comprehensive BIM solution for higher-level implementations, there are several other solutions available such as Revit LT and ArchiCAD Start used by individual designers, Vector works architects used for small or medium sized projects and Bentley AECO Sim and Revit for bigger multi-discipline projects. For design analysis, some other software options are available such as Adapt, CSC, Tekla, CSI, Oasys, RISA, Robobat, SoFiSTiK and SOFTEK (Halvorson, 2008).

BIM Tools

There are several tools of BIM that are available in the market depending on types of applications. This includes 3D modelers, surface modelers. And analyzers. Modelers are key BIM applications that allow parametric designs are detailing all requirements of a construction. Autodesk Revit, VIco, Tekla and Bentley systems are two major players in this set of tools. Surface modelers create a design that only displays surfaces but does not have any extra information embedded. Google Sketch up and Navisworks are some of these tools. Analyzers use BIM data obtained from modelers and perform analysis and simulation of project. Energy plus, DAYSlim, Apache SLIM, and Lifecycle are major analyzers (The Foundation of Wall and Ceiling Industry, 2009).

UK Government Construction Strategy

The UK Mandate for implementing Level 2 BIM on all public sector projects is pushing UK construction industry to use a fully collaborative BIM on public projects by 2016. This requires projects to make all project asset data, assets and other kinds of information collaborative through electronic media. These projects are expected to achieve some major benefits from the transition to BIM such as visualization, data integration, and better collaboration (Ngo, 2012).

The UK construction, as per the figures of 2011, contributes £90 billion each year to the UK economy and with the use of collaborative BIM for public sector construction, government aims to save £18 billion per annum. IBM has developed a 6 step process of adoption of BIM including identification of value preposition, setting of requirements, identifying information requirements, choice of technology, change implementation and benefit realization (Hornsby & Allan, 2012).

Value Proposition: Understanding of the value that BIM would generate on a project accurately is important failing which can lead to errors. For instance, the value proposition for designers would be in the form of reusability and productivity improvement. Better sequencing of construction processes would also contribute to the designing process and the benefits would percolate to the entire supply chain system (Royal Academy of Engineering, 2014).

Set Requirements: After the value is established, business requirements could be mapped to deliver system functionalities required for smooth implementation of BIM. Requirement mapping is done after having discussions with stakeholders of a construction project so that conflicts do not arise at later stages of the project lifecycle (Royal Academy of Engineering, 2014).

Information requirements: The value generated by BIM is produced by the data that is an information asset of the project. As level 2 involves increased collaboration, it also comes with more challenges occurring due to fragmentation or defects in design. To avoid such risks, data traceability or provenance techniques may be used (Royal Academy of Engineering, 2014).

Choice of Technology: Technology to be used is chosen based on a positive result of an evaluation. Evaluation criteria differ with projects and with industry. This evaluation may be based on ease of integration, improvement in quality, cost savings, and so on (Royal Academy of Engineering, 2014).

Change Implementation: For adoption of BIM, traditional methods have to be changed and the staff of the changing organization had to adapt to new styles of work. New behavior has to be incorporated through training of employees. Any shortfall in understanding of BIM or skills has to be overcome through these training (Royal Academy of Engineering, 2014).

Benefit realization: Metrics may be used to develop insights on whether the value intended was achieved. Dashboards and process measures can be used for tracking benefits against initial requirements (Royal Academy of Engineering, 2014).

Construction Growth Plan

The growth plan of UK Construction industry as established by the BIM task group has certain actions to be taken in coming future and these include:

Embed BIM in Domestic market and Plan for international expansion: Local government of UK sees potential in the international market also and thus, on one side the government launched a Mandate for BIM level 2 for local construction projects, the focus is also on global expansion.

Exploit UK leadership to achieve success globally: UK is a leading nation in using BIM for construction projects as the government aims to increase the international competence of construction projects in UK. There are limited opportunities within UK construction industry and thus, the BIM-driven organizations aim to expand beyond their local boundaries.

Coordinate with EU and develop international standards and practices: EU level BIM can drive growth and make the market more competitive and thus, the government plans to adapt to EU Sustainable Construction strategy such that performance of European projects can be improved and practices can be promoted globally. The aim is also to build BIM protocols that are consistent across regions and can be used internationally.

Identify need for BIM technology and address it: The construction market needs to be explored for the need of ICT techniques such that the opportunity for the use of BIM software for construction projects can be identified. A further step would be to provide BIM software for these projects and look for more opportunities where BIM services can be utilized. To do this, government has created a BIM Technologies Alliance, which aims to embed existing BIM solutions in the construction industry as well as develop new solutions such as advanced products, data, standards, procedures and protocols.

Equip UK manufacturers with BIM data for delivering it to clients: The government aims to collaborate with manufacturers of the construction-related products, as it is believed that construction products give 40% of the value in the overall construction and are significant contributors for improvements in efficiencies. BIM program would involve Construction Product Association that would be coordinating with manufacturers for supplying information as well as produce quality data.

Enhance BIM Enabled DFMA capacity: Forward pipelines of BIM projects would be published such that innovations solutions could be developed speeding up the adoption of BIM globally for infrastructure and construction. DFMA construction techniques would be encouraged for use by early adopters of BIM.

Enhance operational and function efficiencies: BIM data can be used for bringing efficiencies in operation, maintenance and management of energies and can help save costs. Thus, organizations would strive to achieve efficiencies through the use of BIM data that would be treated as an asset for a construction project organization.

Build capability to handle BIM data for global recognition: The engagement of government with the construction industry would be increased through the use of procurement portals. However, it can also lead to wastages if the acceptance of BIM data on the portal takes time.

Commitment to Digital Built Britain: The aim of Digital Built Britain is developing both the construction sector and government departments on equal level by using fully integrated BIM models. The ambition of Digital Built Britain is to achieve leadership in BIM and create smart cities.

Develop International BIM standards: Develop practices through an increase in the available varieties of BIM software applications to support data connectivity.

Develop program for data collection and analysis to get lessons and share best practices: Government would look for finding ways of using the BIM data in order to improve construction and related operations.

Launch Future Cities Demonstrator: For economic excellence, it is important that consumers are provided with all kinds of information about services, which is possible with collection of data from multiple resources, and BIM can help achieve through creation building blocks of information. This needs an efficient integration of data and powerful tools for the search of information from the huge volume of data that is generated in BIM. The government has planned to develop applications using semantic web that help in incorporation of BIM in designing and management towards building smart cities (Blackwell, 2012).

Digital Built Britain

UK government had an ambitious plan for turning all constructions into Level 3 BIM whose first stage was the mandate for level 2 BIM adoptions in public construction projects. The strategy of moving to level 3 BIM was called Digital Built Britain and it had some specific goals including creation of knowledge sharing environment in organizations, establish collaborative working, create open data standards, train public sector employees on BIM techniques including processes and operational methods and driving organizational growth as well as create more jobs. The name Digital Built Britain was given considering construction field as an enabler for the UK economy. The document, which was created for recording the government strategy, identified collaboration as the biggest challenge in construction industry and BIM was seen as the solution.

The document established a contractual framework that encourages collaboration within industry through integration with the use of Laing O'Rourke Model. However, despite clear frameworks, the working towards adoption of BIM level 2 in UK construction firms is very slow mainly due to lack of understanding of BIM. Moreover, in real practice, early collaboration does not happen very often and specialists do not give manufacturing design. However, early adoption of BIM could greatly benefit projects (Cautons, 2015).

BIM Level 2 and UK Mandate

UK government has given a mandate for compliance to Level 2 BIM for public construction projects. This requires owners of the construction organizations to have employers information requirements (EIR), CDE for managing capital and operational expenditure of project, early involvement from end users and facility managers, defining of models in terms of uses, views and updates, reuse of BIM data such as for creating visitor guides and capturing performance data to augment the BIM design.

When contractors deliver BIM-driven projects to their clients, the compliance requires them to implement execution plan with required standards and formats, use of CDE for populating, validating and exporting of data in Construction Operations Building Information Exchange (COBie) format, document sharing with PAS1192-2-style workflows, model viewing, clash detection, project planning and supporting downstream supply chain for incorporating different BIM objects.

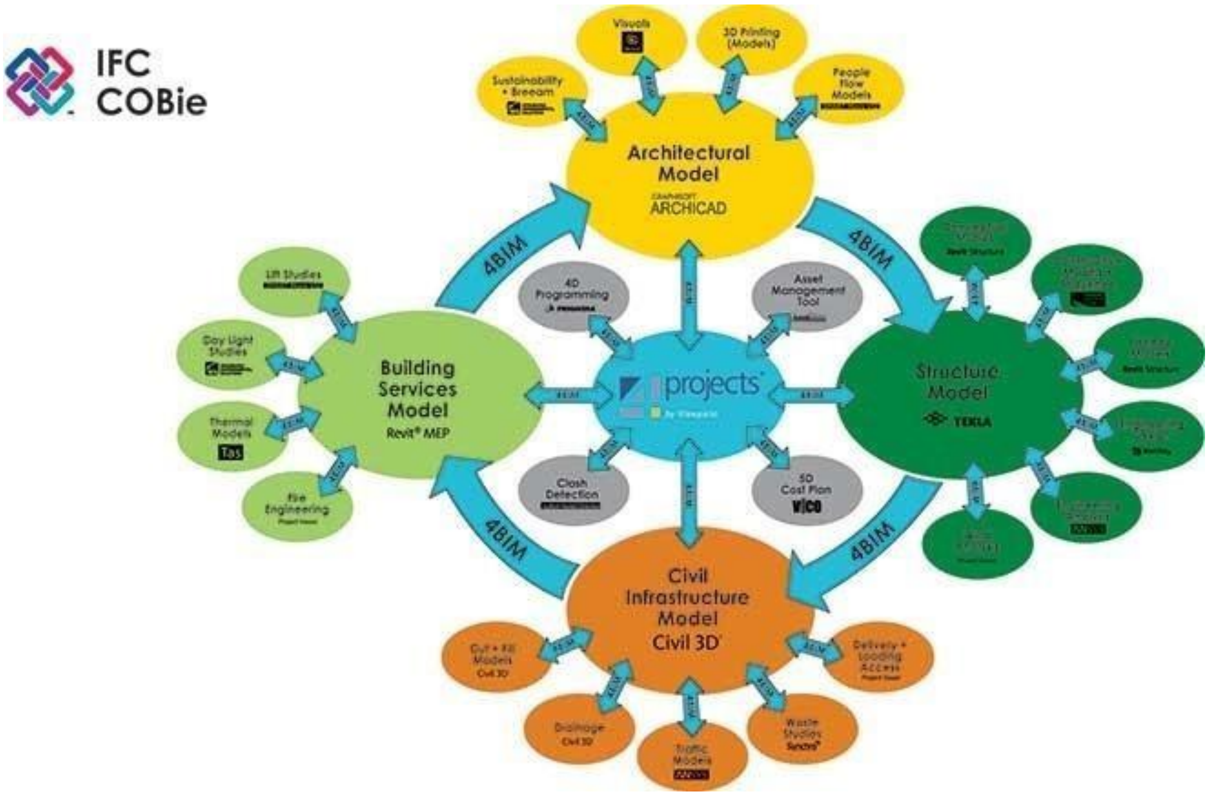


Figure 11: Program management software

EIR: UK BIM Task group has defined Employers Information Requirements (EIR) document as one key requirement in the IM mandate. It is an addendum to asset improvements, replacements or building of new projects. It includes information on what information to deliver at specific stages and the required format. In this document, employer confirms stakeholders and information requirements for each stage of the project. For dissipating this information, a production and delivery table (PDT) is created for each level. The response to this document comes in the form of a BIM Execution Plan.

Table 2: EIR Contents (Consortium of Local Authorities Wales, 2015)

Technical	Management	Commercial
o Software Platforms o Data Exchange Format o Co-ordinates o Level of Detail o Training	o Standards o Roles and Responsibilities o Planning the Work and Data Segregation o Security o Coordination and Clash Detection Process o Collaboration Process o Health and Safety and Construction Design Management o Systems Performance o Compliance Plan o Delivery Strategy for Asset Information	o Data drops and project deliverables o Clients Strategic Purpose o Defined BIM/Project Deliverables o BIM-specific competence assessment

COBie: Construction Operations Building information exchange defines the formats and transfer of information that is transferred during construction. COBie are delivered in the format of spreadsheets. These spreadsheets contain data related to size and coordinates of the components of BIM objects. It also contains facility management data that is about the managed assets that require maintenance and periodic inspections for their parts (Nagy, 2013).

PAS1192-2: This acts as a guide for adhering to BIM level 2 requirements. This standard contains some BIM questions related to supply chain such as suppliers and their capabilities.

These requirements are not exhaustive but they do present key requirements of the BIM Level 2 compliance (BD Online, 2014).

RIBA Plan of Work

In order to achieve the mandate of BIM Level 2, new BIM protocols were created such as PAS that was sponsored by Construction Industrial council. Professional institutions created task groups for training people through professional development practices. Royal Institute of British architects Work stages (RIBA) plan of work, which was a model already utilized for designing and construction processes added online resources for onscreen help in 2013.

RIBA work stages are defined for multiple phases of construction project including preparation, design, construction and usage in order to make the development sustainable and operational. Stage A and B are the stages of preparation and it involves setting up of project steering group for development of vision and identification of Key Performance Indicators in the stage A and study of user requirements, monitoring of performance and development of contracts in stage B.

The stage C to stage H of RIBA plan is developed for Design phase of construction projects. Development of briefs and contracts are done in stage C followed by preliminary design creation in stage D. At stage E, full design with all the components added is created and by the stage F is reached, project is ready with final production information including schedules, specifications and drawing requirements. In stage G, tender documents are prepared and performance of the project is measured against vision and the KPIs defined. At stage H, pre-tender briefing is done for stakeholders so that they can understand the project well (Carmichael, Crosby, & Dobson, 2013).

In the construction stages, that is, stage J, K and L, actions are taken according to the RIBA plan beginning with appointment of contractors to performing inspections to monitoring performance. Last phase of RIBA, that is, Stage M, is defined for the use of BIM and involves analysis of records, study of buildings using BIM and monitoring of performance of project against KPIs and vision of the organization.

BIM Projects in UK

In UK, there have been several construction projects that have used BIM and have resulted into significant savings and benefits for construction companies thereafter. For instance, Olympic Park made for Olympics Games in 2012 was able to save around £1bn from £8.1bn of final budget set by Olympic Delivery Authority (ODA). This was made possible with collaborative planning, effective procurement, and cost control and leadership skills. While planning project, supply chain was culturally aligned to the vision of ODA. The planning was done consuming 2 years of the project, which included time allotment to construction of 4 years, commissioning trails were given a year and final logistics was to be managed for 7 years (Royal Academy of Engineering, 2014).

Surrey County Council - Project Horizon was another project which made use of innovation in methodology for upgrading roads of the country with a budget of £90m as capital investment. The initial project was commissioned by Surrey Highways that faced procurement problems because of limited opportunity for value engineering but later, a new proposal was set under Project Horizon with a 5-year road maintenance program. It reduced

15% of the overall costs and identified a six-step implementation plan that could be later used for future projects as well (Royal Academy of Engineering, 2014).

Barnard Castle, County Durham: BIM was used for refurbishing of L block of the Barnard Castle drug-manufacturing site. The scope also included stripping out of old machinery, structural openings, partitioning, fire protection, and MF ceilings. The project was completed within 17 weeks (Building Projects UK, 2012)

BIM in Middle East Construction Industry

Adoption of BIM is low in Middle East countries and least efforts are taken mandate use of BIM on public construction in these areas. Companies using BIM are only using basic features like 3d Visualization and drawing extraction (Awwad & Ammoury, 2013).

A key challenge of the construction industry of Middle East whose productivity is reducing as unlike other industries that have started to use digital prototyping, construction industry still uses paper drawings and employs a significant amount of labor. The result is in the form of reduction of labor productivity. Moreover, the fatal accidents that happen with this labor are more pronounced in construction than any other industry. Some key reasons behind these mishaps are lack of organized work procedures, various types of workers requiring different expertise and lack of information (Ieiri, 2011). The market in developed countries in the construction arena is almost saturated as most projects use BIM but the demand in developing countries like those in Middle East is rising.

The infrastructure in advanced countries is already ageing and key growth drivers of construction industry are the gaps in construction of structures in developing countries like Middle East. Growth of cities in these countries that is happening due to urbanization is another key driver of construction demand in developing countries.

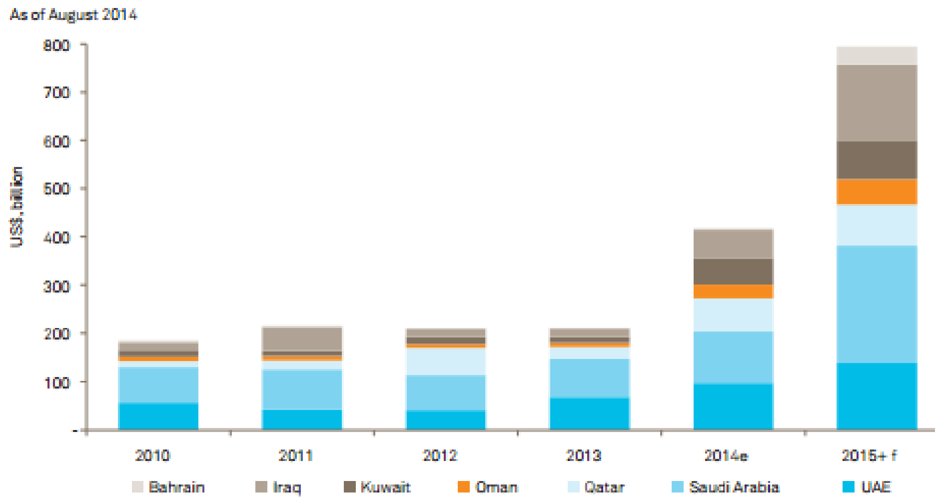


Figure 12: MIDDLE EAST PROJECT AWARDS

The flow of projects however in Middle East countries like Kuwait and Qatar remains low despite huge spending plans because of slow decision-making and frequent changes in scope. In some organizations, construction workload has increased while in others it has reduced with improvements in the industry performance. Businesses in UAE are more likely to experience improved performance as the economic growth of the region is strong and the demand in the region is emotionally boosted. For instance, in Qatar, the investments in infrastructure are increasing in response to the expectations of performance for 2020 FIFA World Cup. The demand in Saudi Arabia is majorly for transport and social infrastructure projects (AECOM, 2014).

Future of BIM

BIM till now has only been used in limited organizations but with its expansion worldwide, it is likely to shape the construction industry of future. BIM led project may see higher profits and more of other benefits using BIM. It is expected that by 2020, BIM would reach into all building codes. It would also affect the speed with which a design can be permitted and thus, construction process can move ahead. An analyzer receiving a design could connect it with codes to find if it is appropriate and then grant permission within a week or so.

NBS International BIM report of 2013 compares the actual growth of BIM with the expectations that were revealed during the 2011 survey to find the extent to which BIM expectations have been achieved. While 2011 was only the beginning for BIM; the picture changed quite significantly by 2013 and thus, delivers positive expectations even for the future. The awareness of BIM is significantly rising over these years and the trend is expected to remain in coming years and may indeed result into more pronounced levels of awareness. The number of users of BIM is also increasing as the BIM adoption has already tripled in UK from 2011 to 2013. During the surveys, BIM was seen as the future of construction. There is a clear need of shared standards seen in the world including developing countries like Middle East. The information sharing happens over a single set of information in the project lifecycle (Malleson, 2013).

Conclusions

BIM practice has several benefits as well as challenges that were discussed in the literature. It also explored different ways that BIM can be used in practice. Further, it was found that there were certain projects in UK that were successfully completed using BIM that saved the construction companies costs. However, the projects of Middle East are not being explored in much depth on the same lines. Moreover, the comparison between the project management practices using BIM in UK and Middle East project is another gap that was identified in the research.

Thus, this research would explore the UK projects to understand their best practices, methods of implementation, success factors and ways to overcome challenges. The same would be done for selected Middle East projects and then a comparison would be done between the projects in the two regions to identify performance gaps in Middle East and if they could be filled with the insights obtained from UK BIM projects.

3 METHODOLOGY

A collection of research principles and procedures that would guide this research in developing a method to collect and analyze data are covered here as a Research Methodology. This section would illustrate the selection of various methods of research; explain the methods of data collection and analysis of data. Additionally, it would briefly state the limitations and ethical issues encountered in the research.

As the research comprises of acceptance and comprehension of BIM by the individuals involved with construction sector. The research would begin with a qualitative comprehension of the various concepts via analysis of secondary data and then the insights obtained would be utilized to develop an appropriate questionnaire which would be used for gathering data required for resolving the objectives of this research from the chosen set of respondents. The procedure utilized in this research is a qualitative research.

The main idea for this research is to grasp the methods used for implementation of BIM and develop and understanding of the perspectives of users of BIM. To do this, first, the BIM and related concepts would be assessed on the basis of its utilization, fundamentals, issues, present projects, etc. The research utilizes Critical review of the Literature for exploring the BIM with allusions to the ideals that are further utilized to recognize the gaps in the present body of knowledge.

Finally, the procedures that are to be utilized for performing the research are recognized in accordance with the necessity of the research and with considerations of the constraints on the resources available to researcher. The research would involve analysis of content and in-depth interviews that would be used for examining different project scenarios examined. For the purpose of the survey, a sample size of 50 is been selection which includes in-depth interviews conducted with the BIM Project Managers who have handled BIM projects in past.

Research Techniques

The research will begin with a consequential analysis of qualitative data with regards to the content found relevant from an exploration of in the literature. The Literature Review encompasses the data on BIM related to the context, fundamental procedures, utilization, benefits, issues, requirements for implementation and acceptance in the regions studied that include UK and Middle East

After this, a set of questions would be formulated using the knowledge obtained from the analysis of secondary content in the literature so that through interviews and surveys can be conducted with BIM users and field specialists. The interview sample would contain 10 respondents who would be involved in the projects that have used BIM as the tool of project management.

This sample size of 50 for the whole study has been selected to represent a population of BIM users for qualitative and quantitative analysis, which is done to identify various themes or patterns of understanding. As after conducting a few surveys, themes might become repetitive and therefore duplication would occur if the sample were expanded further. The Rule of thumb states that a sample of 30 respondents would provide sufficient data to reach to a conclusion in the case of interviews. In this scenario, it needs to be ensured that all the themes are covered and the most commonly occurring themes are also analyzed. Therefore, a sample of 50 is selected which would justify the generalization of the representative population as it would encompass almost all possible variations in patterns and redundancy would also be avoided (Nastasi, 2014). The insights obtained during the analyzes in the literature review is being used for creating a guide for a research to be used for conducting interviews.

As the objective of this research is to understand the adoption scenario of BIM in the Middle East, all the respondents are selected from this region. To understand the BIM adoption in the UK, literature study is being used and then, a comparison follows between the two selected regions.

Content Analysis

The subject knowledge is developed using the Literature Review, which is studied for a thorough understanding of the BIM process and implementation. The analysis of content consists of a systemic identification of themes and patterns that are explored objectively and systematically.

The textual data is obtained for understanding through various methods of BIM that have explored the concept of BIM and these include journals, books and past researches on the subject. This data is analyzed to identify most relevant information required to resolve objectives of the current research such that the chosen literature findings can be integrated into the research.

Survey

When questions of a research can be answered by taking responses directly from some people or through observation, primary research may be used. As in this research, the researcher required an understanding of BIM from the perspective of experts, it required a primary research. In primary researches involving a significant number of respondents, which is true in this case, two key methods may be used for data collection including survey and observation.

As BIM is a very complicated concept and thus, observation method may not suffice for understanding of researcher, survey method could be explored to find if it is more appropriate. A very frequent procedure of collection of data within a qualitative research is survey, which involves a methodical pre-decided series of questions that can be answered by respondents in surveys.

As the researcher requires to understand general aspects of BIM in practice and requires understanding of small areas of information pertaining to BIM, a survey method would researcher to reach out to more audience to collect such a data and understanding the subject through analysis of the same.

The questionnaire prepared by the research would contain objective questions as well as an open-ended question to gain more understanding of BIM from the field experts.

Case Study

Case studies are used for developing comprehensive models of the concepts studied. Case studies explore a phenomenon in depth through observations. It is a very flexible approach and data collection methods to be used in case studies depend on the subject that is studied. Data collection can be done using observation, interviews or through the study of secondary documents. In this research, case study method is used for it provides flexibility of research design and a deep exploration of specific phenomenon for specific situation such that insights would be developed for understanding the actual practice of BIM (Fidel, 1984).

Case Study is utilized for analyzing a person or a team or a community or a company. In this research, comprehending the incorporation of BIM and the experiences of the individuals involved can be effectively understood via the case study procedure due to that fact that it chooses a number of BIM projects in the UK and Middle East that utilized BIM to find solutions of the various research objectives.

Analysis

The analysis would be done by using 'content analyses' which would include ideas and concepts presented in case studies and individual responses to interviews. As these responses would be descriptive, the analysis would involve identification categories and parameters for a thorough comprehension of the reviewers. Thus, a thematic analysis is being used which involves encoding of the responses as well as case study content and analysis of the coded data would be done. The analysis results would then be summarized using charts and graphs for illustrative representation that can enhance the reader's understanding.

The steps involved in thematic analysis of the data are:

- **Coding Framework**: A coding framework is created based on theoretical interests disclosed during the research and the textual data obtained would be dissected into segments for coding. Further, some of the segments would be coded along identified keywords that could be further used for developing more themes.

- **Identify themes**: The coded textual segments would be used for identifying various themes that would be basic, which would be further refined by identifying repetitions and scope for combinations.
- **Construct thematic networks**: This would involve arranging of the basic themes identified in previous step. Using these basic themes, organized clusters would then be created and rearranged in order to create global themes. Hierarchical or web-like network representations would be used for illustrating these global theme connections.
- **Describe and Explore networks**: The network created in previous step would be described as per the relevance to research objectives and then patterns would be identifying for finding the answers to the research questions.
- **Summary**: The data, themes and networks identified would then be presented succinctly and explicitly for the understanding of the audience of the research.
- **Interpretation**: Deductions would be made from the network summaries of themes, concepts, patterns and structures based on relevant theories discussed in literature review section (ATTRIDE-STIRLING, 2001)

The thematic analysis would be used for obtaining insights from the textual data that is obtained through the survey using the last open-ended question of the questionnaire and through the case studies. It would require identification of common patterns and themes and their analysis. Because of the resource constraints, the researcher decided to perform this process of thematic analysis manually rather than using qualitative analysis software, which was an option, considered by researcher.

Limitations

The main objective of the research is to understand the adoption process of BIM in the Middle construction projects. The research doesn't include the data or statistics on the projects that are utilizing BIM face. The case studies explore the already completed projects from UK and Middle East. Thus, new trends being followed in the industry are not covered.

Further, the sample of respondents selected is low for the whole population and therefore, the consequences can't be generalized on a larger scale, that is, for the world.

Another limitation is that the research doesn't involve exploration of all the features of BIM but only involves the ones that are presented by respondents. It doesn't involve the functional details or the infrastructural issues that might be important for understanding the components of a BIM project. Additionally, the chosen region – Middle East – has only recently accepted the BIM procedure and thus, the presence of data and people's understanding of the subject is quite limited.

Another limitation was that the case studies that were discussed used only secondary document for study and analysis and there was no primary data taken from people working on the projects discussed. Thus, the analysis was totally depending on the presentation of the cases by other researchers or experts of BIM. Thus, it can be said that the picture was only partially presented and this would mean some data, which could have been crucial for obtaining objectives of the research, was not available. Further, thematic analysis was performed over a small textual data and thus, prominent patterns were not identified in case studies.

Ethics

In a survey which is one key method used in this research, ethical standards require researcher to consider voluntary participation, maintain confidentiality and anonymity, and avoid any bias (Driscoll, 2011). Such ethical benchmarks are being strictly followed in this research as the responses are collected from the individuals such that the response data obtained is used only for analysis and the personal data that is collected is not disclosed as the names would be kept anonymous. Each response is collected only after the respondent has provided his/her written permission on its usage for the use of information for the research purpose. Further, the questionnaire used for conducting the study in case of survey is thoroughly discussed and tested with peers to ensure that it does not suffer from the researcher bias.

While performing case analysis, the researcher ensured to remain ethical as the documents used for the case studies were not copied but properly cited. Also, the data was not presented as copied but a critical analysis was performed to make interpretations based on personal research experiences (Simone, 2009).

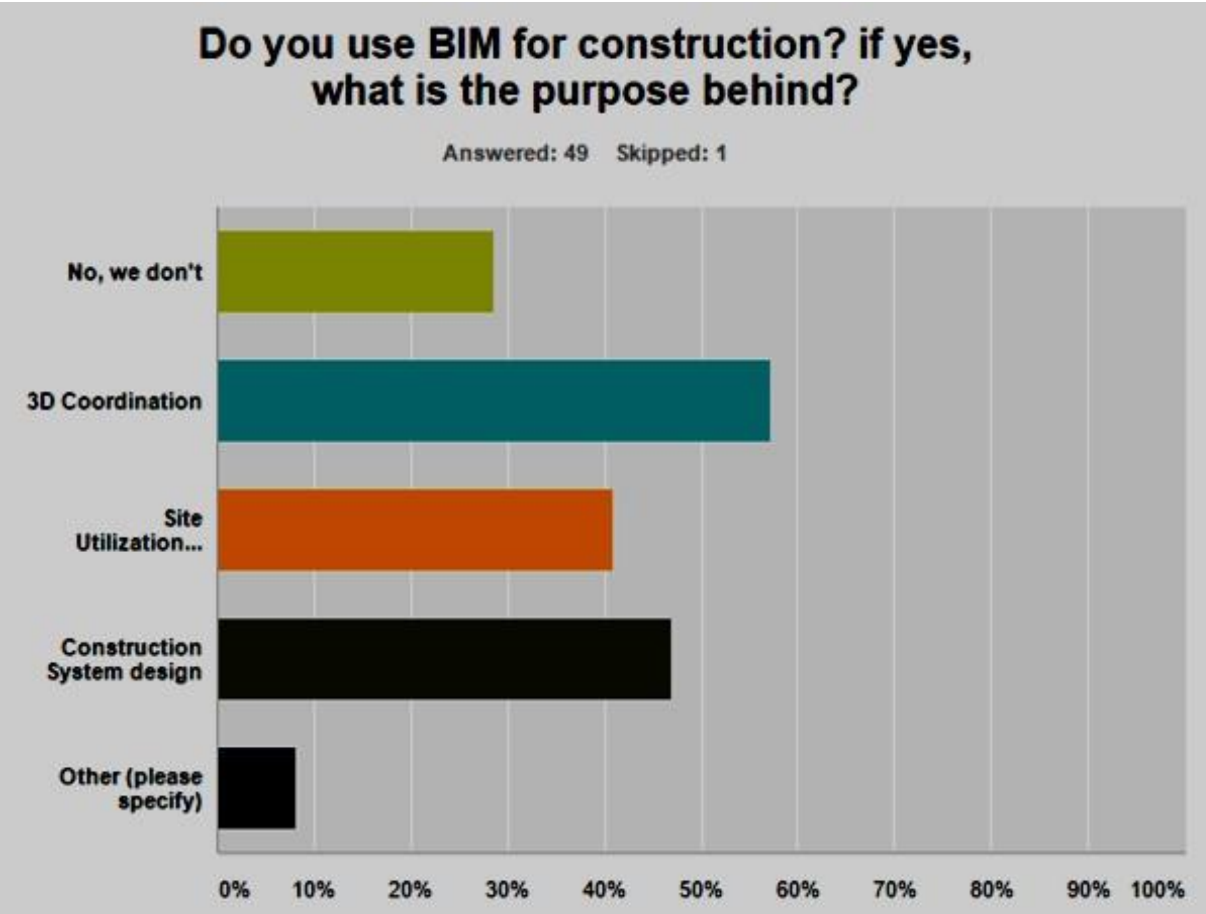
Summary

The research procedure consists of literature content analysis, which would be utilized to develop a thorough interview guide that is tested with peers before finalizing. Publicly available case studies of BIM projects from UK and Middle East are analyzed to develop cases. The data obtained from the interview and case studies is unified to create a series of questions that are utilized for conduct interviews with 50 respondents. The data collected from the survey will be further examined by utilizing thematic analysis tools and content analysis. This research also has various limitations in relation to availability of respondents, scope of research, coverage of concepts and so on.

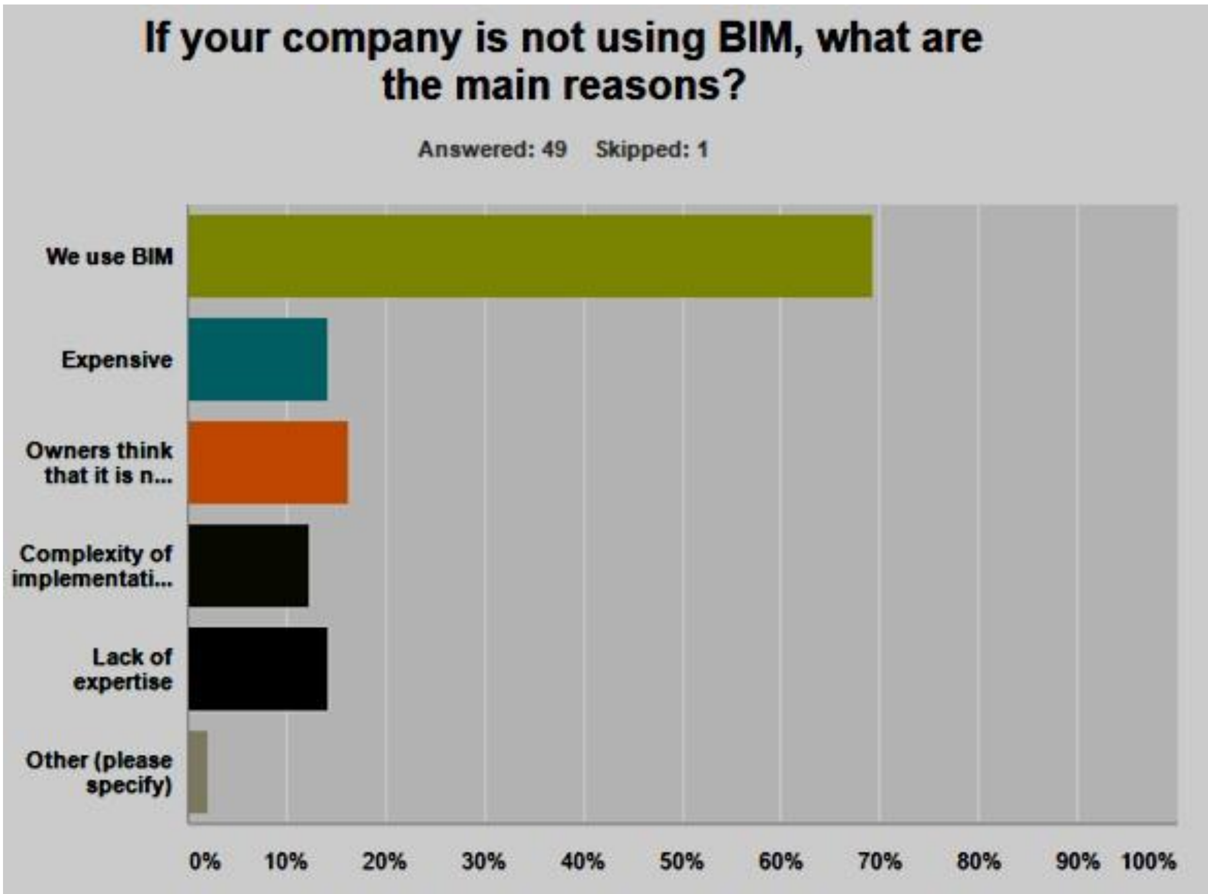
4 DATA ANALYSIS & DISCUSSION

This section explores the primary data that is collected during survey whereby critical discussion is done in order to make interpretations of results and findings. Further, a thematic analysis is performed on the qualitative data obtained both from the survey and during case analysis in the end. The section is divided into three parts. First, survey data is analyzed, three case studies from UK BIM projects and three case studies from Middle East BIM projects were discussed and lastly all the textual data of the case studies and survey were analyzed together using thematic analysis.

Survey Results

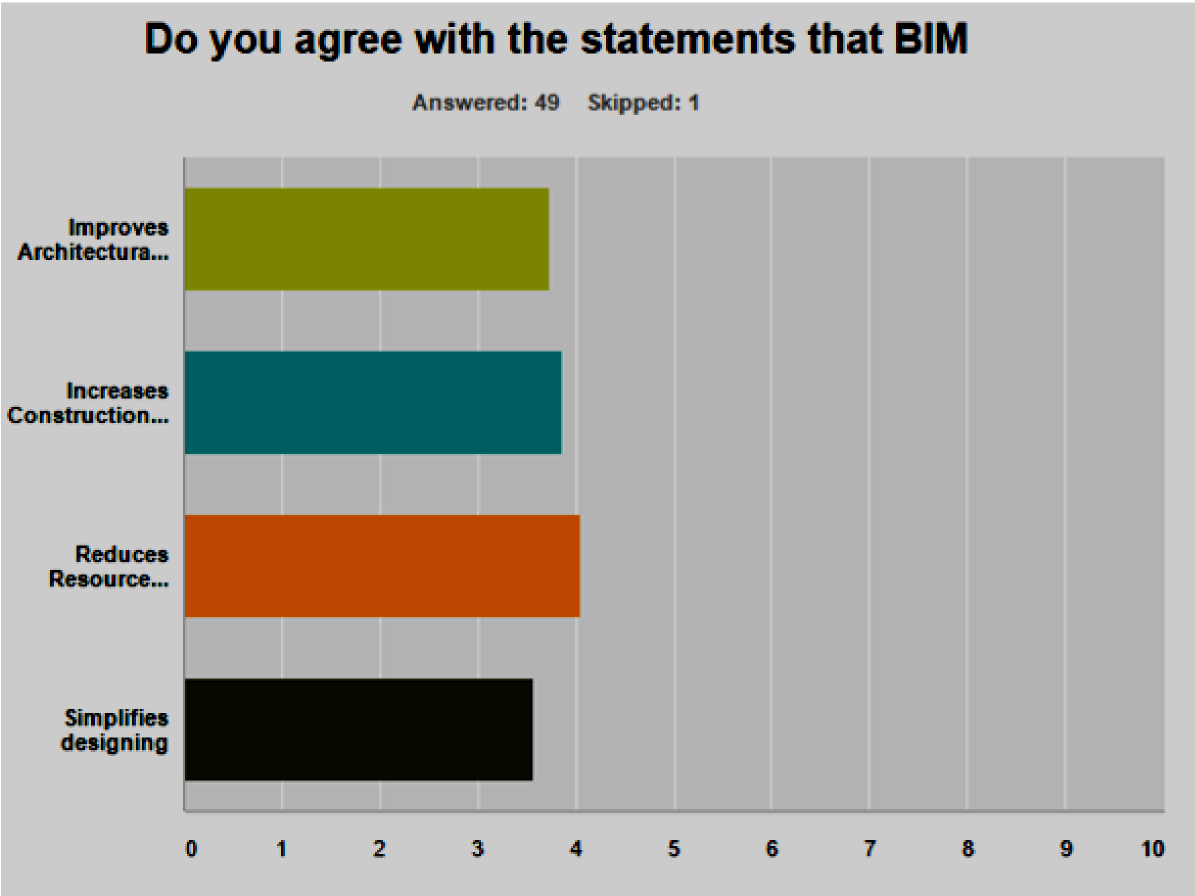


The survey was conducted using respondents from the UK and Middle East who were involved in large construction projects. Over 70% of the respondents were project managers involved in a project that was using BIM for designing stages of construction projects while about 28% did not use BIM for construction.

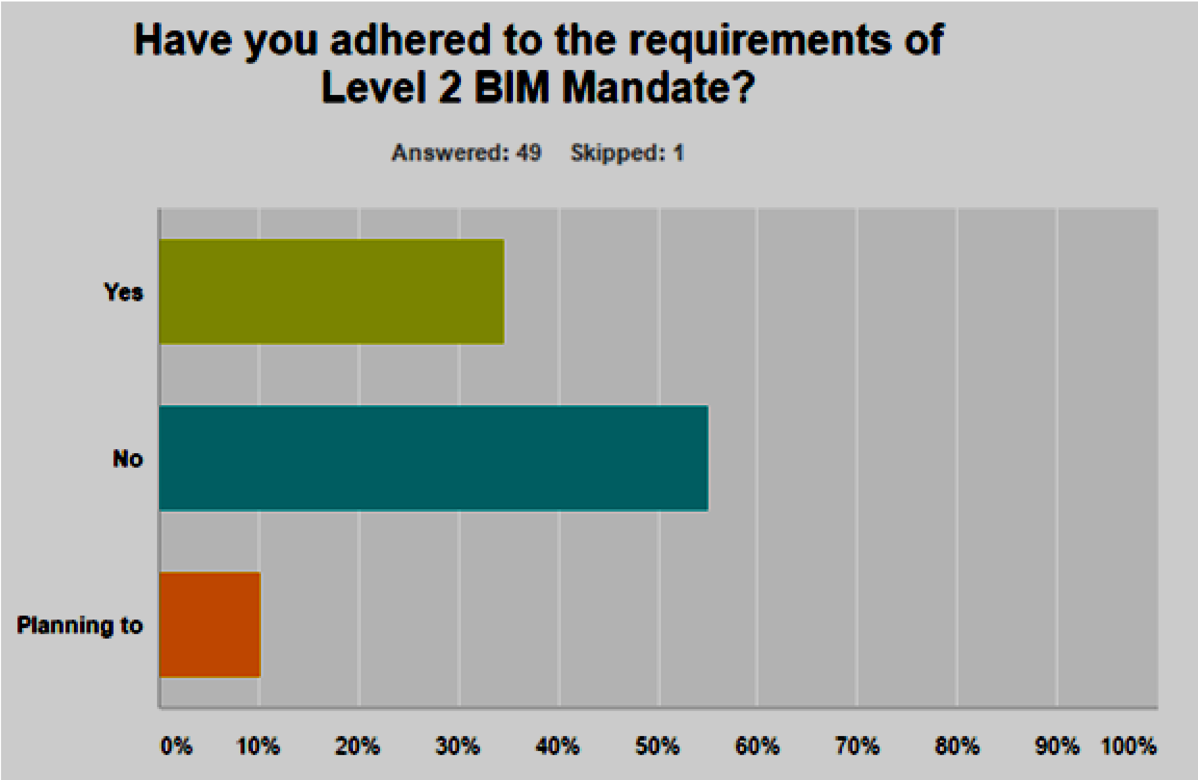


One aim of this research is to understand the reasons behind non-adoption of BIM on construction project and thus, the respondents not using BIM were further probed to find the reasons behind non-adoption. It was found that most of the project managers did not use BIM as owners did not feel it was importance. Other likely reasons including cost, complexity and lack of expertise were also considered significant.

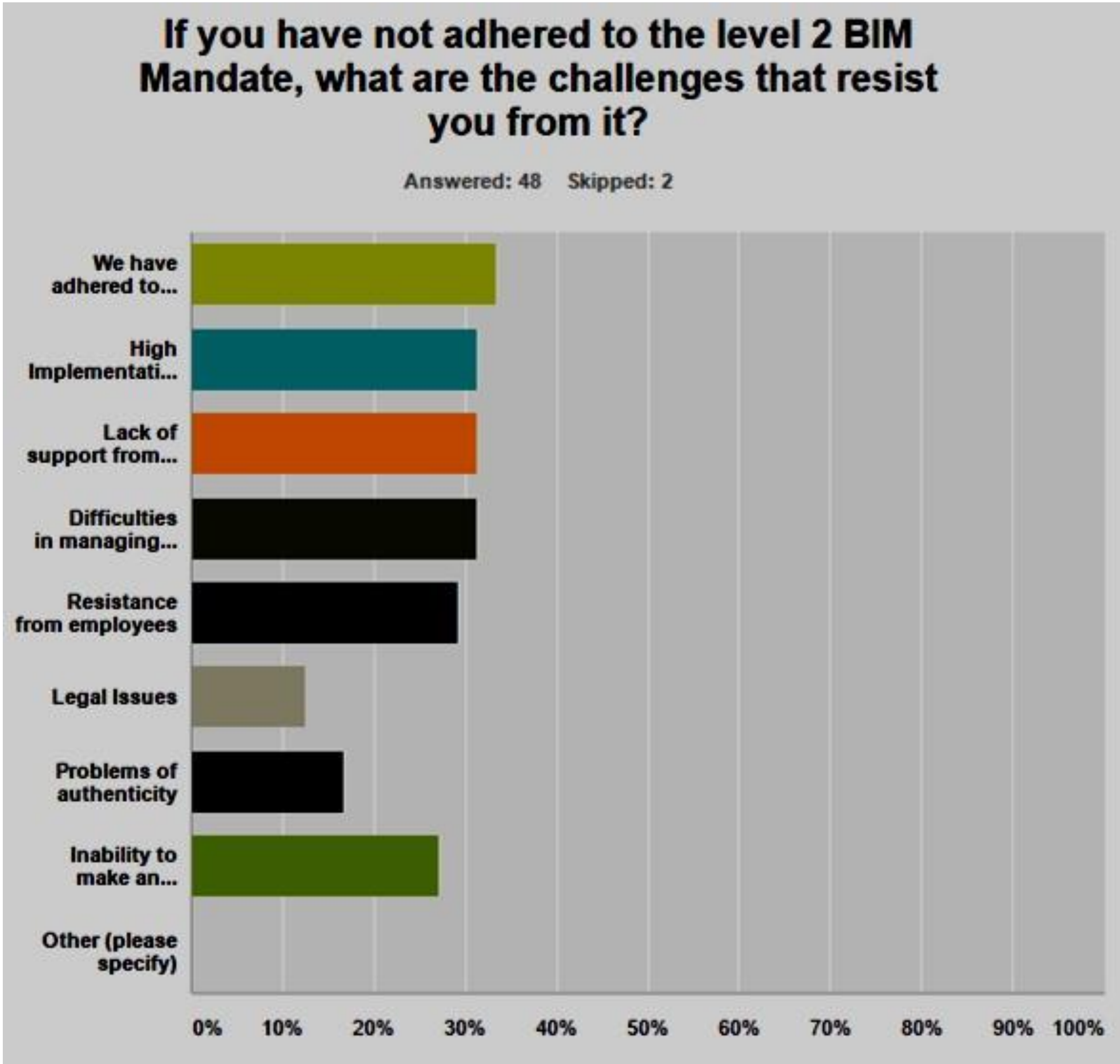
To understand the benefits of BIM in practice, the respondents using BIM were asked about the benefits they were able to derive from usage and it was found that majority of them that is 69% and 63% were able to reduce rework and conflicts. Over half of the respondents agreed on BIM's capability to detect clashes as well as improvement in construction project productivity. The responses also revealed more benefits that were not found in the literature review and these included better product quality, improved predictions on costs, error reduction and speedy deliveries.



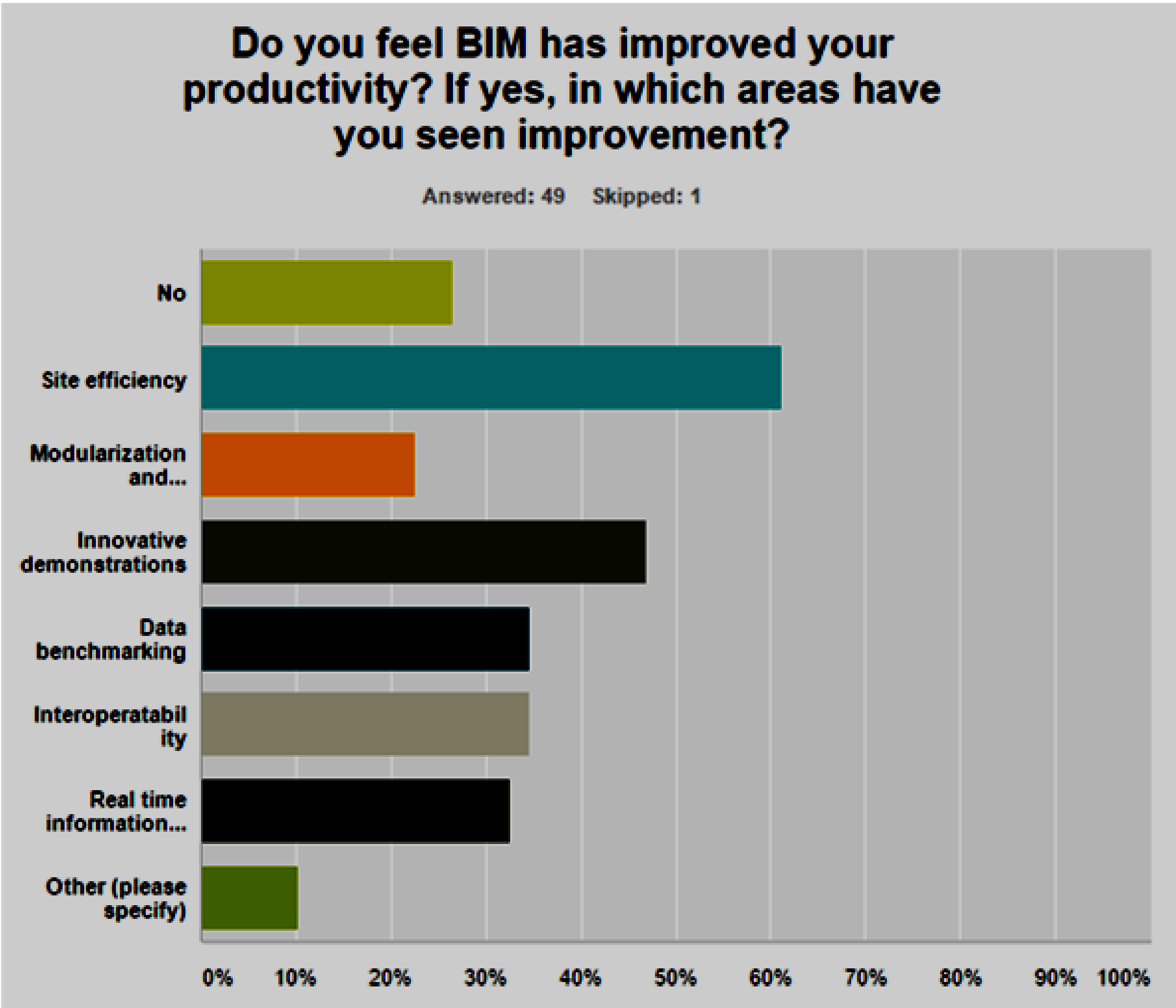
When asked about the areas of improvement which these respondents perceived as achieved through BIM irrespective of their experience, it was found that BIM was believed by majority to be able to improve architecture, construction efficiency, simplify designing and reduce wastages. Around 69% of respondents said that BIM could reduce wastage. There were very few who doubted on the potential of BIM in simplifying designing, increasing construction efficiency and improving architectural work. To understand their perspectives, the researcher explored their individual responses and found that those saying BIM did not improve productivity, simplified designing and reduced rework were actually not using BIM actively. Thus, it can be said that the companies not using BIM for construction were actually not aware about the real potential of BIM. Thus, there is a clear need to increase awareness among them.



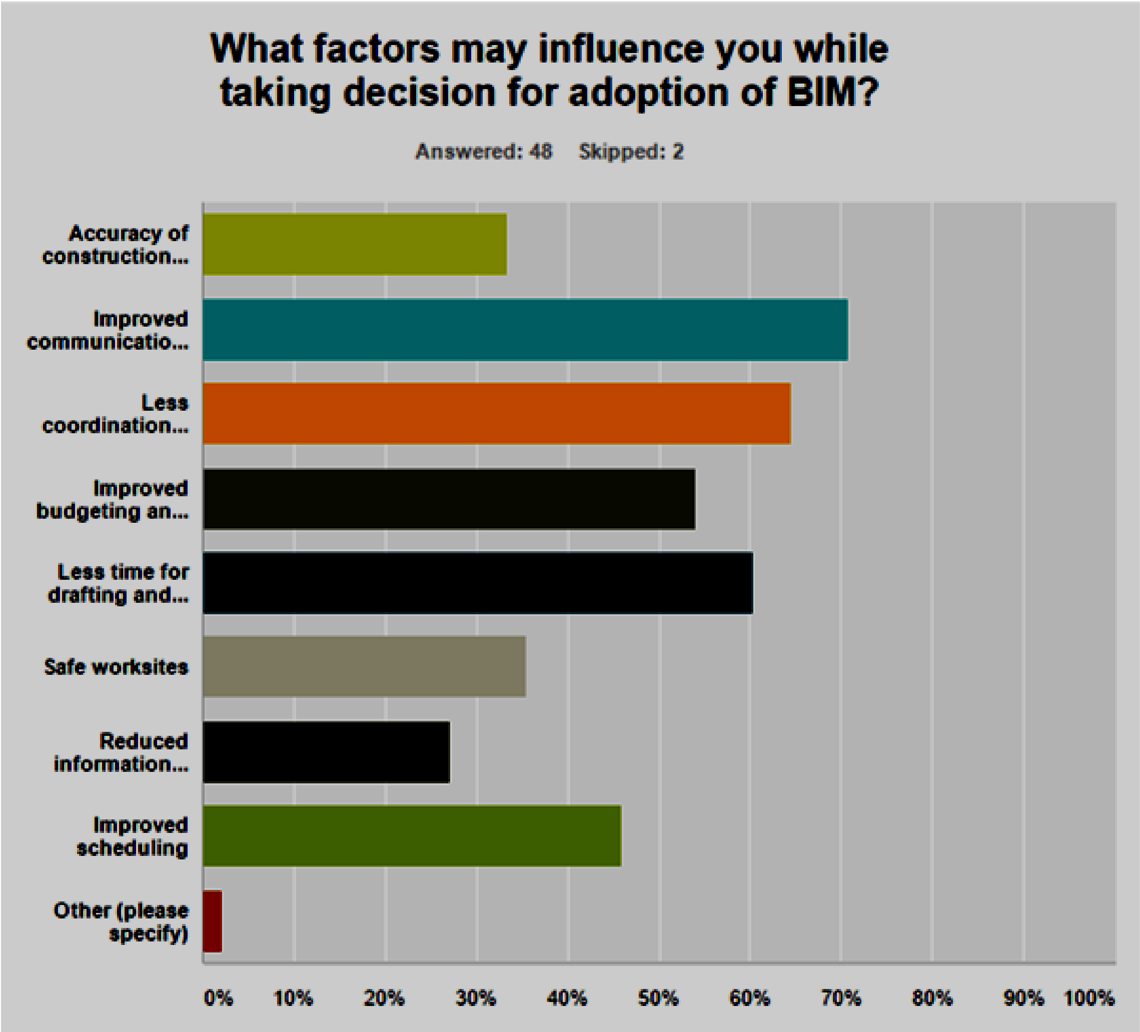
Out of total respondents who were from UK and Middle East, 70% were from UK while others were from Middle east. Out of total respondents, around 35% of respondents only said that their companies adhered to BIM Mandate for Level 2 while 10% were planning to. Out of respondents from the UK, around 45% were using BIM in some way but did not adhere to the UK BIM Mandate.



Out of the respondents who were using BIM but did not adhere to the UK Mandate, around 33% used BIM for site planning or construction system design while 66% used it for 3D Coordination. Knowing the low level of adherence UK BIM Mandate, the researcher also tried to find the underlying reasons. Several of these reasons that emerged out in the literature review were presented to the respondents as objective choices. It was found that high cost of implementation, lack of support from top management, challenges in managing changes and resistance from employees were the primary reason for companies not being able to adopt BIM level 2 practices.



The researcher further went deep down onto the benefits achieved by asking these respondents direct questions on whether use of BIM for construction was able to improve ROI and productivity. 30% of respondents were able to see over 10% of improvement in ROI while another 30% were able to either break even or achieve up to 10% ROI. Thus, it can be interpreted that BIM does have potential to achieve as well as improve ROI of construction work. Almost all respondent who used BIM agreed on its potential to improve productivity. A majority that is 61% said that it was majorly due to increased site efficiency. 47% used BIM for innovative demonstrations that helped them in business. There were some more productivity related improvements that were seen by users add these included improved quality, better deliveries, better coordination and scheduling.



Another important aspect of BIM that was to be explored in the research was understanding of reasons behind adoption such that both its reason of acceptance and non-acceptance could be understood. Over 70% of respondents were looking for improvements in communication and 65% wanted to reduce conflicts. 54% wanted improvement in budgeting practice and a higher of 60% respondents used it for speeding up the designing process.

The last question in the survey was left open ended as researcher wanted to explore the differences between UK and Middle East BIM project practices and the result was:

Table 3: Comparison

UK	Middle East
Lots of experience and expert professionals	Lack of Expertise
Use 3D Visualization	Traditional 2D CAD designs
Heavy BIM users	Light BIM users

BIM Level 2 Mandate for government	No such Mandate
Better coordination on projects	Lack of coordination because of the use of 3D drawings
Focus is on procedures, documentation, and process improvements	Focus is on improving communication and scheduling
Advanced BIM features used	Basic features used

Despite the differences, the regions in Middle East are likely to adopt efficient BIM practices for most of their construction projects in future. Use of Mandate in Middle East could play a crucial role in improving acceptance and adoption.

Case Studies

This section discussed certain cases of use of BIM on construction projects from UK and Middle East to understand the adoption of BIM, its application and the benefits achieved in practice. The case studies discussed in this section include Burj Khalifa in Dubai, Jahra hospital in Kuwait, Basrah Sports city in Iraq, Heathrow Terminal , Oratory preparatory school and Leeds Arena in UK

Burj Khalifa, Dubai in Middle East

Burj Khalifa is a skyscraper, with 828 m height with 162 floors, built using 55,000 tonnes of steel and 330,000 m3 of concrete material in 200 million work hours involving 12,000 workers. The mega-structure has broken records of tallest structures and also got an excellence award against construction of concrete pump of 601 meters (O’Dwyer, 2010).

The project needed accurate quantification of structural concrete work which involved 25 people who had to prepare 360 evaluation sheets for every building that was constructed under the project. To manage this, a quantity surveying system was created by CCC's Building Information Modelling Centre that provided automation of development of evaluation sheets. The system used MicroStation VBA and TriForma for developing various tools required for survey (Bentley Systems, Incorporated, 2013).

The project involved integration of wind engineering and dynamic shaping for taming wind effects which were the key criteria in designing. Newer techniques were required for evaluation of design for structural responses of the tower. The BIM system was used to link these structural requirements so as to analyse design. The project used Revit 3D and GSA models for creating an architectural model of the Tower. Further, real time Health Monitoring Programs were used for tracking the structural behaviour of the tower during construction and even after that (Abdelrazaq, 2012).

Dubai Mall

The Dubai Mall, which was the part of Burj development is the largest retail development of the world was built over 12 million square feet space with $1.3 billion of investments. The structure had large number of shops and other attractions such as Skating ring which was Olympic size and indoor aquarium. The key element of the structure was 600,000 meters of concrete. While managing design and performing evaluations, traditional methods were initially used that appeared overwhelming to workers as a large number of reports have to be made. There was a requirement of producing 32,000 spreadsheets every month and 1,152,000 in total. All this work was required to be done by limited staff of 25 surveyors delivering 75 man-years of work.

Thus, CCC which was managing the project IT came up with a BIM solution for automation of processes and using existing 2D models, 3D models were created. The production of spreadsheets was automated. With automation of reports, human errors were minimized as well as the total staff requirement was reduced to 15. This reduced man-hours to 700 man-months that reflected improvement of 86% in the efficiency. Moreover, the costs were also saved to the amount of $7 million and thus, BIM proved out to be profitable.

Another benefit realized from the use BIM by the construction project management was that material requirements forecasted were very accurate and thus, only the needed amount was ordered leading to reduction in wastages by 5% and saving of $3 million worth of concrete waste (Husseini, 2010).

Jahra Hospital in Kuwait

New Jahra Hospital in Kuwait was built over 720,000 m2 of space and used BIM for project management, mainly for design review and clash detection. It had used 1,200,000 elements and 16,000 tasks were performed. A 4D and 5D simulation was done during designing phase of the construction project.

Figure 13: New Jahra Hospital (Bexel Consulting, 2015)

BIM was used for the creation of a 3D model of architecture which was based on structural and MEP designs. PACE consultant was the main contractor who used BIM to keep the design always updated throughout the project. The contractor used constructability analysis as well as clash detection to find conflicts related to structure or MEP elements. BIM analysis tools that were used on the project were developed by BEXEL who provided the propriety software package for managing the construction project (Bexel Consulting, 2015).

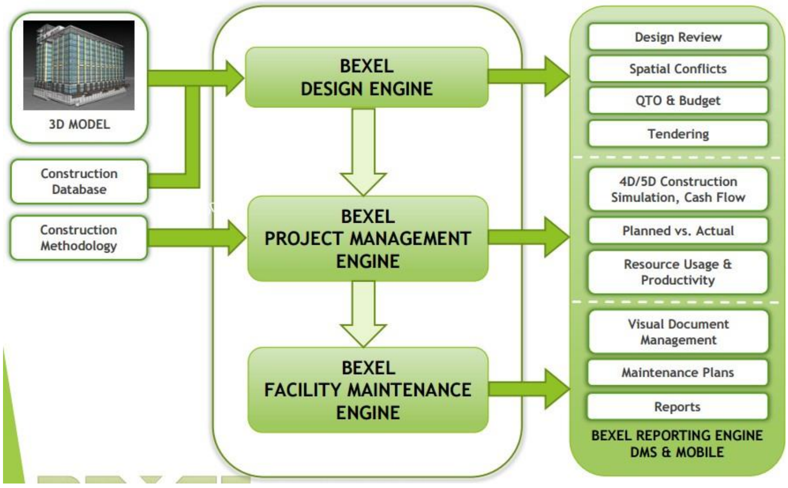
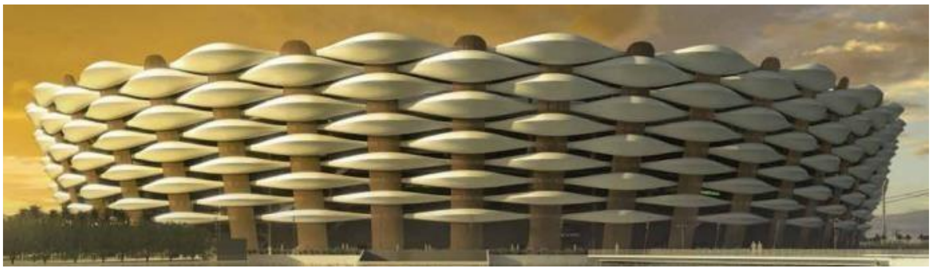


Figure 14: BEXEL Solution

BEXEL solution that was used for managing this project was built over a construction database that was used to create a 3D model of the building using specifications of the construction methodology identified. The software was used for conducting design reviews, identifying conflicts, assessing impacts of decisions on budget, tendering, simulation of the model with cash flow forecasts, resource usage and productivity analyses, document management, maintenance planning and automatic report generation as well as management (Janjić & Lesničar, 2014).

Basrah Sports City in Iraq



Basrah Sports city is a multi-purpose and mixed-use complex that was designed using BIM which help create designs for the construction of two stadiums, fire station, athlete housing and four of the training fields. Parametric modeling was used for creating the design of the skin of the structure which required understanding of curved elements. The design was optimized for the geometric variations caused by these curves which resulted in savings in the costs of fabrication. The main stadium was constructed over 232,260 m2 are and was able to occupy 65,000 seats while the secondary stadium was spread over 25,000 m2 occupying 10,000 seats (Thornton Tomasetti, 2014).

Catia model was created for the façade panels during designing and the design also considered the truck sizes that were to be used for transportation from the fabrication unit to the construction site (Zetlin, 2012).

The construction program was scheduled very tightly and construction had to be completed within 32 months. Thus, prefabricated elements of construction were used including timber beams, steel soldiers, and other support systems. BIM was used for sequencing the assembling of these elements along with other processes involved in the formwork of the project.

Heathrow's Terminal in UK

Heathrow Terminal 2B was the largest project in European countries which was completed on schedule and within budget. The success of this project could be attributed to the innovative approach and proactive collaboration (Weaver, 2010). The stakeholders of project and its delivery team collaboratively decided to construct 3D CAD models for design and construction. This BIM model was used early on the project. It was used for identification of mechanical, engineering and plumbing (MEP) elements such that prefabricated elements were procured or those were assembled offsite.

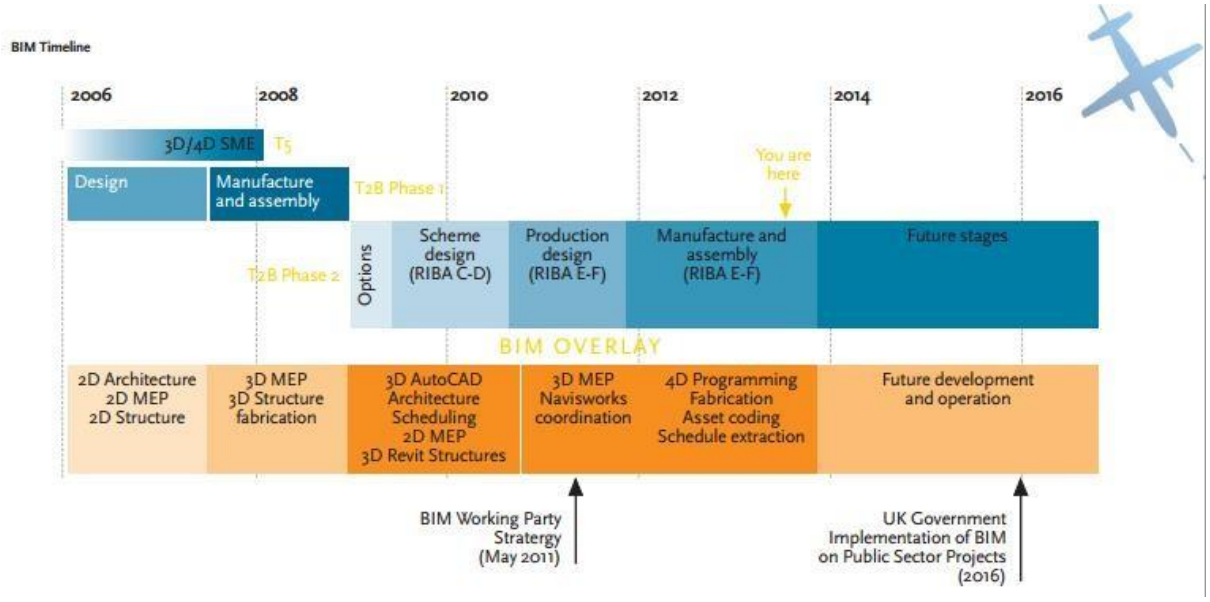


Figure 15: BIM HEATHROW TERMINAL 2B

The first phase of the project was design that started in 2005 and took one-third of total efforts. 2D Microstation was used for this phase where 3D coordination elements were used for developing 2D MEP elements. Further into the designing phase, substructures were also designed such as tracked transit system and future satellite piers. The lessons learnt during these stages were used by designers for building a coordinated level 2 BIM model of the structure for next stage of the design. A 3D model was then developed using AutoCAD Architecture 2009 by combining 2D CAD information and 3D localized information. The new model helped project team to conduct reviews of design strategies, identify constraints, bring coordination, embed intelligence into service equipments, assess transportation needs as well as schedule requirements, track design decisions, detect clashes and build prefabricated modules.

With the two case studies comparison, it can be said that the approach taken by UK management for BIM projects is much more organized, extensive and the companies uses more advanced features of the technology. While Middle East project of Burj used some basic features with clear advantages in productivity and costs, UK project was able to do more such as embedding of intelligence, scheduling, clash detection and prefabrication. It clearly suggests that there is a need for Middle East construction industry to gain more experience into BIM.

Leeds Arena, UK

Leeds Arena project was initiated in 2011 and had costed £60m by the completion that was done by 2013. The result was building of a theatre with 13,500 capacity, 4,000m2 of public space and a restaurant offering 100 seats. The design was made using steel framing for 62 tiers of seating in the amphitheater. One key requirement of the project was to create a double layered, acoustically sealed, multi-skin envelope in the form of the roof such that noise interference could be minimized. Further, there were limitations in terms of budget and time. The contractor identified the need for reduction of wastages to remain cost effective and increase in the efficiency of designing as well as construction in order to ensure that the project completed on time. Thus, the contractor decided to use BIM for the applications. The use of BIM delivered significant benefits to the company in terms of cost savings and efficiency improvements.

Cost savings: There were major cost savings achieved on the project due to clash detection that saved £97,800 with 62 clashes detected within first few weeks of construction. Due to accurate predictions of material requirements, the wastages were reduced by 8% leading to reduction in the costs.

Efficiency improvements: With close collaboration between teams, early management as well as integration of expertise on project, the design process of construction project was streamlined. This reduced wastages as well as design stage costs. As the number of stage requirements were reduced, the progress of the project was faster and thus, time was saved. As the project used 3D model for designing, the need for 9000 paper drawings that would have been needed in traditional methods was also eliminated. The efficiency was not only seen to be improved in team management and designing but also in the entire supply chain. There was a saving of 15,000 work hours within the design development process (Cash, 2014).

Oratory Preparatory School in UK: Small Project

The school building at Headmasters House was constructed by Francis construction was to be constructed for which the management decided to adopt BIM add they found the traditional methods used for managing construction projects would make their schedule hectic and would add to complexities of different kinds. After awarding the project to Francis construction which acted as information advisor, BIM teams were created to work the technical's and the design was created by a few people from the team headed by Micheal Aubrey.

In the traditional methods, the major challenge was the distraction that designers would face as they would have to also take care of margins and rates that contractors offered to make the project cost efficient for the company. Use of BIM helped the organization in automatic identification of the contractors offering most competitive rates for required material quality and thus, costs were saved. The labour rates were also identified using BIM processes which further saved manpower costs for the company. Clash detection improved the build ability and with reduced errors, the productivity of the project was improved.

Another major benefit achieved on the project with the use of BIM was high level of coordination among the team members that both simplified the work and improved its efficiency. The designs were delivered on time and 3D visualizations helped customers remain informed from the beginning of the construction project and that increased customer satisfaction. Zero defects, achievement of targets within budget early completion of project and high quality of work were the objective benefits achieved by the organization that managed designing of the project (Michael Aubrey Partnership Ltd, 2015).

Thematic Analysis

Thematic analysis is performed on the textual data taken from the response to the last question of the survey and the case studies. Thematic analysis is primarily done to make a comprehensive view of the situation. Both the primary data and secondary data are analyzed together to understand common patterns and the same are further compared with the insights obtained during literature review to understand the gaps between the literature and the actual practice of BIM in the industry.

Coding:

Initially, the tentative codes were identified by researcher after reading through the textual data obtained as responses to the last open question in the survey and these were:

lack of expertise, expert knowledge in UK, hiring experts from UK, CAD designs, 3D Visualizations, better results with experience, light BIM users, heavy BIM users, UK BIM Level 2 Mandate, BIM adoption rate, resistance to acceptance, competition, collaboration, productivity, communication, scheduling, processes, costs, learning stage, benefits, design improvements, new customers, customer satisfaction, added services, procedures, documentation, productivity, designing errors, training, challenges, design authoring, construction efficiency, engagement level, resistance, management support, project size, working style, technical work.

Further categories were identified from the textual data obtained in the case studies in this research and these were:

Megastructure, quantification of work, quantity surveying, development automation, evaluation sheets, Health Monitoring Programs, design evaluation, structural responses, architectural model, performance evaluation, design management, traditional methods overwhelming, less staff, process automation, automatic reports, less human errors, 2D models, 3D models, reduced man-hour, improved efficiency, cost saving, reduced wastages, accurate estimation of material requirements, within budget, on time, innovative approach, proactive collaboration, identification of MEP elements, prefabrication, offsite assembly, reduced efforts, tracking transit system, conduct reviews of design strategies, identify constraints, bring coordination, embed intelligence into service equipments, assess transportation needs as well as schedule requirements, track design decisions, detect clashes, embedding of intelligence, scheduling, more experience, basic features, main features.

Themes

From these initial categories, certain themes were identified by the researcher and the keywords were further categorized accordingly.

Table 4: Thematic Analysis

Key Theme	Keywords
Challenges	Lack of expertise, resistance to acceptance, training needs, change in working style, high cost, management support, hiring experts from UK

Adoption Rate High Low	Resistance: Lack of management support, technical work requirement
	Overwhelming work in traditional methods, proactive collaboration, bring coordination, UK BIM Level 2 Mandate, procedures, documentation, productivity, quantification of work, Health Monitoring Programs, development automation, productivity
Application	3D Visualizations, performance evaluation, architectural model, design authoring, construction efficiency, engagement level, quantity surveying, design evaluation, scheduling, light BIM users, heavy BIM users, 2D CAD designs, identification of MEP elements, prefabrication, offsite assembly, track design decisions, detect clashes, embedding of intelligence, scheduling, reviews of design strategies, identify constraints, embed intelligence into service equipments, assess transportation needs, schedule requirements, tracking transit system, structural responses, performance evaluation, design management
Benefits	Design improvements, new customers, customer satisfaction, added services, reduced designing errors, process automation, automatic reports, reduced man-hour, improved efficiency, cost saving, reduced wastages, accurate estimation of material requirements, within budget, on

	time, innovative approach, better results with experience

The next step in a thematic analysis is counting of keywords in each of the identified themes to find the most prominent categories such that interpretations could be made on the effect of each theme. However, the researcher chose to skip this step and rather considered all identified themes equally important. This was done because the textual data which was used for analysis was limited and thus, sufficient number of occurrences cannot be found and thus, identification of patterns would have been difficult. Thus, the researcher chose to explore the identified themes qualitatively to make interpretations rather than using statistical counts.

Analysis

The result of the analysis of the thematic data as per the understanding of the researcher considering the literature review and personal learning from the subject at hand, is presented below categorized into key themes identified:

Challenges: The researcher found that most of the instances where companies were facing challenges in adopting BIM processes in middle east, lack of expertise was the key issue. Other than this, companies also faced resistance from employees, top management and stakeholders which making changes primarily due to the fact that BIM adoption required a major change in the working style of an organization. Training requirements was another challenge as there was a lack of expertise in the Middle East region and thus, most companies ended up hiring BIM experts from UK. This further increased the costs for companies in addition to the expenses incurred in the implementation of BIM.

Adoption Rate: The adoption rate of BIM is lower in Middle East countries mainly due to the lack of management support in organization and the requirement of performing a lot of technical work which the existing staff of companies was not equipped for. The adoption rate for BIM in construction projects of UK was higher due to several reasons. First, the BIM Level 2 mandate issued by the UK government was a key driver to adoption by the public sector projects. Another reason that was identified as a driver for adoption was the overwhelming work that was required to be done when using traditional methods of managing construction projects. The use of BIM is believed to be simply and minimize the hard work. Further, there were some more reasons of adoption that were identified by the researcher and the most prominent of these were need for efficient collaboration to bring coordination, quantification of work and improvements in productivity. Other reasons organized procedures, simplified documentation, Health Monitoring, and automation of developmental processes.

Applications: The researcher explored this theme to understand how the BIM was being used in the industry in practice. The research found there were variety of applications that BIM was used for by the construction industry. The key reason why it was used by organizations in UK was for performing 3D Visualizations and creating architectural models. Middle East companies on the other side were light users of BIM and mostly used 2D CAD designs and basic features of BIM. Advanced use of features and applications in different areas was seen in the UK projects and these included performance evaluation, architectural model, design authoring, bring more engagement, quantity surveying, design evaluation, scheduling, identification of MEP elements for prefabrication and offsite assembly, track design decisions, detect clashes, embed intelligence in the information and service equipments of the system, conducting reviews of design strategies, identifying constraints, assess transportation needs, tracking transit system, evaluate structural responses, and design management.

Benefits: This theme of the research was very crucial to understand the actual benefits that are achieved by BIM projects. In the literature review, it was already found that BIM was promoted because of a lots of benefits they have for construction projects. However, the real situation and performance of BIM could only be judged when finding the actual benefits achieved by the companies using BIM. In the thematic analysis, the researcher identified certain benefits that are not ranked here but only presented by researcher with equal importance given to them. The researcher does not comment on the level of importance that could be attached to specific benefits as it was out of the scope of this research. The researcher however could identify key benefits of BIM those were actually experienced by BIM users working in different organizations. These included design improvements, acquisition of new customers, customer satisfaction, added services, reduced designing errors, process automation, automatic reports, reduced man-hour, improved efficiency, cost saving, reduced wastages, accurate estimation of material requirements, within budget, on time, innovative approach, better results with experience.

A critical analysis of these benefits based on the literature studied may be required here so that the key reasons behind these benefits could be understood and thus, the researcher decided to critically analyse this specific theme for discussion. The aim is to understand how these benefits may be achieved in practice

Design Improvements: The improvements in design may be achieved due to embedding of intelligence into the system, 3D visualization which would simplify understanding and evaluation data that would help designer make assessments about the impacts of design on the project such that changes could be made in design for improvement.

New Customer acquisition: As BIM was capable of adding intelligence into service equipments, new services could be offered and thus, organizations can attract new customers.

Customer satisfaction: Additional features offered by BIM can add to the satisfaction of existing clients as well. For instance, use of 3D visualizations while giving presentations to clients can help a sales person make the potential client understand the design better and thus, make decisions fast.

Improve efficiency: With embedded intelligence that allowed real-time information retrieval, reduction in staff requirement as well as man-hours leading to reduction in costs, reduction in human errors and improved prediction capabilities, the efficiency of projects must be improved with the use of BIM.

Cost Saving: As organizations were able to reduce manpower costs and reduce wastages in materials, there was a clear saving seen in costs on projects. Wastages could be reduced due to more accurate prediction of material requirements that lead to limited ordering of only the required material so that the unused material did not stay at the site for longer or get wasted.

5 CONCLUSIONS AND RECOMMENDATIONS

This dissertation was aimed at understanding how BIM worked in practice using the cases of UK and Middle East. The objective was to compare how the BIM is being used in the selected two regions such that researcher could understand the factors behind success and failure, factors influencing adoption of BIM in construction industry, benefits received from the use of BIM and challenges faced by organizations while adopting it.

First objective was to understand BIM, its implementation and associated challenges and thus, the paper began with a discussion on the concepts of BIM that included descriptions of four levels of BIM starting from Level 0 to Level 3. Further, the implementations, benefits and uses of BIM in construction were explored. The information obtained while the literature review was used to identify factors and create a questionnaire for a primary survey which was one key method used in this research. The primary survey helped researcher achieve understanding of use of BIM in UK and Middle East as well as compare the two that were intended to be explored in this research.

Another method used in this research to explore the subject and achieve the objectives of the paper was case study method. The study also aimed to understand the practice of BIM in UK to identify best practices which was not only discussed in the literature review briefly but also, UK projects were chosen for discussion in case studies. Moreover, as the objective of this research also included understanding of BIM potential in Middle east, case studies of construction projects that used BIM during designing from UK and Middle East regions were considered to understand the actual use of BIM and the benefits in practice.

The survey results revealed some important insights. Main reason behind non-adoption of BIM for construction project was that owners did not feel it was needed. Also, other major reasons included cost, complexity and lack of expertise. Key benefits of BIM included reductions in rework and conflicts. Respondents of the survey also agreed on the BIM's capability to detect clashes and increase productivity. Other benefits that were experienced by the on projects included better product quality, improved predictions on costs, error reduction and speedy deliveries.

BIM was found to be improving architecture, construction efficiency, designing and reduce wastages. However, some of them who were not using BIM actively in construction were mostly unaware of the potential of BIM. There were several of respondents who worked on BIM projects that did not adhere to the BIM level 2 mandate mainly because of high cost of implementation, lack of support from top management, challenges in managing changes and resistance from employees.

Selection of BIM as a tool to managing construction project was primarily done on the basis of several criteria including improvements in communication, reduction in conflicts, improvement in budgeting practice and for speeding up the designing process

The objective of this study included understanding of BIM usage in practice through discussion of real case studies which was achieved by consideration of some projects that were constructed using BIM as a tool for project management. The study majorly revealed that BIM was actually capable of improving ROI, detect clashes, improve construction efficiency and reduce wastes which was found in the survey and was confirmed from the case studies. In terms of productivity, improvements were seen in quality, deliveries, coordination and scheduling.

It was found that there was a clear difference between practices that are used for BIM in UK and Middle east such as use of 2D modeling in Middle East projects and 2D coordination in UK projects. In Middle projects, most managers focused on improving communication and scheduling while in the UK focus was more on procedures, documentation, and process improvements.

Despite the differences, some big projects in Middle East actually used level 2 of BIM for construction designing and one such case that was studied in the research was the case of Burj Khalifa. With the use of BIM, most of the processing work was automated and there was also a reduction in man-hour utilization that converted into huge savings. Improvements were reflected by significant increase of 86% in productivity and in profits because of cost savings of $7 million.

The other project was chosen from UK such that comparison could be done between the practices of Middle East and UK. Heathrow Airport terminal was the case discussed as it used BIM in its design and construction. The project went through different design phases that suggested that their approach was more coordinated, organized and advanced as compared to BIM projects of Middle East. It was found that Middle East projects used basic features and benefits of BIM while UK was able to make use of the technologies in several areas.

Further, a thematic analysis was performed on the qualitative data obtained from the open-ended question of the survey and from case studies. Several key themes were identified by the researcher that included challenges of BIM adoption, adoption rate, benefits achieved, and applications of BIM in practice. It was found that BIM had limited applications on projects in Middle east by there were advanced features used for more applications in UK BIM projects such as design authoring, Health Monitoring. identification of MEP elements, embedded intelligence and so on. Further, the benefits achieved from the use of BIM were critically analysed by researcher and it was found that the benefits that were discussed in literature for BIM were actually achieved by companies using BIM in practice. Major benefits of BIM include design improvements, improvement in efficiency, increased chances of customer acquisition, customer satisfaction, cost saving and improved efficiency.

In the literature review, the key reason of adoption of BIM was found to be communication and the main benefits realized were better coordination and improved productivity. However, with this research, new insights were added as new applications, reasons of adoption and benefits were identified. This research would help BIM software solution companies identify needs of their clients as well as help organizations understand the benefits they could achieve from adopting BIM so that they can take decisions about the adoption as well as on the BIIM level that they should be using.

The research suggests that there have been adoption plans made by UK government and related associations to support the adoption of BIM by companies in different ways such as the Digital Built Britain strategy, BIM level 2 Mandate, and RIBA plan of Action 2013. Presence of these programs has helped the construction sector of UK gain a global edge and the government also plans to expand their reach and establish leadership globally. This would be specifically beneficial to countries that lack BIM experts such as those in Middle East. However, it would also add to the cost of construction.

In the future, it is expected that more and more organizations would start adopting BIM for their construction projects and thus, to remain competitive, Middle east organizations also have to adopt to BIM which already has several operations and performance benefits. In the long run, the expertise can be established through training and practice of the use of BIM in Middle East countries for which organizations in these countries have to involve actively in adopting and using BIM.

6 REFERENCES

Naya, F., Jorge, J. A., Conesa, J., Contero, M., & Gomis, J. M. (2002). *Direct Modeling: from Sketches to 3D Models* . SmartSketches.

MacLeamy, P. (2009). *Industrial strategy: government and industry in partnership - Building Information Modelling.* HM Government.

Cable, R. H. (2014). *Digital Built Britain: Level 3 Building Information Modelling - Strategic Plan.* UCL.

Sebastian, D. R. (2011). *Basic Principles of Building Information Modelling.* TNO.

Autodesk, Inc. (2002). *Autodesk Building Industry Solutions* . USA: Autodesk, Inc.

AEC(UK). (2012). *AEC (UK) BIM Protocol : Implementing UK BIM Standards for the Architectural, Engineering and* . Revit and Bentley.

Sinclair, D. (2012). *BIM Overlay.* Royal Institute of British Architect. London: RIBA Publishing.

Kreider, R., Messner, J., & Dubler, C. (2010). Determining the Frequency and Impact of Applying BIM for Different Purposes on Building Projects. *International Conference on Innovation in Architecture, Engineering and Construction (AEC).* Pennsylvania: Penn State University.

Strafaci, A. (2008, 10). *What does BIM mean for civil engineers?* Retrieved 3 3, 2014 from CE News: http://www.cenews.com/article/6098/what_does_bim_mean_for_civil_engineers_

Thorpe, D. (2013, 11 8). *Massive Civil Engineering Projects Worldwide: BIM Comes of Age*. Retrieved 3 3, 2014 from Sustain Ablecities Collective: http://sustainablecitiescollective.com/david-thorpe/195591/taking-over-world-massive-civil-engineering-projects-bim-comes-age

Studio4 Consultants Pvt. Ltd. (2013). *Characteristics and Benefits of BIM*. Retrieved 3 25, 2014 from http://studio4.in/v1/knowledge-base/bim/characteristics

ULTra Globe PRT. (2011). *world's first and largest urban PRT system is announced;* . Retrieved 4 4, 2014 from http://www.ultraglobalprt.com/wheres-it-used/amritsar-india/

Khosrowshahi, F. (2012). *SUPPLY CHAIN INTEGRATION & BIM.* UK: Leeds Met University.

Rashidi, A., & Rashidi, A. (2010). *Central Park Tower Project* . Denver: Weitz Company.

MagiCAD. (2013). *Helsinki Music Centre sounds better with BIM.* Retrieved 5 3, 2014 from http://www.magicad.com/sites/default/files/files/PDF%20case/Musiikkitalo_case_A4_ENG.pdf

Tarantola, A. (2012). *Revit Implementation*. Retrieved 5 3, 2014 from http://reviteer.blogspot.in/

Chan, C. (2011, 12 15). Gensler's Chris Chan on the Sustainable Shanghai Tower, Asia's Tallest Skyscraper.

Portland Sustainability Institute . (2012). *The EcoDistricts™ Framework Building Blocks of Sustainable Cities.*

Hicks, J. (2010). *BIM to the Rescue: Creating Sustainable Buildings*. Retrieved 5 3, 2014 from http://www.triplepundit.com/2010/05/bim-building-information-modeling/?doing_wp_cron=1399096690.5528628826141357421875

New Zealand Government. (2008). *Integrated Whole Building Design Guidelines.* Wellington: eCubed Building Workshop Ltd.

Sullivan, C. (2013). The future of construction: Meet BIM (or else). *Smart Planet* (17).

Qian, A. Y. (2011). *BENEFITS AND ROI OF BIM FOR MULTI-DISCIPLINARY* . Singapore: National University of Singapore.

BIS. (2010). *ESTIMATING THE AMOUNT OF CO2 EMISSIONS THAT THE CONSTRUCTION INDUSTRY CAN INFLUENCE.* London: Crown.

Ko, J. (2010). *Carbon: Reducing the footprint of the construction process.* UK: strategic Forum for construction and the carbon trust.

arkitektur, A. (2012). *NORWAY'S GREEN BIM NINJA COMBATS CARBON FOOTPRINTS*. Retrieved 2014 йил 11-5 from http://www.betechdata.com/case-studies-single/article/norways-green-bim-ninja-combats-carbon-footprints.html

Stubbs, B. (2013). *SUSTAINABILITY AND BIM*. Retrieved 2014 йил 11-5 from http://www.fgould.com/uk-europe/articles/sustainability-and-bim/

Mactavish, A., Iqbal, N., & Marsh, D. (2013). Resource efficiency through BIM: A Guide for BIM Managers. *WRAP* (1).

Levy, F. (2012). *BIM in Small-Scale Sustainable Design.* Canada: John Wiley & Sons.

Pearson, A. (2013). Case Study: Bushbury Hill Primary School. *CIBSE Journal* .

Bagot, W. (2011). *Case Study Melbourne Convention Center Development*. Retrieved 2014 йил 15-5 from http://greensource.construction.com/green_building_projects/2011/1102_Melbourne_Convention.asp

Hänninen, R. (2011). First Annual Conference in the Middle East Building Information Modeling (BIM) Vision, Strategy and Implementation . Finland: Abu Dhabi Men's College.

Morrin, N. (2010). *Carbon Footprinting in Construction - examples from Finland, Norway, Sweden, UK and US.* SKANSKA.

Bronswijk, J. E., & Maas, G. J. (2012). Joint conference of the 8th World Conference of the International Society for Gerontechnology (ISG) and 29th International Symposium on Automation and Robotics in the Construction (ISARC). Eindhoven, The Netherlands: Drukkerij SNEP.

Barlish, K. (2011). *How To Measure the Benefits of BIM.* ARIZONA STATE UNIVERSITY.

Moon, H. S., Kim, H. S., Kang, L. S., & Kim, C. H. (2013). *BIM functions for optimized construction management in civil engineering.* Jinju, Korea: Gyeongsang National University.

Ovlisen, M. (2011). *Guidelines for sustainable supply chain management.* The Danish Council.

Autodesk, Inc. (2005). *BIM for Sustainable Development.* USA: Autodesk Revit.

Kim, H., Moon, H., Choi, G., Kim, C., & Kang, L. (2013). Development and Application of BIM System for Construction Project by Project Phase- Focusing on Bridge Project. *Journal of Korea Institute of Construction Engineering and Management,Development and Application of BIM , 13* (2), pp. 11-24.

Nastasi, B. (2014). *Qualitative Research: Sampling & Sample Size Considerations.*

Kim, H., Moon, H., Choi, G., Kim, C., & Kang, L. (201213). Development and Application of BIM System for Construction Project by Project Phase- Focusing on Bridge Project. *Journal of Korea Institute of Construction Engineering and Management,Development and Application of BIM , 13* (2), pp. 11-24.

Fehrenbacher, J. (2011). *How Building Information Modeling (BIM) Helps Buildings Go Green*. Retrieved 2014 йил 30-June from http://inhabitat.com/building-information-modeling/

Autodesk. (2011). *Building Information Modelling for Sustainable Design .*

ATTRIDE-STIRLING, J. (2001). *Thematic networks: an analytic tool for qualitative research.* Sage Publications.

Philp, D. (2015). *BIM: The UK Government Strategy.* UK Government Strategy Task Group.

Cable, R. H. (2015). *Digital Built Britain: Level 3 Building Information Modelling - Strategic Plan.* HM Government.

Ventures Middle East LLC. (2012). *New Technologies Utilized in the GCC Market.* DMG.

Aouad, G., Wu, S., & Lee, A. (2006). nDimensional Modeling Technology: Past, Present, and Future. *Journal of Computing in Civil Engineering* , 151-153.

Tizani, W. (2010). *A driver for change. Proceedings of the International Conference on Computing in Civil and Building Engineering.* University of Nottingham.

Jung, Y., & Joo, M. (2011). *Building information modelling (BIM) framework for practical implementation, Automation in Construction.*

Eadie, R., Odeyinka, H., Browne, M., McKeown, C., & Yohanis, M. (2014). Building Information Modelling Adoption: An Analysis of the Barriers to Implementation. *Journal of Engineering and Architecture* , 77-101.

Arayici, Y. C., Koskela, L. K., Usher, C., & K., O. (2011). *Technology adoption in the BIM implementation for lean architectural practice, Automation in Construction.*

Oluwole, A. (2011). A preliminary review on the legal implications of BIM and model ownership, Journal of Information Technology in Construction. *IT Conference* , 687-696.

Defining High Performance Buildings for Operations and Maintenance. (2010). *International Journal of Facility Management* , 1-16.

Race, S. (2012). *BIM Demystified.* London: RIBA Publishing.

Christensen, S., McNamara, J., & O'Shea, K. (2007). Legal and contracting issues in electronic project administration in the construction industry. *Structural Survey* , 191 - 203.

Harty, C., Throssell, D., Jeffery, H., & Stagg, M. (2008). *Implementing building information modeling: a case study of the Barts and the London Hospitals.* UK: Nottingham University Press.

Royal Academy of Engineering. (2014). *Public projects and procurement in the UK: sharing experience and changing practice.* Royal Academy of Engineering.

Weaver, P. (2010). *THE EFFECTIVE MANAGEMENT OF TIME ON MEGA PROJECTS* . Mosaic Project Services Pty Ltd .

O'Dwyer, P. (2010). Burj Khalifa opens in Dubai. *GHDNews* , p. 133.

Bentley Systems, Incorporated. (2013). *THE BUILDING PROJECT SHOWCASE.* Exton, PA: Bentley Systems.

Abdelrazaq, A. (2012). Validating the Structural Behavior and Response of Burj Khalifa: Synopsis of the Full-Scale Structural Health Monitoring Programs. *International Journal of High-Rise Buildings* , 37-51.

Husseini, N. (2010 йил June). CCC uses Building Information Modelling for the Dubai Mall Project. *Bulletin* .

Philp, D. (2012). *First Steps to BIM Competence: A Guide for Specialist Contractors.* Newcastle upon Tyne: SEC Group.

Sinclair, D. (2012). *BIM Overlay to the RIBA Outline Plan of Work.* London: Royal Institute of British Architects.

Building and Construction Authority. (2013). *BIM Essential Guide For BIM Execution Plan.* Building and Construction Authority.

The Computer Integrated Construction Research Group. (2010). *Project Execution Planning Guide.* Pennsylvania State university.

Ngo, M. H. (2012). The Computer Integrated Construction Research Group Strategy BIM deadline and applications to civil engineering education. *Civil and Environmental Engineering Student Conference* (pp. 1-6). London: Imperial College London .

Hornsby, S., & Allan, J. (2012). *The BIM Revolution.* London: IBM.

Driscoll, D. L. (2011). Introduction to Primary Research: Observations, Surveys and Interviews. In D. L. Driscoll, *Writing Spaces: Readings on Writing* (pp. 153-174). Library of Congress.

Michael Aubrey Partnership Ltd. (2015). *BIM Case Study, The Oratory Preparatory School*. From mapl.co.uk: http://www.mapl.co.uk/projects/bimcasestudy/

Cash, G. (2014). *BIM (Building Information Modelling) utilisation to achieve resource efficiency in construction: Leeds Arena.* WRAP.

Bexel Consulting. (2015). *New Jahra Hospital / Medical Complex*. From BEXEL Consulting: http://www.bexelconsulting.com/ProjectGalleria.aspx?Project=newjahrahospital

Janjić, V., & Lesničar, R. (2014). *BUILDING INFORMATION MODELING – A BUSINESS APPROACH.* BEXEL Consulting.

Thornton Tomasetti. (2014). *Thornton Tomasetti – Middle East.* Thornton Tomasetti.

Zetlin, L. (2012). *Building Skin: Innovative, Integrated Exteriors.* Thornton Tomasetti .

Chang, S.-Y., & Al, S. K. (2013). *Advances in Civil Engineering and Building Materials.* CRC Press.

Fidel, R. (1984). *The Case study method: A case study.* Seattle, WA: University of Washington.

Simone, H. (2009). *WHOSE DATA ARE THEY? ETHICS IN CASE STUDY RESEARCH.* Sage Publications.

Das, J., Lee, P., Kiat, T. C., Leng, L. E., Yang, G. K., How, H. Y., et al. (2011). BIM your way to higher productivity. *Build Smart* , pp. 1-16.

Bedrick, J. (2013). *The Model Development Specification (MDS)* . AEC Process Engineering .

Halvorson, C. (2008). *BIM RECOMMENDATIONS JOHN WAYNE AIRPORT IMPROVEMENT PROGRAM* . ARCADIS.

BD Online. (2014 йил 6-June). *CPD 14 2014: BIM - collaboration and the common data environment*. From bdonline.co.uk: http://www.bdonline.co.uk/cpd-14-2014-bim-collaboration-and-the-common-data-environment/5068904.article

Consortium of Local Authorities Wales. (2015). *The CLAW All Wales BIM Toolkit: Employers Information Requirements* . CLAW .

Nagy, L. (2013 йил 4-August). *to COBie or not to COBie*. From Practical BIM: http://practicalbim.blogspot.in/2013/08/to-cobie-or-not-to-cobie.html

Building Projects UK. (2012). *Pharmaceutical Case Study: GlaxoSmithKline.* Building Projects.

Awwad, *., & Ammoury, M. (2013). *SURVEYING BIM IN THE LEBANESE CONSTRUCTION INDUSTRY.* Byblos, Lebanon: Lebanese American University .

Ieiri, R. (2011). *3D Systems For a Safer and More Productive Construction Site.* Japan Productivity Center.

Cautons. (2015 йил July). Digital Built Britain: The Verdict. *BIMUK* .

AECOM. (2014). *Middle East Handbook.* AECOM.

Storer, D. (2012 йил December). *Six Dimensional Building Information Modeling*. From J K High Construction: http://www.hjhigh.com/news-and-media/market-trends/six-dimensional-building-information-modeling/

The Foundation of Wall and Ceiling Industry. (2009). *Building Information Modeling:Understanding and Operating in a New Paradigm.* The Foundation of Wall and Ceiling Industry.

Arayici, Y., Khosrowshahi, F., Ponting, A. M., & Mihindu, S. (2009). Towards Implementation of Building Information Modelling in the Construction Industry. *Fifth International Conference on Construction in the 21st Century (CITC-V)* (pp. 1-10). Istanbul, Turkey: University of Salford.

Sebastian, R. (2010). The Basic principles of BIM. *Proceedings of CIB World Congress* (pp. 1-7). Salford Quays.

Thomassen, M. (2011). *BIM & Collaboration in the AEC Industry.* Aalborg University.

Berlo, L. v., Bomhof, F., & Korpershoek, G. (2014). *Creating the Dutch National BIM Levels of Development.* Netherlands organisation for applied scientific research.

HUNGU, C. F. (2013). *Utilization of BIM from Early Design Stage to facilitate efficient FM Operations.* Göteborg, Sweden : CHALMERS UNIVERSITY OF TECHNOLOGY .

Rancane, A. (2014). *BIM IMPLEMENTATION IN EARLY DESIGN STAGE.* Aarhus, Denmark: VIA University College.

Malleson, A. (2013). *NBS International BIM Report* . NBS International.

Blackwell, D. B. (2012). *Industrial strategy: government and industry in partnership.* HM Government.

Carmichael, L., Crosby, M., & Dobson, A. (2013). *Delivering Construction 2025 RIBA Action Plan.* Construction Industry Council.

7 Appendices

Questionnaire:

Introduction:

This questionnaire is aimed to understand the application of BIM in the construction work. The target audience include the project management professionals who have worked on the BIM projects for construction work or are planning to get BIM. The questions included are designed based on the literature review that suggests lower level of BIM adoption in the Middle East as compared to UK. Thus, this research attempt to understand this difference in adoption for which questions asking about the challenges of adoption are included in this questionnaire.

1. Do you use BIM for construction? if yes, what is the purpose behind?

- *3D Coordination*
- *Site Utilization Planning*
- *Construction System design*
- *Other (Please Specify)*

2. If your company is not using BIM, what are the main reasons?

- *Find it expensive*
- *Owners think that it is not needed*
- *Complexity of implementation and usage*
- *Lack of expertise*

3. What are the benefits of using BIM in construction industry?

- *Regular business from existing clients*
- *Marketing to get new clients*
- *Offer new services*
- *Positive ROI*
- *Reduce rework*
- *Reduction in conflicts and changes*
- *Clash detection*
- *Improved productivity*

4. Do you agree that BIM

- *Improves Architectural work: A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Agree*
- *Increases Construction Efficiency: A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Agree*
- *Improves Carbon Emissions: A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Agree*
- *Reduces Resource Wastages: A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Agree*

5. Have you adhered to the requirements of Level 2 BIM Mandate? If yes, what all activities have you done for that?

6. If you have not adhered to the level 2 BIM Mandate, what are the challenges that you are facing?

- *High Implementation cost*
- *Lack of support from top management*
- *Difficulties in managing change*
- *Resistance from employees*
- *Legal Issues*
- *Problems of authenticity*
- *inability to make an accurate prediction of liabilities*
- *Others (Please specify)*

7. Do you feel BIM has improved your ROI? If yes, then to what extent?

- *No*
- *Breakeven*
- *Below 10%*
- *10-25%*
- *25-50%*
- *50-100%*
- *Over 100%*

8. Do you feel BIM has improved your productivity? If yes, in which areas have you seen improvement?

- *Jobsite efficiency*
- *Modularization and pre-fabrication*
- *Innovative demonstrations*
- *Data benchmarking*
- *Interoperability*
- *Real time information availability to allow better decision-making*
- *Others (Please specify)*

9. What factors may influence you while taking decision for adoption of BIM?

- *Accuracy of construction documents*
- *Improved communication between project parties*
- *Less coordination problems*
- *Improved budgeting and cost estimation*
- *Less time for drafting and more time for designing*
- *Safe worksites*
- *Reduced information requests*
- *Improved scheduling*

10. Do you feel there is a difference in BIM practices used in UK and in Middle East, if yes, please explain

Consent Letter for Respondents

Dear____:

Aim of Study:

This research is being carried out by_______(Student name)__________, a student of the _______(Subject) ____ at the_________(College/University name) to understand BIM Trends in UK and Middle East. This research contains information on the applications of BIM, its benefits, implementation challenges and trends. The results of the analysis done on the data obtained from survey respondents would be published on_(Date)____

Survey Description:

Your contribution to this research through the survey is deeply appreciated. Your participation in this research project is crucial and it would significantly affect results. The survey enclosed here focuses on applications of BIM, it's usage trends and scope in UK and Middle East for construction of sustainable buildings, and it will take around half an hour for answering one set of questions.

Maintaining confidentiality:

When you give your response to the questionnaire, it would be considered as your consent for the use of data for research. However, our personal details will remain confidential and would not be disclosed to anyone. It would only be used for the purpose of understanding demographics and for performing analysis.

Benefits of the study.

The participation in this survey would help you explore BIM and its applications in construction. The construction society would specifically be benefited as the results could be used for understanding BIM applications and its best practices. The results of the study *would be shared with the respondents so that they can take the benefit out of them for their own organization.*

Contact information*.*

For any queries, researcher can be reached at:

Name of Researcher:

Name of Supervisor:

College/University:

Address:

Telephone Numbers:

Email Addresses:

This survey is created considering ethical standards that are approved by ______________________________

I am keenly looking forward to your participation in the study.

Sincerely,

Transcripts

Respondent 1:

Q1: Do you use BIM for construction? if yes, what is the purpose behind?
No, we don't
Q2: If your company is not using BIM, what are the main reasons?
Owners think that it is not needed
Complexity of implementation and usage
Lack of expertise
Q3: What are the benefits of using BIM in construction industry?
Reduction in conflicts and changes
Clash detection
Q4: Do you agree with the statements that BIM
Improves Architectural work ***Neither agree not disagree***
Increases Construction Efficiency ***Neither agree not disagree***
Reduces Resource Wastages ***Neither agree not disagree***
Q5: Have you adhered to the requirements of Level 2 BIM Mandate?
No
Q6: If you have not adhered to the level 2 BIM Mandate, what are the challenges that resist you from it?
Inability to make an accurate prediction of liabilities
Lack of support from top management
Q7: Do you feel BIM has improved your ROI? If yes, then to what extent?
Not Applicable
Q8: Do you feel BIM has improved your productivity? If yes, in which areas have you seen improvement?
No
Q9: What factors may influence you while taking decision for adoption of BIM?
Safe worksites
Less time for drafting and more time for designing
Improved budgeting and cost estimation
Less coordination problems
Improved communication between project parties
Q10: Do you feel there is a difference in BIM practices used in UK and in Middle East, if yes, please explain.
Middle east do not have the required expertise and it has to depend on regions like UK for ht supply of experiential knowledge

Respondent 2

Q1: Do you use BIM for construction? if yes, what is the purpose behind?
3D Coordination
Construction System design
Q2: If your company is not using BIM, what are the main reasons?
We use BIM
Q3: What are the benefits of using BIM in construction industry?
Reduce rework
Reduction in conflicts and changes
Clash detection

Improved productivity

Q4: Do you agree with the statements that BIM

Improves Architectural work Strongly Agree

Increases Construction Efficiency Agree

Reduces Resource Wastages Agree

Simplifies designing Strongly Agree

Q5: Have you adhered to the requirements of Level 2 BIM Mandate?

No

Q6: If you have not adhered to the level 2 BIM Mandate, what are the challenges that resist you from it?

Inability to make an accurate prediction of liabilities

Difficulties in managing change

Q7: Do you feel BIM has improved your ROI? If yes, then to what extent?

No

Q8: Do you feel BIM has improved your productivity? If yes, in which areas have you seen improvement?

Innovative demonstrations

Q9: What factors may influence you while taking decision for adoption of BIM?

Improved budgeting and cost estimation

Improved communication between project parties

Q10: Do you feel there is a difference in BIM practices used in UK and in Middle East, if yes, please explain.

BIM projects in Middle East are still using traditional CAD designs while UK have moved to 3D visualizations

Respondent 3

Q1: Do you use BIM for construction? if yes, what is the purpose behind?

3D Coordination

Q2: If your company is not using BIM, what are the main reasons?

We use BIM

Q3: What are the benefits of using BIM in construction industry?

Reduce rework

Reduction in conflicts and changes

Clash detection

Q4: Do you agree with the statements that BIM

Improves Architectural work Agree

Increases Construction Efficiency Neither agree not disagree

Reduces Resource Wastages Neither agree not disagree

Simplifies designing Agree

Q5: Have you adhered to the requirements of Level 2 BIM Mandate?

No

Q6: If you have not adhered to the level 2 BIM Mandate, what are the challenges that resist you from it?

Difficulties in managing change

Q7: Do you feel BIM has improved your ROI? If yes, then to what extent?

No

Q8: Do you feel BIM has improved your productivity? If yes, in which areas have you seen improvement?

Innovative demonstrations
Q9: What factors may influence you while taking decision for adoption of BIM?
Accuracy of construction documents
Q10: Do you feel there is a difference in BIM practices used in UK and in Middle East, if yes, please explain.
Middle East projects face lack of expertise while UK engineers have more experience and are thus able to produce better results