ADAPTATION OF BIM WORKFLOW IN STRUCTURAL ENGINEERING PROJECTS & THE NEED TO ESTABLISH A NATIONAL BIM STANDARD

تحسين تطبيق نمذجة معلومات المباني في المشاريع الإنشائية والحاجه لتأسيس كود عالمي لها.

by

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ABSTRACT

The Introduction of the concept of BIM into the construction industry, have made significant changes to the working standards and workflow pattern. This thesis examines the said changes in comparison to the traditional working methods in all phases of project starting from pre-concept to demolition with respect to the structural engineering discipline. Case studies are done to check the typical workflow in a BIM environment for structural design. Thus analysing the skills required and deliverables that are to be produced in BIM working environment for optimum workflow. The BIM implementation strategies and the rate of BIM adaptation in 5 selected countries including UAE are analysed. The relation between national BIM standards and the rate of BIM implementation in the respective countries are also evaluated. The current BIM awareness in the UAE is also analysed by a market survey conducted among industry experts in the UAE, focusing on the obstacles for the implementation of a national BIM strategy.

The adaptation of the BIM into the structural engineering workflow has shown many improvements in comparison to the traditional workflow such as software interoperability, ease of production of schedules and drawings, 3D representation of reinforcement and other technical data, etc. National mandates and standards in relation to BIM have shown to increase the rate of BIM adaption in respective countries and also achieve a sense of regularity in the construction industry and authority standards. From the market survey conducted, the professionals have expressed the need for similar BIM standardisation in the UAE and also the current obstacles for the same.

Keywords: BIM in Structural Engineering, National BIM Standards, BIM in UAE

نبذة مختصرة

لقد أدخل مفهوم BIM في صناعة البناء تغييرات كبيرة على معايير العمل ونمط سير العمل. تبحث هذه الرسالة التغييرات المذكورة مقارنة بأساليب العمل التقليدية في جميع مراحل المشروع بدءًا من التصميم الاولي إلى الهدم فيما يتعلق بقسم الهندسه الانشائية. هذه الرسالة تبحث سير العمل النموذجي في بيئة BIM في الهندسة الانشائية. وبالتالي تحليل المهارات المطلوبة والتسليمات التي سيتم إنتاجها في بيئة عمل BIM من أجل سير العمل الأمثل. يتم تحليل استراتيجيات تنفيذ BIM ومعدل التكيف BIM في 5 دول مختارة بما في ذلك الإمارات العربية المتحدة. كما يتم تقييم العلاقة بين معايير BIM الوطنية ومعدل تنفيذ BIM في البلدان المعنية. يتم أيضًا تحليل الوعي بـ BIM الحالي في الإمارات العربية المتحدة من خلال دراسة استقصائية للسوق أجريت بين خبراء الصناعة في الإمارات العربية المتحدة ، مع التركيز على العقبات التي تحول دون تنفيذ استراتيجية BIM الوطنية.

أظهر تطبيق BIM في الهندسة الانشائية العديد من التحسينات مقارنة بسير العمل التقليدي مثل ترابط البرمجيات ، وسهولة إنتاج الجداول والرسومات ، والتمثيل ثلاثي الأبعاد للتعزيز والبيانات الفنية الأخرى ، وما إلى ذلك. الحاجه العالميه لتطبيق معاير BIM أظهرت زيادة معدل التكيف في البلدان المعنية ، وكذلك تحقيق شعور بالانتظام في صناعة البناء والمعاير المستخدمه على مستوى الجهات المعنيه . من مسح السوق الذي تم إجراؤه ، أعرب المحترفون عن الحاجة إلى توحيد معايير BIM في دولة الإمارات العربية المتحدة وأيضًا العقبات الحالية أمامه.

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Tony Thomas Thampy

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SYMBOLS

AEC – Architecture Engineering Construction

BCA – Building and Construction Authority

BIM – Building Information Modelling

BOQ –Bill of Quantities

BS – British Standard

CAD – Computer Aided Design

COBie – Construction Operations Building Information Exchange

CWM – Construction Waste Management

FEM – Finite Element Method

f_{ck} – Characteristic Compressive Strength

f_y – Yield Strength

IFC – International Foundation Class

ISO – International Organization for Standardization

LOD – Level of Development

LL – Live Load

NBS – National Building Specifications

RSA – Robot Structural Analysis

SDL – Simply Disturbed Load

CHAPTER -1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Architectural / Engineering documentation has been an essential part in the conversion of a design into built structures. The traditional documentation process that existed till 1980s involved the technical skill of a tracer or draughtsman to represent the design as hand drawn lines and hatches. The amount of information on each drawing varied and coordination of drawings even inside discipline have been found to be difficult. The man hours spent for documentation process was found to be more in comparison to the modern documentation methods.

Manual drafting slowly started declining towards the end of 1980s with introduction of computer aided design into construction market. Beginning of 1990s saw a huge revolution in the construction industry with the wide scale implementation of computer aided design into design firms across the globe. By 1994, Autodesk have already made steps to make the designs 3D compatible. Though earliest versions of BIM can be dated back to 1982 by the development of ArchiCAD software, it was only by 2000s that a real inclination towards BIM implementation had started in the construction market.

Autodesk developed software Autodesk Revit mainly contributed to this shift in construction industry. Survey results showed an increase from 28% to 71% in BIM implementation among contractors in North America from the year 2007 to 2012.

Change is sweeping the globe. Project teams are benefitting from faster communications, smaller, more powerful and mobile computers, robust digital modelling tools and a transformative shift toward integrated delivery processes, all of which are generating positive outcomes, efficiencies and benefits unimaginable just a few years ago" (Jones A S,2014).

Building Information Modelling (BIM) can be broadly classified as a model-based design process which involves the integration of all construction based information into a 3D model. With the introduction of BIM into the project work flow, all the building based information and central model can be shared as a single data base for all the disciplines. This will ensure proper co-ordination in between the disciplines from start to finish of a project. In other words, clash detection, resolving of design issues, preparation of BOQs and Quantity surveyor checks can be done is more accurate scale in comparison to the traditional 2D based information system. BIM have been instrumental in the cost/ time reduction in projects from concept to construction stage in a project life cycle.

BIM has provided a platform for visual co-ordination in between the disciplines such as Architecture, Structure and MEP with accurate building information. This can ensure lot of design based clashes / problems to be sorted before the actual construction phase commences. Any change of design elements or equipment in any particular discipline model will be notified to all other linked discipline models. On the current internet based cloud interfaces, different design companies working in different parts of the world can co-ordinate their design models more accurately using the BIM platform.

The application of BIM is not just limited to Building Design / Construction projects. Projects that have relatively lesser margin for error and coordination issues such as Infrastructure projects, Water/ Irrigation Projects, Transport Engineering projects, Special constructions (Airport / Metro rail / Harbours) etc, have huge applications & usage of the BIM workflow. The cost and impact of these kind of projects establishes the benefits of BIM. Clash detection and design issues being sorted before actual construction takes place on site will ensure time and cost reduction. The adaptation of BIM workflow on site will ensure the proper the documentation of any design changes made on site. Hence a proper information model containing all the 'As – Built' data can be stored into client or authority archive library, for future reference, design changes or extensions of the project.

1.2 CONTEXT ISSUES

The scope and applications of BIM workflow is still more or less ambiguous in nature for most of design / construction professionals. This is mainly because of the absence of set guidelines or codes for BIM applications. As the case is with any given discipline, structural engineering has also been highly influenced by the introduction of BIM. There have been new established BIM approaches that have shown to increase the efficiency of the project workflow from concept to demolition. But due to the absence of a universal BIM standards or mandates, there has been information gap in between the disciplines and thereby not achieving the full benefits and possibilities of adaptation of BIM into the project workflow.

1.3 RESEARCH QUESTIONS AND OBJECTIVES

This thesis paper aims at compiling the best BIM practices available currently in relation to structural engineering. The paper looks at the relation between developing national BIM standards / guidelines and the BIM implementation success percentage in selected countries. The need for establishing national BIM standards and guidelines in the UAE and also the current challenges are reviewed in the project.

The main research questions are as follows:

- What are the best practices that exist for the BIM workflow in Structural Engineering?
- What is the current status of BIM implementation strategies in different parts of the world and the relation between the national BIM standards?
- What are the challenges and Possibilities of adaptation of BIM implementation strategy and relative national BIM standards in the UAE?

In order to answer the above research questions and support the aim of the research, the analysis will be structured to achieve certain objectives that will enable the confirmation of the research hypotheses which will be proposed later on. The research objectives are the following:

- Determine the best theoretical BIM workflow through consultation from the BIM experts and analysis of the written articles on the said topic along with case study conducted.
- Determining the aspects of BIM implementation strategies through review of BIM standards and guides in the selected countries and achieving a comparative study between UAE and them.

- Determining the current status of BIM awareness in UAE and recognising the challenges for a similar approach in UAE.

1.4 RECOGNISED CLASSIFICATIONS OF BIM

In order to get a more accurate grasp of BIM definitions and classifications that are widely used across the world, the following divisions can be made use of

1.4.1 MODES OF BIM

Contrary to popular belief, BIM is not just limited to the knowledge or expertise of certain software. It is actually a work flow that is in-cooperated into a project life cycle that will ensure better efficiency and all together better performance. With the inclusion of BIM into the project cycle, certain modes and stages comes into existence. The term "Level of Development" or LOD is a common terminology that determines the current stage of the information model in respect to the design stage. The common LODs and their specific design and information level for a typical new project are listed below:

- LOD 100

It can be defined as the concept stage of design. The model is primarily generic in nature and serves as graphic representations of elements with approximate representation of size and orient.

- LOD 200

Initial quantities, size, shape, orientation and non-graphical information are defined for elements inside the model. This stage corresponds to the schematic or design development phase. Coordination models are set up initially by providing space allocation for specific design elements.

- LOD 300

The proper documentation stage starts from here. The Model can be used for costing & biding for contractors for each disciple design elements. The production of shop drawings and construction documents happens in this stage. Accurate measurements and specifications of design elements will be available in this stage. The Detailed design and Tender phase of the project life cycle takes place in this stage.

- LOD 350

The clash detection in between coordination models takes place in this stage. The design issues and clashes in between multiple disciplines such as architecture, structure, MEP etc can be detected using clash detection software.

- LOD 400

After the design model is handed over to the contractor by the client / design team, the contractor sets up the model for the specific and detailed construction details and documents. The fabrication, installation and detailing information is set up by the contractor according to the design and specifications.

The work sequencing, production & checking of shop drawings, etc. happens during this stage. The main contractor can further divide the model among sub-contractors for specific information and tendering.

- LOD 500

After the completion of construction on site, a final model is made by the contractor or the surveyor with ‘As built’ data regarding the geometry and locations of construction elements. This model is instrumental for the facilities management team of the building/ project for future maintenance and operations related problems. Proper updating of the model after any change is made on the construction elements will ensure correct information being referred to in case of any future demolition or extension of the project.

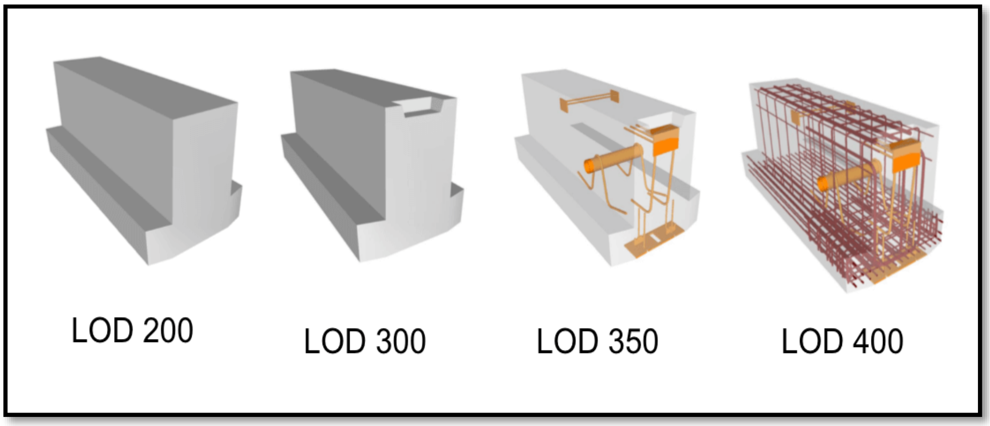

Figure 1.1 LOD Representation of a Concrete Girder

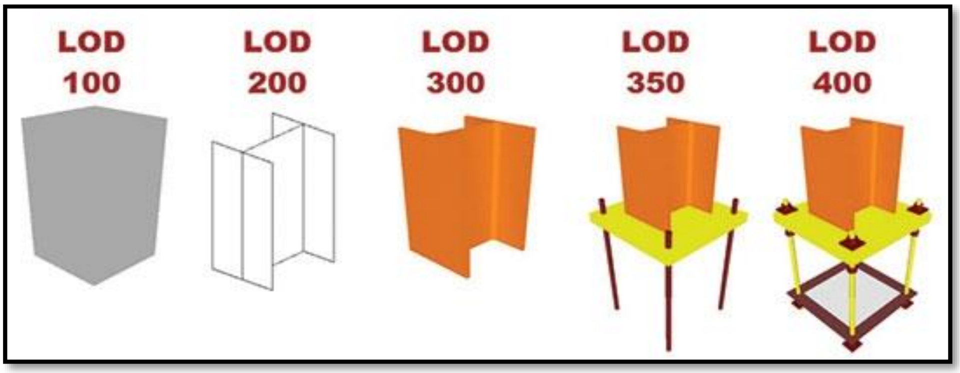

Figure 1.2 LOD Representation of a Steel Column

1.4.2 DIMENSIONS OF BIM

BIM has paved the way for representation of construction information in a 3D model form. But the application of BIM does not limit itself to mere 3D visual model. The different dimension of BIM gives a clear idea on the practical uses of BIM.

- 3D BIM

The primary use of BIM is the production of a shared information model with both graphical and non-graphical information. The model is populated with project data & details according to the LOD level, till the model is handed over to the client.

- 4D BIM

The sequencing of the construction process using BIM can be termed under 4 Dimensional BIM. The sequential development of the project using the project information model is visualised and proper data is extracted. The time allocation of a particular process in a project will be constrained to the normal or practical time required to finish the said process along with the relation to the associated work processes. Logical and efficient sequencing of project work will ensure timely and cost effective completion of construction. The visual representation of the construction cycle will ascertain the early coordination before commencement of actual work on site. Project planning engineers can provide solutions and recommendations in very early stage of the project and hence efficiency is increased.

- 5D BIM

Cost applications of project components can be described under 5 Dimensional BIM. The cost information of a component from purchasing/ installing to replacement can be extracted from a BIM model. This extraction of data is purely based on cost information associated with the components of the model. The overall cost is calculated with this process.

Any change in components or design as a whole will be updated in the cost calculation of the project by the automated counting mechanics of BIM. The monitoring of costs from construction sequencing will ensure the timely cost and budget reports to be generated and analysed by the construction and project managers. Quantity surveyors make use of 5D BIM by checking the accuracy of data associated to building components from the different disciplines. The accuracy of data and logical calculation methods play an important role in determining the cost cycle of the project.

An information model is likely to contain three types of quantity. Quantities based on actual model components (with visible details) which you can explore through the model are the most obvious. Quantities may also be derived from model components (such as mouldings around windows) that aren't always visible. The third kind of quantity is non-modelled quantities (these include temporary works, construction joints etc.). Unless the construction phase is modelled then the design model will show, graphically, design quantities but not the construction quantities.

A cost manager is likely to be skilled in picking up the quantities that aren't solely based on model components. A properly organised BIM model will help cost managers get a hand on approach in a quite early stage of the project life cycle in comparison to the traditional methods.

- 6D BIM

6D building information modelling helps to analyse the energy consumption of a building and come out with energy estimates at initial designs stages. Accounting for various life stages of a structure, 6D BIM ensures accurate prediction of energy consumption requirements.

6D BIM technology takes the industry a step beyond the conventional approach that just focuses on the upfront costs associated with a project. This approach helps in getting an idea of the entire cost of an asset and how the money should be spent on achieving sustainability and cost efficiency.

6D BIM is also known as integrated BIM as it involves detailed information that can help in supporting facility management and operations at a future date. This essentially involves information about a component’s manufacturer, installation date, and maintenance schedule, configuration details for best performance, energy requirement and decommissioning information.

- 7D BIM

BIM models with integrated information to help facilities management team of a building is known as 7D BIM. The model can consist of the specific manufacture information of the building component to the expected life cycle. Hence proper documentation of construction documents is availed to the end user. Any change or extension in a particular project can make use of a 7D BIM model.

Traditional 2D documents and drawings are replaced by graphical representation of data along the coordination in between the disciplines. This is ensured minimum surprises on site when any kind of maintenance issues popes up. The life span of the building components and the building as a whole can be monitored by the end user for maximum business output.

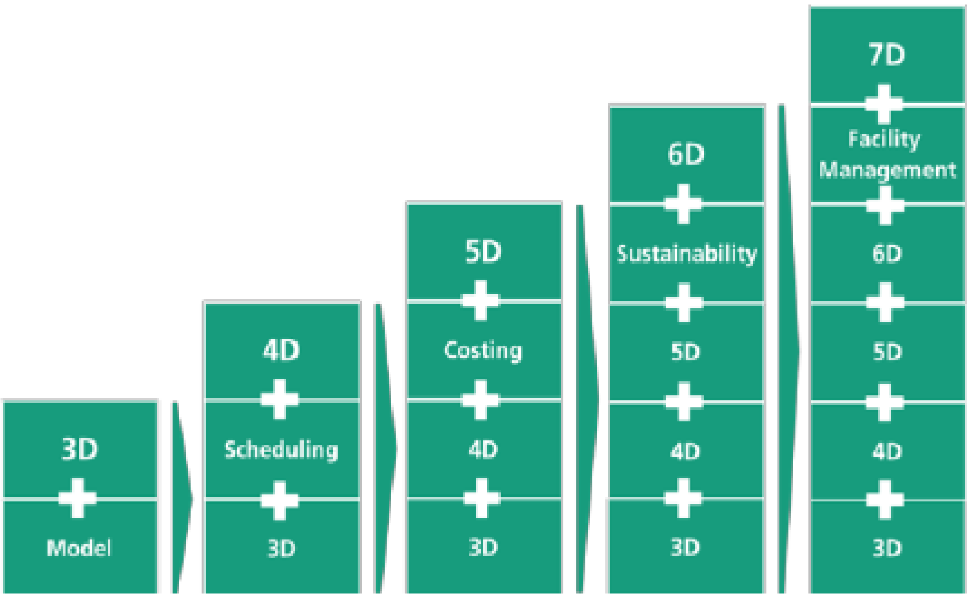

Figure 1.3 BIM Dimensions Break down

1.5 BIM APPLICATIONS AND POSSIBILITIES IN STRUCTURAL ENGINEERING OVERVIEW

Structural engineers can take advantage of BIM in different ways, as the model can be constantly updated with any changes in the design or general specifications. From concept stage to the structural analysis, BIM transforms the way design is done in the modern day. With amble reduction in design and drafting errors, BIM has provided improved efficiency and reduction in cost.

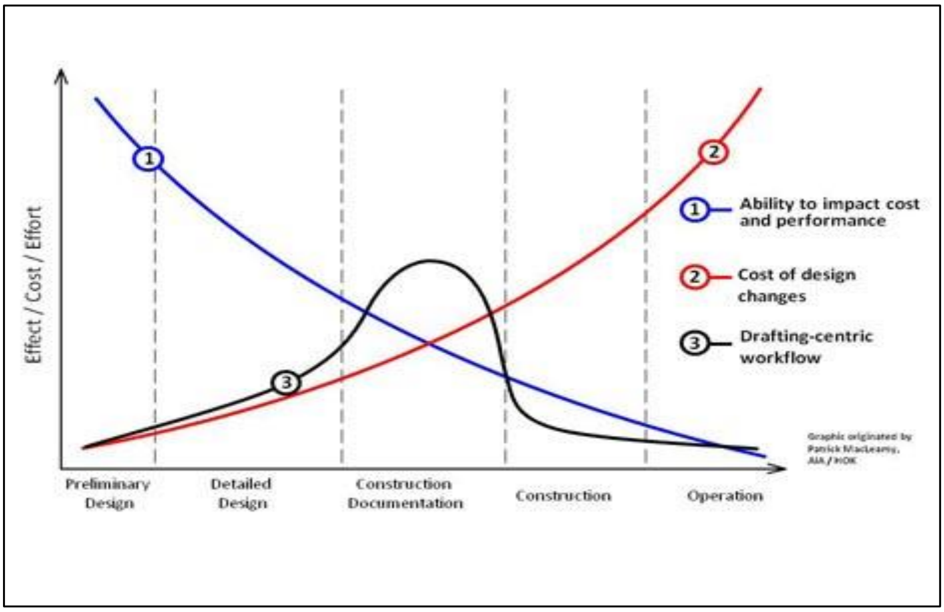

Figure 1.4 Design process – level of effort with respect to time

(Source: What does BIM mean for civil engineers?)

The graph above represents the life cycle of a typical structural design project from concept to operational stage. It is evident that the ability to impact the cost and performance of a project is highest during the concept stage and it goes down steeply till it reaches the minimum at the operational stage. In contrary, the cost of design changes is low during the concept stage and reaches the peak once the construction is finished. In the drafting centric workflow, the construction documentation phase requires the highest amount of time and effort.

The problem with this workflow mainly lies in the coinciding of the peak of the effort required in the construction documentation stage and the declining nature of the designer's ability to affect cost and performance and the increasing nature of the cost for design changes. So in a typical 2D drafting centric environment, once the documentation process of project is well beyond the detailed design stage, the level of impact of any major design changes is more time consuming and will affect the productivity of the project.

The interpretation of the architectural plans is the first step of the structural design workflow. After the structural engineer does an inspection of the plans, the analytical model is set up, which will be analysed using a structural design software taking into account the design criteria such as gravity, seismic, dynamic, wind loads etc. At the same time, the documentation process is also initiated by the drafting staff. This will result in the creation of multiple representation of the design, that won't be linked to the other disciplines and hence will create mis-coordination in between the disciplines.

The error percentage of the design work flow also increases due to the lack of updating the drawings by the drafting staff whenever a change in the design elements is made by the structural engineer. Hence the design will be disorganised. Building information modelling will ensure the interconnection of the physical elements and the analytical information. This will ensure proper relation with the structural analytical design and the construction documents produced.

Structural elements such as beams, columns and slabs are design information such as loads, material properties etc. Structural analysis programs can then import all this information thanks to embedded tools and application programming interface (API). After the analysis process is completed, the model is exported with the results and hence all the information and documentation related to the same will be updated. Analysis results such as the internal force of structural member and the area of the steel rebar can be restored in the model. Since the geometric information of a structural member such as size, type and material properties in the model is updates, the time taken for detailing and drafting process is significantly decreased. Thus dynamically relation in between elements of design is established.

Tight deadlines that have become the norm of AEC industry can be achieved more smoothly and relatively more error free by the introduction of BIM into the design workflow. Basic documentation process such as axes and column, formwork and sectional elevation drawings can be set up along with the analysis process. The amount of information contained in the model such as geometric sizes and spacing of the structural elements can be easily altered as the design progress without the need to go to each and every plan for checking coordination issues.

The use of multiple models, models that are not coordinated with each other or the documentation, requires a manual effort to keep them and the documentation package synchronized to the detriment of a firm's efficiency, quality and flexibility. The use of BIM reduces these problems to a large extent.

After the initial reference of architectural plans, a single integrated structural model is created, which includes both a physical representation that drives documentation and coordination and an analytical representation used for analysis process is created. BIM facilitates evaluation of many more design alternatives and enables the designer to conduct simulation and analysis on the information model itself and hence optimum design taking into account sustainability, constructability and structural safety can be achieved by the design engineer. Deliverables includes typical 2D construction document along with information rich 3D model that can be made use of as 4D, 5D, 6D and 7D information models.

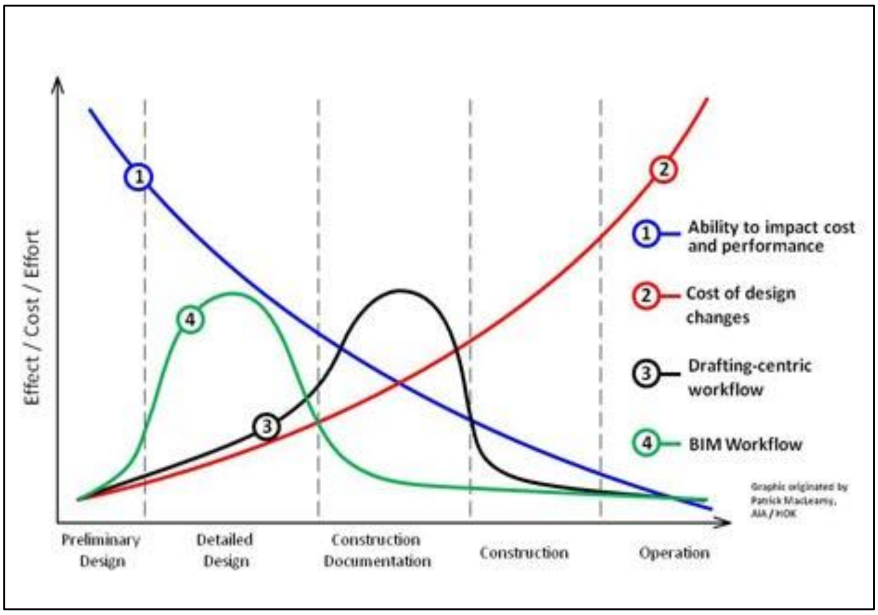

Figure 1.5 Design process – level of effort with respect to time

(Source: What does BIM mean for civil engineers?)

The green line in the above graph clearly represents the cost effective nature of the BIM workflow. The cost and effort reaches its peak in the detailed design stage, where the ability to make design changes is still high and the cost of design change is still low. This gives the engineer, the ability to work out different structural systems and recommend the optimum design without largely affecting the time taken to generate the related construction documents.BIM enables the structural engineer to schedule the construction activities and also plan out cost implications for the same. Among the important points that are included into the information model are the reinforcement, load types, loading conditions, steel/concrete quantity etc.

Since the material properties of construction materials changes over time, the loading conditions also changes with time. This is why structural analysis during constructions has a lot to do with the loading conditions, and the resistance of the elements in question.BIM software is based on the object oriented programming, in which instances of structural members are assembled to create a building structure. Each member possesses information and functionality that fully defines it. BIM based structural design tools help engineers to optimize their design, improve life cycle of design and also reduces their effort and time to check construction documents.

CHAPTER-2

BIM IMPLICATIONS IN DIFFERENT STAGES OF A PROJECT

There have been numerous scholarly articles published on the BIM implementation strategy and the corresponding success rate for different countries. BIM introduced into the project workflow has shown to impact all aspects of the project from concept stage to sustainability concerns. BIM has contributed to reducing design and drafting errors, higher productivity, flexible design, improved project communications etc. (Chi H L.et.al.2015)

On traditional 2D based workflows, the information exchange in between players and project stages is often found to be jumbled. The BIM workflow however ensures flexibility and transparency in the project information exchange between all disciplines and members. There have been found to be lot of information waste in the transition from concept to schematic/ detailed design phase in the traditional workflow. BIM adaptation has found to have high ability in transforming traditional design workflow process into lean design process.

2.1 BIM IN DESIGN PHASE

The efficient exchange of information by enabling BIM in the concept and schematic stage has found to reduce design clashes early on, as disciplines such as Structural, MEP can start developing their design concepts simultaneously with architecture (unlike the traditional way of waiting for the initial architectural design to finish first).

This way more flexibility in design options, early coordination and client inputs is achieved. (Hattab A M, 2013) BIM provides a platform to represent structural analysis models; design and documents together in one place and hence helps in reduction of loss of information. (Hunt A C, 2013) By addition of BIM concepts in structural engineering has enabled real time interactions in the aspects of design and analysis by the help of visualization tools widely used in BIM. Designers have more flexibility to visualize the results through analyses.

2.2 BIM IN CO-ORDINATION REVIEW

Project coordination in between disciplines is also found to increase with the introduction of BIM into the workflow, which allows users from different disciplines to perform individual analysis according to their calculation methods and enrich the central model with design data at the same time. Once the amount of data reaches a particular limit, the models are found to be hard to handle. The need for splitting the models into some disciplines, interoperability in between softwares and having a fixed maximum file size is relevant in this case. (Holland J R & Pihlak)

The positioning and the inter relation in between building elements are found to be more precise in the construction phase due to the introduction of BIM.(Li.J.et.al.2014) The interoperability between sustainability analysis tools and a BIM based design can increase the quality of the workflow between analysis, applications and design deliverables. (Khan A & Ghadge N A)Reduction of errors and coordination issues in construction projects helps in reducing the construction waste and hence projects more sustainable construction practices. (Ismail A A N, 2019)

2.3 BIM IN CONSTRUCTION MANAGEMENT

BIM implementation has been highly beneficial for construction managers also, due to the high level transparency in project communications and data rich models. (Lin C, Jung S, Sui C Y, 2019) Parametric values and economic indicators available in BIM throughout the process of design, construction, operation and maintenance enable factual decision making. (Doumbuya L, Gao G, Guan C, 2016) Quantity take off and estimation for building components have become more reliant and less time consuming since the introduction of BIM usage by contractors.

Larger amount of information added to the model will ensure lesser RFI's for the architect. The quantity take off inputs from contractors in cooperated in the model before the final BIM model leaves the design office will ensure accurate measurements and lesser wastage. (Olsen D, Taylor M J, 2017) BIM data helps in earlier decision makings and hence reduces the cost implication of traditional construction methods. (Kulkarani S B & Mhetar G, 2017)

The possibility of showing a construction model visually will enable the cooperation between multiple sides of a project, as changes in the structural elements can be understood more quickly. (Baran W, Zymancy K B, 2018) The production of a good EIR, BEP & PEP specific to the project is required to establish a good collaboration using BIM adhering close to the set industry standards.(Ganah A &Goulding J,2015)

2.4 BIM IN SUSTAINABILITY / GREEN BUILDING ASPECT

Green Building Analysis coupled with BIM is shown to produce various benefits such as estimating GBA scores, managing application documents and overall improvement of efficiency of GBA process.(LuY, Wu Z, Chang R, Li Yongkui,2017) The environmental effects of building construction is reduced by the introduction of BIM and its subsequent waste reduction methods. (Ozturk G B & Eraslan O, 2018)

Sustainability aspect in structural engineering can be achieved to a large extent by reducing the amount of construction waste in structural rebar process. BIM introduced into design and construction phase have proven to reduce structural rebar waste and thereby helping construction waste problem. With the use of BIM integrated cutting waste optimization process to propose discrete bars, the trim loss of rebar is reduced. Optimization process can start from the design phase itself and hence trim loss can largely reduce both in design and construction stages. (Porwal A&Hewage N K,2012)

The green building applications of BIM is mainly based on energy analysis, water usage calculations, lighting analysis etc. but there are many hurdles that hinder proper BIM application in green building mandate. The primary of which is the lack of an effective BIM standards for green buildings.(LuY,WuZ,ChangR,LiYongkui,2017)The collaboration of design BIM model with energy analysis model is essential in producing adequate green building models that are compliant with green building standards. (Wu W, Issa R, 2013)

2.5 BIM IN DEMOLITION & CONSTRUCTION WASTE MANAGEMENT

UK's construction strategy 2025 states that "BIM has the potential to reduce construction waste during design and construction stage." In real life situations, construction waste management will only be considered along with the cost, sustainability, safety etc aspect of design. BIM enables the designer to a comprehensive look into each of the above aspect in design phase itself by the production of virtual environment. Information readiness and computational algorithms enable BIM to help in optimum decision making in CWM process.

The algorithms work in the way of low cost design options or construction schemes.(Lu Webster C,2017)Design/detailing errors, mis-coordination of design changes and improper understanding of the project specifications from the contractor side before the actual construction begins have largely contributed to construction waste issue. The proper and meticulous planning of the work scheduling which includes regional climatic conditions can reduce wastage to some extent. (Faniran O O, 1998)

Studies have shown that the addition of a special waste evaluation component such as "waste factor" will enhance sustainability aspect in CWM. This component can be easily embedded into a BIM platform and hence multiple design options and decisions can be made early on in the project and construction waste reduction can be done in larger scale. (Liu Z et.al.2011, 2015)

2.6 BIM STANDARDS & CHALLENGES

One of the major risk factors associated with BIM enabled projects is the absence of proper or documented BIM standards in many countries, this leaves BIM design/deliverables responsibilities in a cloud of ambiguousness. (Chein F K.et.al, 2014)The standardisation of the key BIM roles and work definitions is a major hurdle in ensuring the effective completion of design and production in any key discipline utilising the BIM workflow. (Davies K.et.al, 2017) BIM encourages integration of the roles of all stake-holders on a project and thus finding more space for working together than finding faults in other's work. (Salman Azhar, 2011) Time constraint for the initial design phases of a project is one of the factors that drive away stake holders from adopting BIM 100%. (Kasim N.et.al, 2017)

BIM had received proper recognition by the mandates, which was first implemented by USA and UK on BIM standards that were to be followed for government related programmes. The United States General Services Administration (GSA) had been instrumental in the implementation of construction projects across the US. They have developed national BIM standard guidelines, which have been internationally recognized. UK has been ambitious in becoming the global leader in BIM implementation and hence started a strategy in 2011 to make all government projects BIM compliant by 2016. (Peter Smith, 2014)

In developing countries like India, BIM implementation is in its early stages. But the forecasted boom in construction industry in India will ensure foreign investors coming to India. This will be instrumental in the wide scale application of BIM in construction projects in India. (Bui N.et.al, 2016)

2.7 RESEARCH GAP

The role of BIM in each specific stage of the project life cycle is discussed in brief above. But a methodology that has the capability to influence every aspect of a project lacks a global approach in terms of set mandates and guidelines till date. The recently released (January 2019) ISO 19650-1 and ISO 19650-2 can be considered as the first steps towards a world-wide BIM standardisation towards BIM. Though there are BIM standards and guidelines that are present in some countries, there lacks a comparative study in between them to know the relation between national BIM standards and the relating BIM implementation rate.

CHAPTER-3

METHODOLOGY

This chapter describes the methodology adopted for this thesis work. The research approaches taken to analyse the aspects of BIM adaptation in different stages of structural design and also the evaluation of the relation between national BIM mandates and standards with the national BIM implementation.

3.1 RESEARCH APPROACH

The literature review have given focuses on how the aspects of adaptation of BIM workflow into engineering projects around the world has changed the way we approach them. BIM has introduced the concept of virtual construction and has had many impacts throughout the lifespan of a project ranging from pre-concept design to demolition phase. The thesis report is divided into 3 main phases:

The first phase has a quantitative methodology adopted, by having an observation study between the traditional workflow and the BIM workflow and to have a critical review of the existing BIM workflow practises that have found to improve efficiency of structural engineering projects. The study relies upon data from previously published reports on the effects of BIM in all particular stages of project in a cradle to grave method and also in close inspection of projects done by design and construction practices.

A case study is undertaken to give a parallel comparison of the key factors that play a role in BIM workflow in structural engineering projects. Case study is done on a sample villa project by using BIM softwares and workflow to have information to have a comparative look with the traditional 2D workflow.

The secondary phase has a quantitative approach as well, by measuring the level of success of BIM Implementation and adaptation in countries having national BIM standards & mandates in place. The advantages and challenges of BIM implementation are discussed through reviewing of published articles, interaction of industry experts and also sample project and intended workflow recommendation. The study takes a critical review on the effectiveness of the current BIM standards and need to develop universal BIM standards.

The tertiary phase takes a look into the current status of the BIM mandates and BIM implementation in UAE is analysed through a market survey conducted through industry professionals and experts. The market survey consists of a questionnaire consisting of 24 questions, which are aimed at recognising the awareness and challenges of BIM implementation in the UAE.

3.2 RESEARCH STRATEGY

For the first phase of the thesis, the difference between the traditional workflow and BIM workflow is evaluated by having a step by step breakdown of the typical BIM workflow in Structural Engineering projects that are normally found to give optimum design and efficiency. The steps are compared to the traditional workflow patterns in the following parameters:

- Software interoperability
- Design Efficiency

- Loss of Information / Ease of Exchange of Information
- Skills required

For the second phase, 5 countries are selected in relation to the correlation of the current BIM adaptation status, Implementation strategies, authority mandates and national BIM standards/ guidelines. The 5 countries are selected from different parts of the world, according to the timeline of BIM adaptation, economical aspects of the construction industry in them and steps taken by the government till now. The 5 countries selected are:

- UK – One of the first country to have a central government regulated BIM mandate
- USA – One of the earliest technology adopters in relation to BIM
- Singapore – One of the earliest BIM adapter in Asia
- India – One of the Developing countries, which is in the earlier stage of BIM adoption.
- UAE – One of the most booming construction industry with the history of adapting to latest technologies

Out of the 5 countries selected, 3 have recognised national BIM standards, which have approved upon by their respective central governments. The countries are namely UK, USA & Singapore. The relation between the development of national BIM standards and the BIM adaptation in the respective countries are analysed.

For the third phase, a market survey was done to understand the current BIM status in the UAE and the need to establish national BIM standards. The data collected was helpful to get a wide spread look into the current status of BIM awareness for different construction professionals and also to have suggestions collected from them for the need to establish national BIM standards and guidelines. Data in relation to following aspects were collected and analysed by the help of Pie diagrams and charts:

- Current BIM status
- BIM Awareness / Experience
- Common use of BIM
- Advantage over traditional methods
- BIM applications in different project phases
- Obstacles in BIM implementation in UAE

3.3 DATA COLLECTION

The data collection for the first phase was done by personal interviews conducted with BIM mangers in consultancy office, BIM managers in contracting and Structural Engineers who have had experience in BIM. The theoretical BIM workflow is derived from the best practices that exist according to them. The case study was done for a sample villa project using the workflow suggested.

The data collection for the second phase was done by collecting data from research and surveys done by different agencies about the BIM implementation and adaptation rate in the countries selected, which are available in the internet. The National BIM Standards of the countries are also analysed for the level of detail in them.

The data collection for the third phase was done by conducting a market survey by sending out a related questionnaire to more than 50 working professionals in the UAE & 30 completed questionnaires came back. The participants ranged from BIM experts to structural design engineers to project managers.

CHAPTER-4

BIM APPROACH FOR STRUCTURAL PROJECTS AND CASE STUDY

BIM related approaches to each project stage namely: concept, schematic, detailed design, construction and demolition is discussed in detail below. The section aims at providing the best theoretical BIM practices and case studies relating to practical applications. Aspects like cost effectiveness, time, optimization, design options, sustainability and man power involved is reviewed and analysed.

Theoretical approach of BIM aims at maximum output from the design / contractors by utilisation of optimum method by research. This method is derived by the combination of separate works published on the said topic and the practices that are followed by different companies. The workflow affects the design from the concept stage till the demolition phase in the construction stage. A breakdown of the theoretical BIM approach for structural engineering projects is given below:

4.1 BIM IN CONCEPT DESIGN

Traditional workflow did not recommend the simultaneous commencement of concept designs of all working disciplines. The architectural discipline was to finish their concept design before structural/ MEP inputs can be put forth in the latter stage. However with BIM, the concept models for all disciplines are set up together and hence earlier coordination and workability in regards to sizes and shapes can be achieved.

The theoretical BIM Workflow for structural discipline in concept stage will involve the following steps:

- For new buildings, architectural models should be examined for framing systems and load transfer schemes. Structural BIM models for design alternatives are made.
- For existing buildings, the load bearing structural system needs to be analysed initially and BIM model for existing structure needs to be developed according to scope of work.
- The BIM models must be initially developed with the initial design concepts and foreseen changes in mind and must not include extensive information.
- The BIM platform and deliverables must be agreed upon, that is contractually bound by the client and the design team.

4.2 BIM IN SCHEMATIC DESIGN

After LOD 100 stage, the project shapes itself to an LOD 200 stage, which can be coined as the Schematic design phase in normal project standards. The initial co-ordination of positioning of building elements and the BIM protocols that need to be taken into account for the desired design output must be decided upon in this phase. The normal steps that need to be taken in the Schematic design phase to attain optimum structural design with the usage of BIM workflow is listed below:

- Initial analysis is done for structural element sizes and structural member optimization

- Analysis data such as the structural member sizes are in-cooperated in the structural BIM model
- Possible design alternatives & building materials are taken into account and BIM models are updated
- Initial Building materials & Quantity schedules are made and analysed according to the architectural design requirements
- Initial coordination models are set up and looked upon for any major design clashes or conflicts in between the disciplines

4.3 BIM IN DETAILED DESIGN

BIM applications in detailed design stage can be labelled under LOD 300 & LOD 350 Model categories. Structural Analysis models needs to be modified under the final design considerations and relevant design and analytic data must be updated in the BIM models for the production of final detailed design information model. The common protocol that needs to be applied theoretically for optimum structural detail design using BIM workflow is listed below:

- Structural analysis & design is done extensively according to the final detailed design specified by the Architectural team
- FEM analysis can be integrated with BIM tools to get better graphical representation and easier decision making abilities
- For concrete buildings, detailed bar bending schedule is generated by BIM software and is latter used for rebar optimization analysis

- BIM enables 3D representation of structural detailing including splices, hooks bends, etc. This will ensure accurate quantity take-offs and reduce the trim loss and percentage waste
- For green building / sustainability requirements, structural elements can be linked to their possible Carbon emission data and BIM schedules can be derived in accordance to the same
- Proper co-ordination models are set up and coordination checks are run in between the design disciplines
- Any further structural design changes are done and the analysis and design non graphical data is integrated on to the structural BIM model
- Clients can be made more aware of the current stage of the project and design implications by 3D graphical representations
- Inputs from all stakeholders are finally reviewed and LOD 300 BIM models are generated
- LOD 350 models are set up by doing clash detection exercise, this can be done by the design team itself or by the clients or contractors according to the contractual agreement
- The design clashes are zeroed up before the BIM model is set across to the site team for further inspection and review

4.4 BIM IN CONSTRUCTION AND MANAGEMENT

Once the LOD 300/LOD 350 model is handed over to the client/contractor according to the contractual agreement, the final clash detection and co-ordination checks are conducted. The contractor, usually subdivides the model with the sub-contractor and building design specific model is generated, which is termed LOD 400. The sequencing of works and proper scheduling such as bar bending schedules are done at this phase of the project. The proper protocol to be followed in order to achieve optimum design and waste reduction using BIM workflow in the construction phase of the project is listed below:

- The contractor sets up schedules of work using the clash free BIM model received from the client
- Calculation models are set up using BIM for the design costs analysis
- Structural steel weight and other quantities are derived from the BIM model
- BIM elements from the sub-contractors is also in cooperated in the model
- The analytical data and loading conditions are assigned to the structural elements for future changes
- Any design changes according to site conditions and can be readily re-analysed and data can be integrated on to the BIM model, this helps in reduction of data loss
- The LOD 400 model should be completed with all the structural fabrication / connection details included.

4.5 BIM IN PROJECT COMPLETION STAGE

On the completion of construction, the contractor or a 3rd party surveyor needs to assess the 'As built' condition of the project and produce an LOD 500 model with all relevant information about the structural elements and the analytical data for future renovations and demolitions. This latter handed over to the client /FM team. The proper production of this model will ensure minimal wastage in future developments and also make the construction future automation ready. The proper theoretical Protocol is as follows:

- After the completion of the construction project, proper site survey must be conducted in order to verify the structural elements assigned in the BIM model matches with the ' As built' condition
- Final co-ordination reviews must be conducted, in order to attain all relevant data from all disciplines and it matches with the site conditions
- Ensure all manufacture details such as service life cycle care details, warranty time, etc are entered and coordinated in the BIM model for all building elements and components
- If required, walkthrough models must also be developed, in order for all the stakeholders to have a proper grip on the construction and all technical information
- The client should ensure all data including analysis and design information has been in cooperated in the final BIM 500 model handed over to them by the contractors

4.6 BIM IN PROJECT FACILITIES MANAGEMENT STAGE

Facilities management is an important phase in a building's serviceability and life span. Any demolition or expansion for the construction project can only be done using the technical details of the 'As built' condition. Any change to a structural element could alter the structural stability of the building and hence proper BIM coordinated model will ensure the structural engineer / designer get all physical and analytic data about the elements and give proper instructions. The proper BIM protocol is given below:

- The LOD 500 model should be obtained by the engineer from the client and analysed according to the scope of work
- Ensure that all analytic data and physical data match the site conditions
- Site surveying can be done using latest augmented reality and cloud point methods using the BIM model in hand
- Any change in the building should be updated in the BIM model as well, to ensure there is no loss of data

4.7 BIM SAMPLE PROJECT-CASES STUDY

After close examination of the BIM strategies and workflow listed above, a sample structural project is modelled and designed below from concept to detailed design phase. The interoperability of the design and modelling software is tested and concerning results are reviewed. BIM modelling software used is Autodesk Revit & the structural analysis is done using Autodesk Robot Structural Analysis (RSA).

4.7.1 SAMPLE PROJECT

The villa project given below is modelled structurally in Autodesk Revit and analysed in RSA software. The villa has a living room, 3 bedrooms and a kitchen. It is just one storied and is supported by columns at regular intervals. The foundation and stair design is omitted.

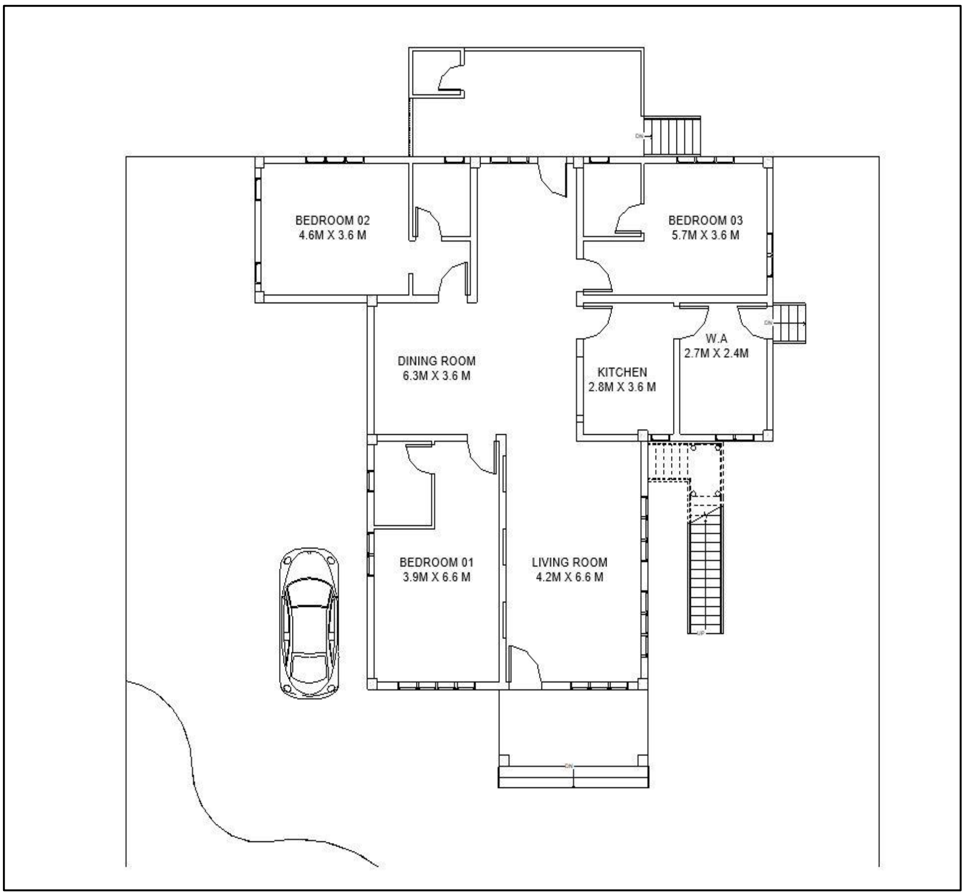

Figure 4.1 Case Study – Architectural Plan

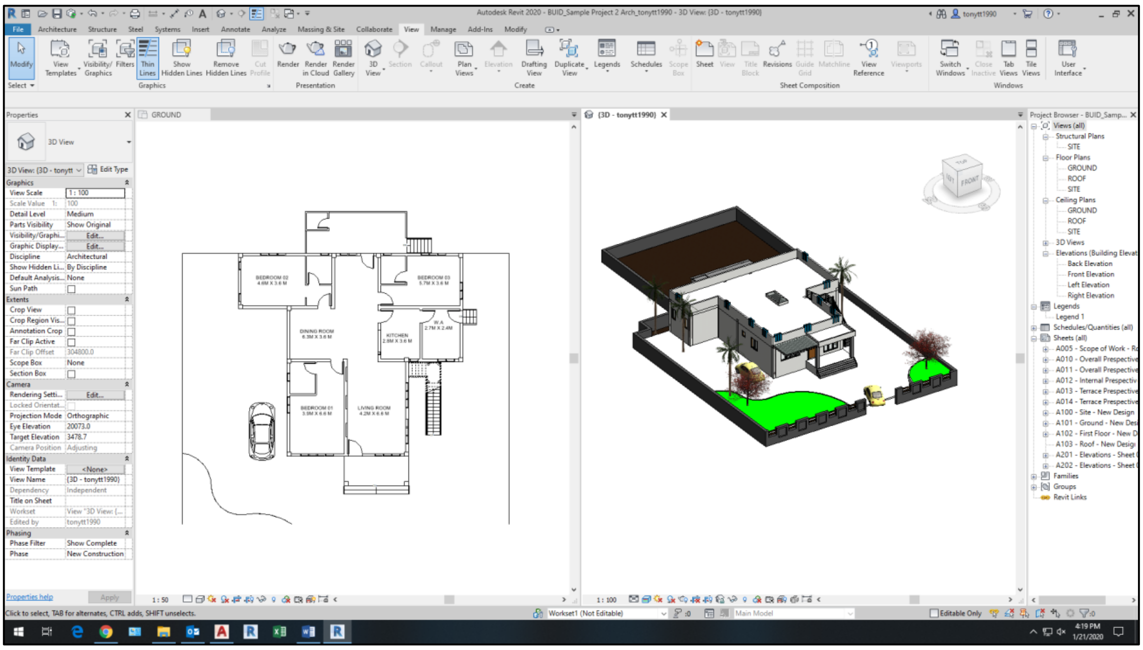

Figure 4.2 Case Study – Architectural Plan / Perspective

4.7.2 STRUCTURAL CONCEPT DESIGN

For the project above, a concept structural BIM model is made with columns of size 300X300 mm & 300x500mm by manual calculations & assumptions. The ground and roof slab edge is modelled as per the architectural drawing.

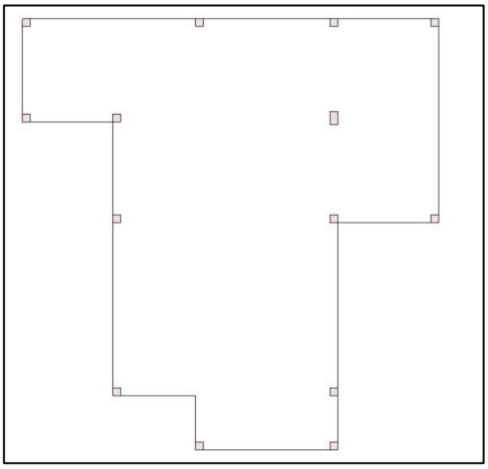

Figure 4.3 Case Study – Structural Plan - Concept

4.7.3 STRUCTURAL SCHEMATIC DESIGN

Coordination checks are done initially to check if the physical members assigned in structural model matches with the architectural model. The ground slab is given 300mm thickness and Roof slab is given 200mm thickness. Beams are provided on the roof slab for the framing purposes. Beam dimensions are initially given as 300x700mm.

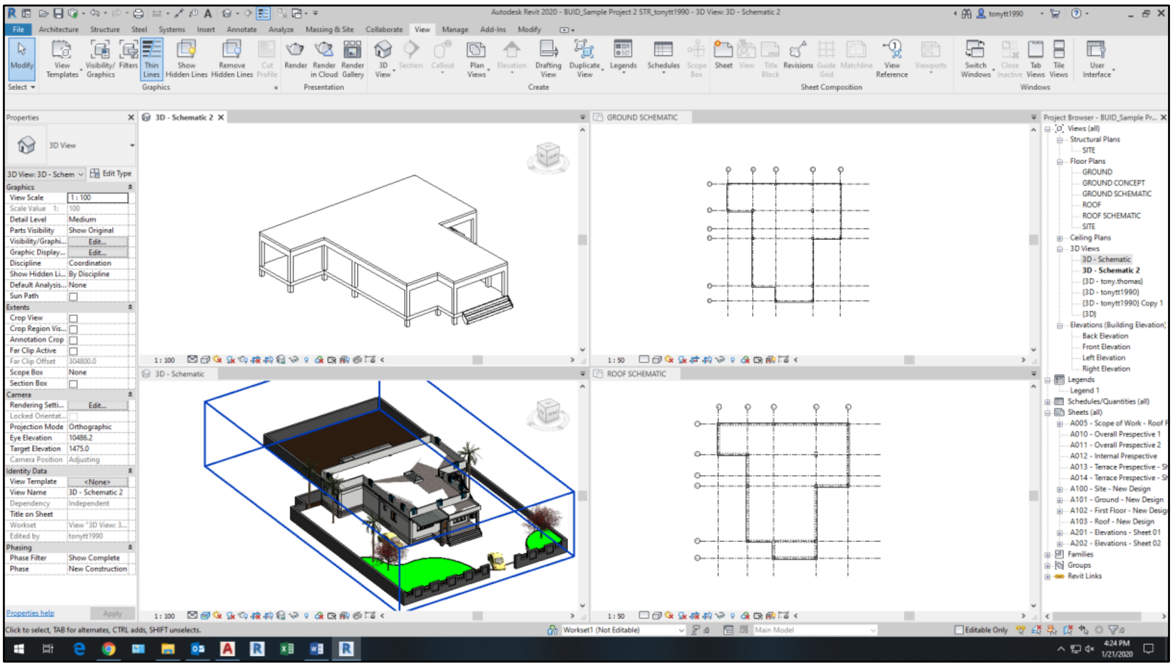

Figure 4.4 Case Study – Structural – Schematic Design

4.7.4 STRUCTURAL DETAILED DESIGN

There should be analysis done for the detailed design stage. So the structural BIM model must have all the physical members fixed and be rechecked with architectural and MEP models for any design alterations.

For the Design & Analysis, following assumptions are made:

f_{ck} = 30N/mm², f_y= 250N/mm²

The load considerations are:

Live Load is considered as LL1 = 2kN/m²

SDL for ground floor = 2kN/m²

SDL for Roof = 5.25kN/m²

Line Load for Exterior Walls = 13.5 kN/m

Area Load for Interior Load = 2.5kN/m²

Ground Beams are provided with 300x700mm dimension and is used to tie all the columns together. Neck columns (C3) are placed at areas where there are large spans.

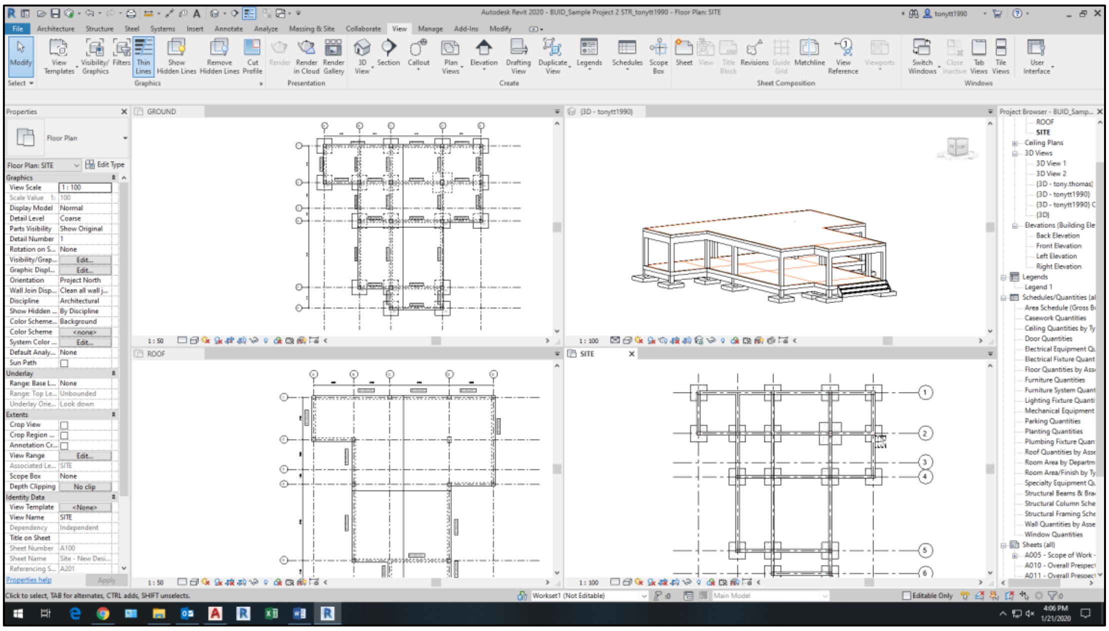

Figure 4.5 Case Study – Structural – Detailed Design

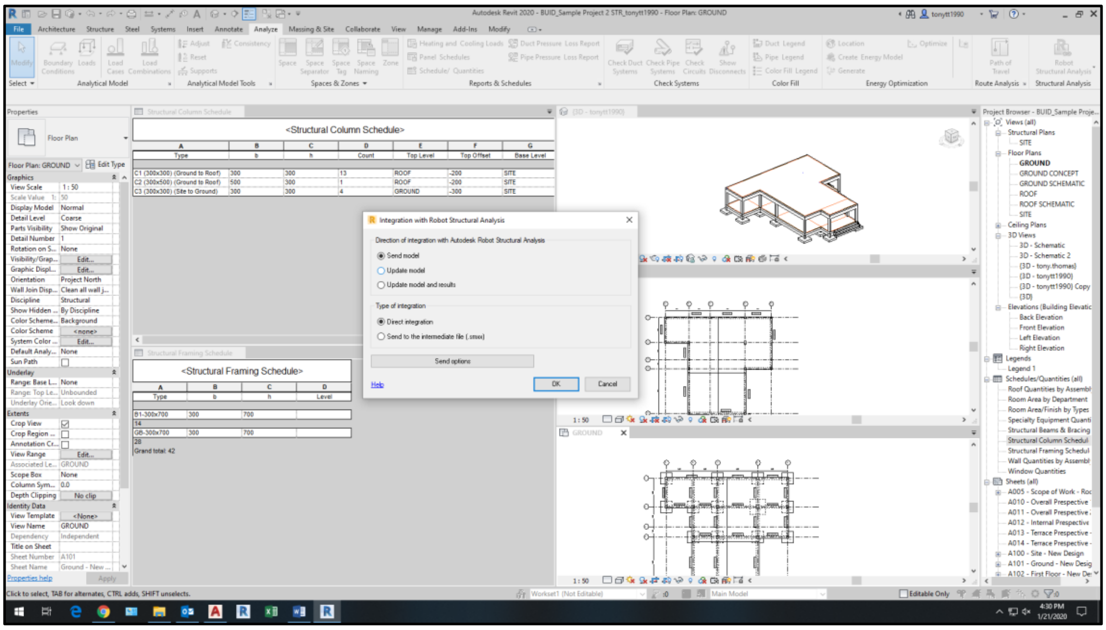

Figure 4.6 Columns & Beam schedules generated in Revit

The loads can be assigned in Revit directly or can be applied after exporting to RSA. The sectional properties and analytical loads that we have assigned in the Revit BIM model will be transferred directly to RSA and hence there is less loss of information.

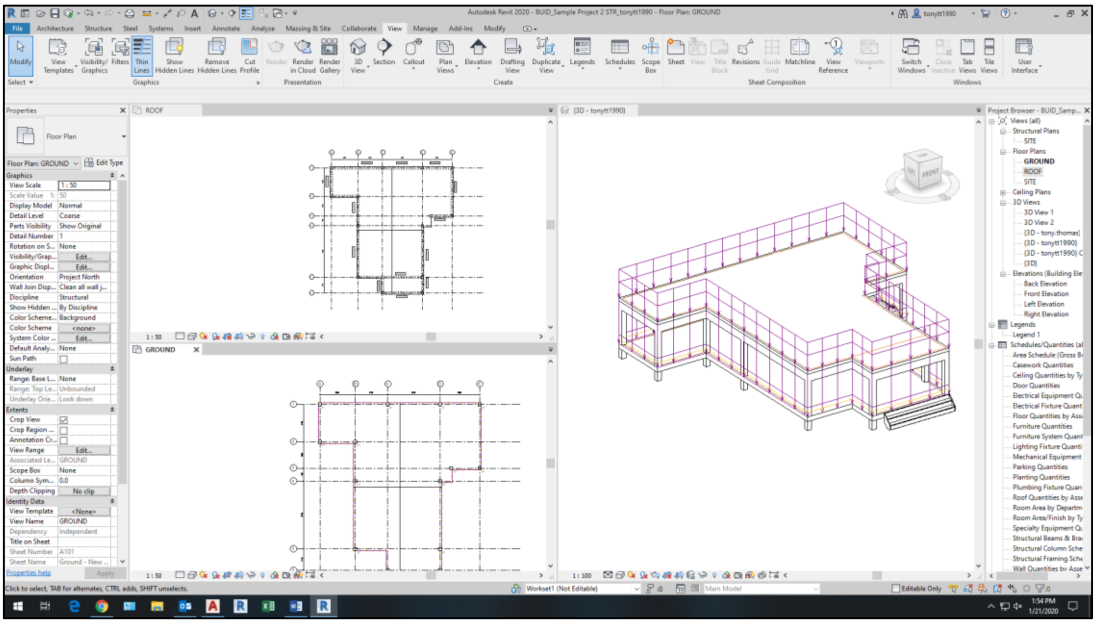

Figure 4.7 Load conditions being defined and applied on Revit directly

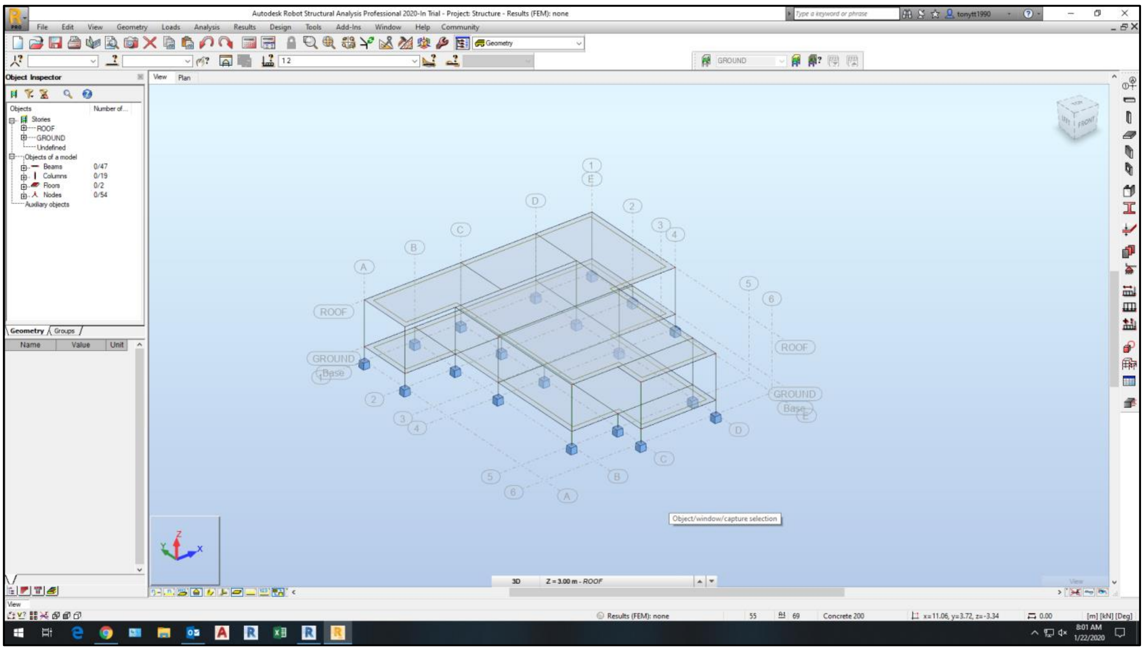

Figure 4.8 The model exported to RSA – View 1

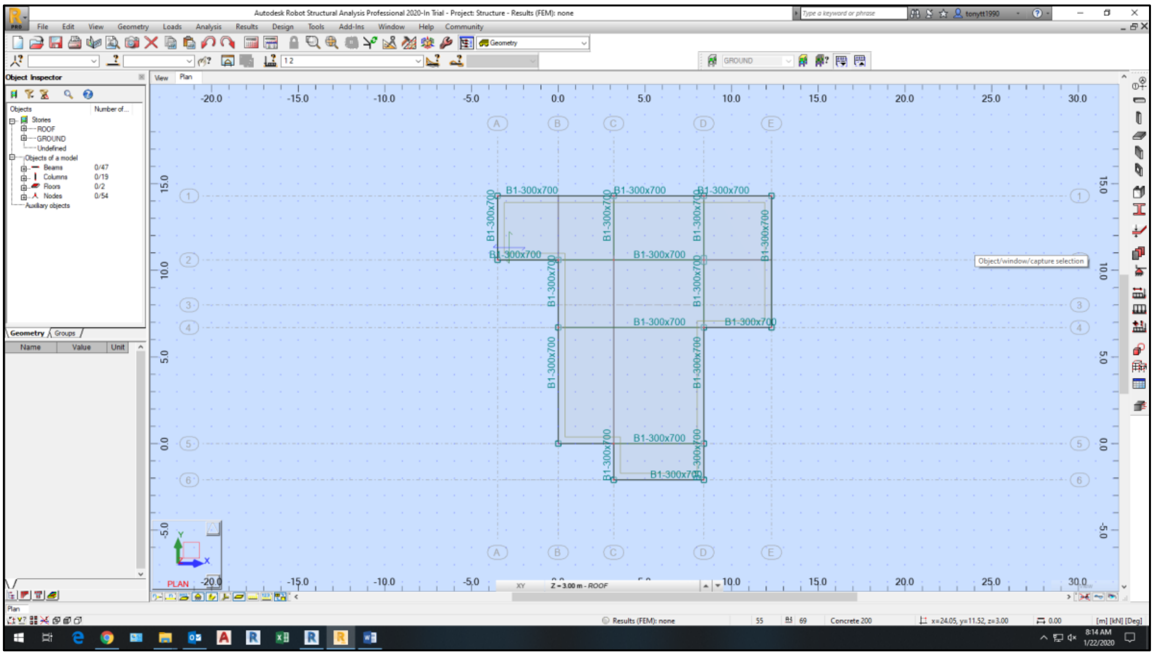

Figure 4.9 The model exported to RSA – View 2

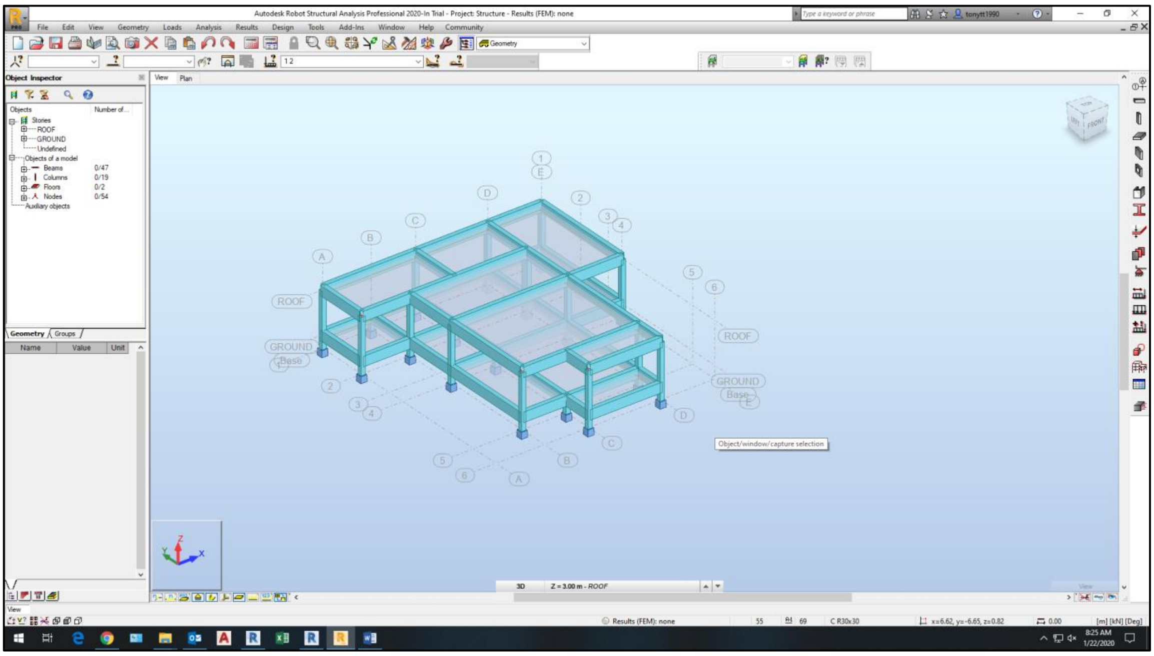

Figure 4.10 The model exported to RSA – View 3

All member sectional details along with the load conditions and cases are retained as per the Revit model.

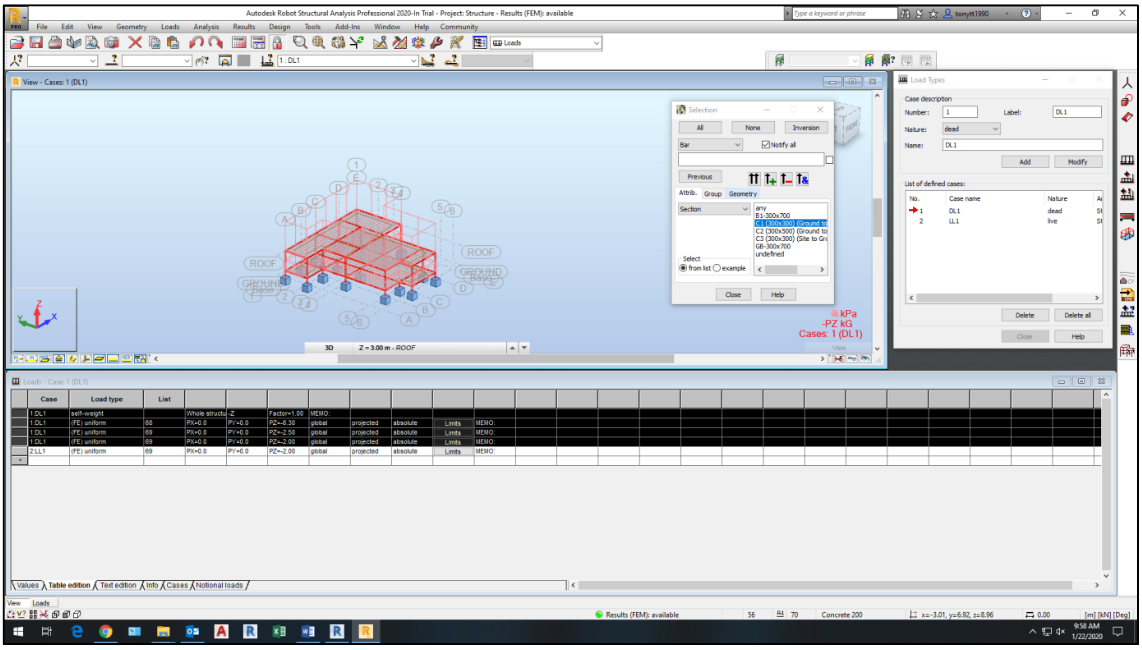

Figure 4.11 Checking of RSA Load conditions

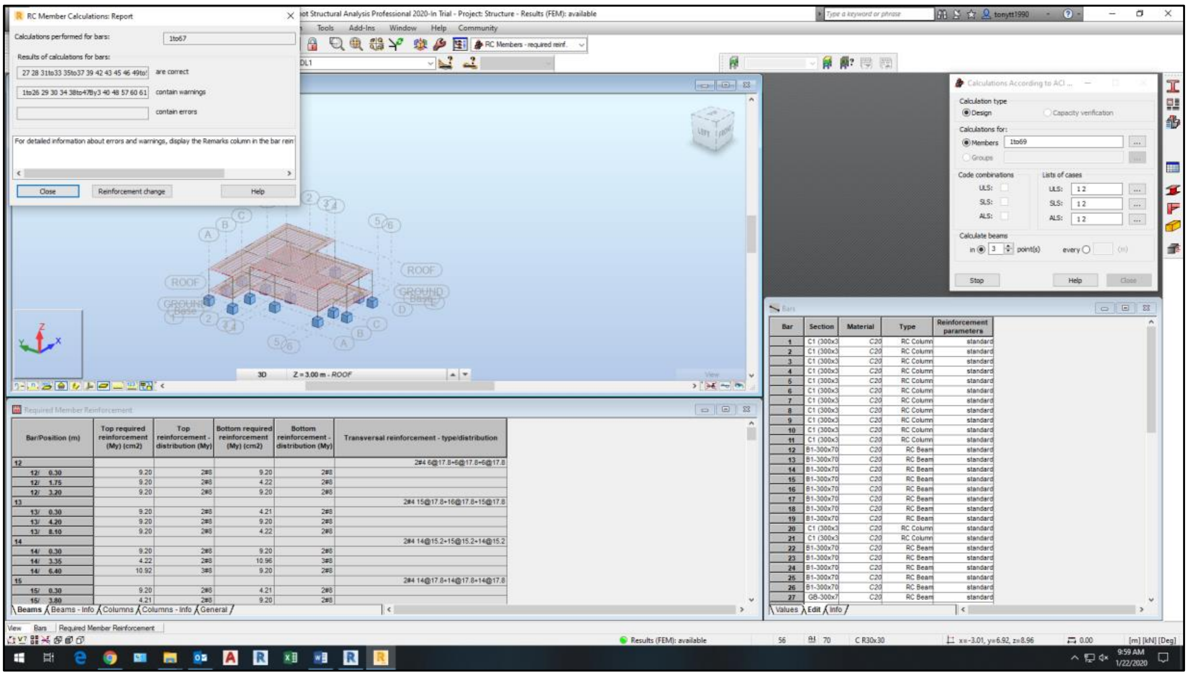

Figure 4.12 Members are analysed and designed in RSA

The model is analysed and designed in RSA and after the reinforcement has been given by the designer, the model is transferred back to Revit and the Revit model is updated as per the design.

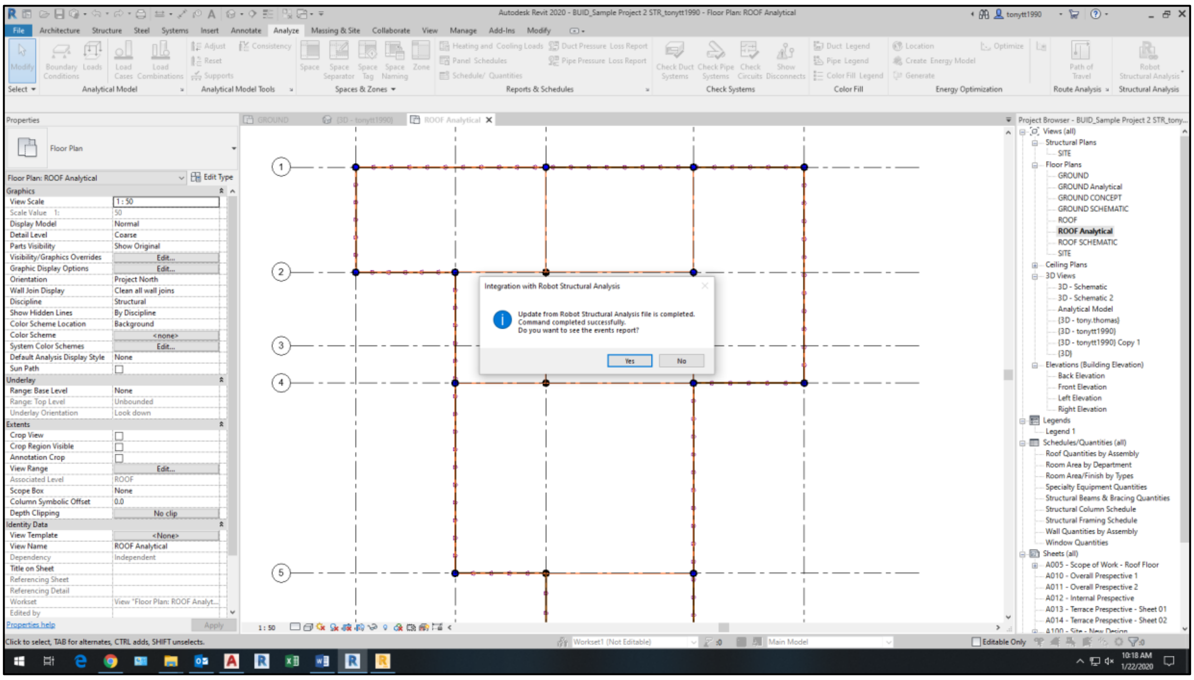

Figure 4.13 Analytic Data transferred back to Revit

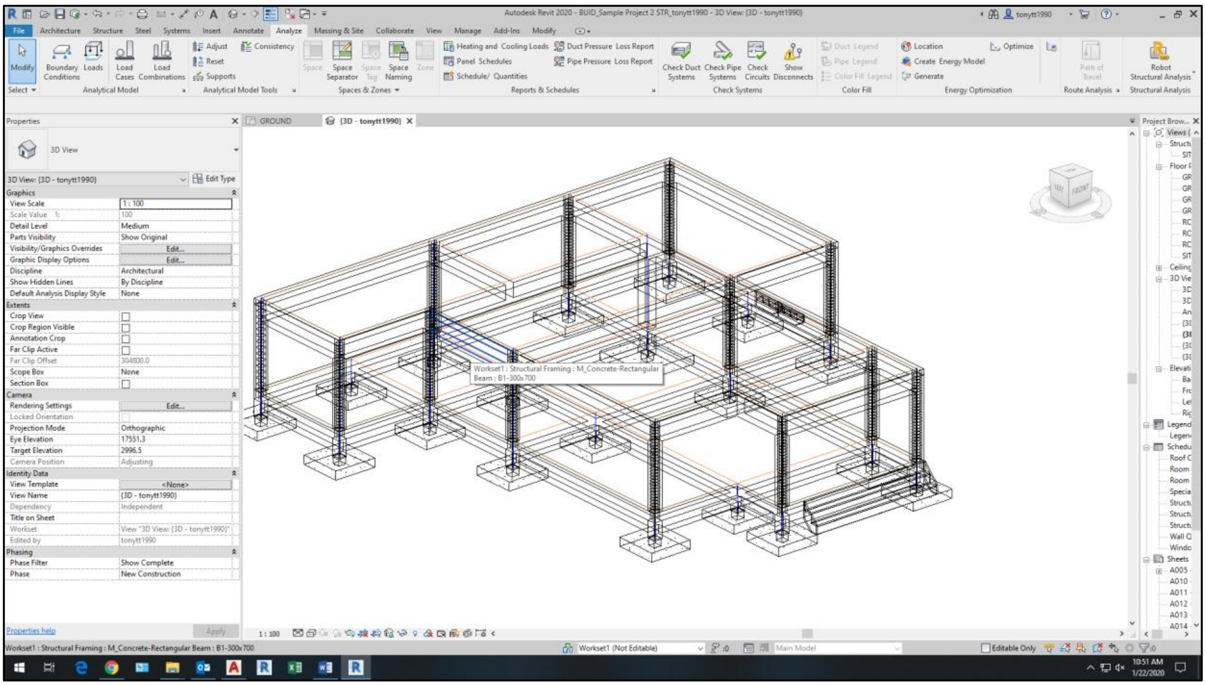

Figure 4.14 3D Representation of Reinforcement in Revit

The reinforcement details are transferred back to Revit from RSA software. The physical structural members in Revit will be having 3D as well as analytical information in cooperated in the model. The loss of information is minimum in this case. Data can be represented as 2D information for drawings issue proposes also with minimum time and man power requirement. The reinforcements can be properly visualized and redesigned, if circumstances are there. The cost indicator can be assigned to the members and structural BOQ schedules can also be extracted, if needed. Clash detection tests can also be run by additional BIM softwares like Navisworks to achieve error free final design.

The above case study is a generalised look into the concept of implementing BIM fully into the structural engineering project workflow. The engineer / designer can make sure that the analytical information that has been developed during the structural design phase gets fully transferred and conveyed in the BIM model and drawings by following this workflow and hence manual re-checking and errors are lessened. The engineer can also have visual information on the coordination between other disciplines such as Architecture and MEP and make sure that no structural design information is out of place from the actual Architectural design or scope. This there by decreases the site errors and coordination issues. However proper work standards should be set for the information that need to be included into the BIM model and that should retained only for the analysis models.

There are numerous other features in BIM to have IFC interoperability between standard design software such as ETabs, SAP2000, etc. BIM modelling softwares such as Tekla structures, Bentley, etc. are also commonly used among the structural engineering platforms to have BIM models ready for design and analysis.

CHAPTER-5

COMPARITIVE STUDY BETWEEN THE BIM ADOPTION RATE & BIM STANDARDS ACROSS THE GLOBE

5.1 BIM ADOPTION RATES IN DIFFERENT PARTS OF THE WORLD

Standards and Guidelines are an essential part of the construction industry in any country. Standards are often mandated by the national authorities to have consistency in design methods, determining building service life, having common engineering calculation methods, etc. Guidelines are often produced by the same authority itself to have a defined path for achieving the standards set across. This however may or may not be mandated. Standards & guidelines have often found to increase productivity in the field of construction.

There is an absence of universal BIM standards that is approved by multiple national authorities across the globe. The recently published ISO 19650-1 and ISO 19650-2 could possibly pave the way to having universal standards in BIM. Establishing a widely recognised BIM standards and codes system will have benefits ranging from proper deliverables and role definitions to optimum design criteria for the structural discipline. Many big construction companies have developed their BIM standards and guidelines. These will be suited for their work culture and thus will lack a universal / national appeal. The following are some of the currently established national BIM standards and mandates aided by the respective government authorised authority, which are being used in different parts of the world.

The study compares the BIM adoption rates between 5 selected countries. The time line and success rate for the BIM adoption of these countries and the general approach towards BIM till date will be briefed below.

5.1.1 BIM IMPLEMENTATION IN THE UK

UK has been ambitious in becoming the global leader in BIM implementation and hence started a strategy in 2011 to make all government projects BIM compliant by 2016. BIM implementation happened in such a pace that, if a party is not Level 02 BIM complaint (Explained in clause 5.1.2.1), no government projects will be awarded to them. Since the mandate came in place, all government funded projects needed to be delivered in a 'fully collaborative 3D BIM format'. BIM adaptation in 2010 was standing at 13%, which increased to 39% by 2013. There have been reported 15-20% decreases in the construction cost in the time frame ranging from 2009-2015 due to the BIM implementation in the industry. Government has the vision to reduce whole life costs of assets by 33% by 2025 (NBS Report 2018).

The National Building Specifications (NBS) conducts yearly BIM adoption surveys in the UK. Their report is often found to give information on the level and percentage of BIM adoption in the country. According to the 2018 survey report, the BIM awareness level in the construction industry stands at 74%.

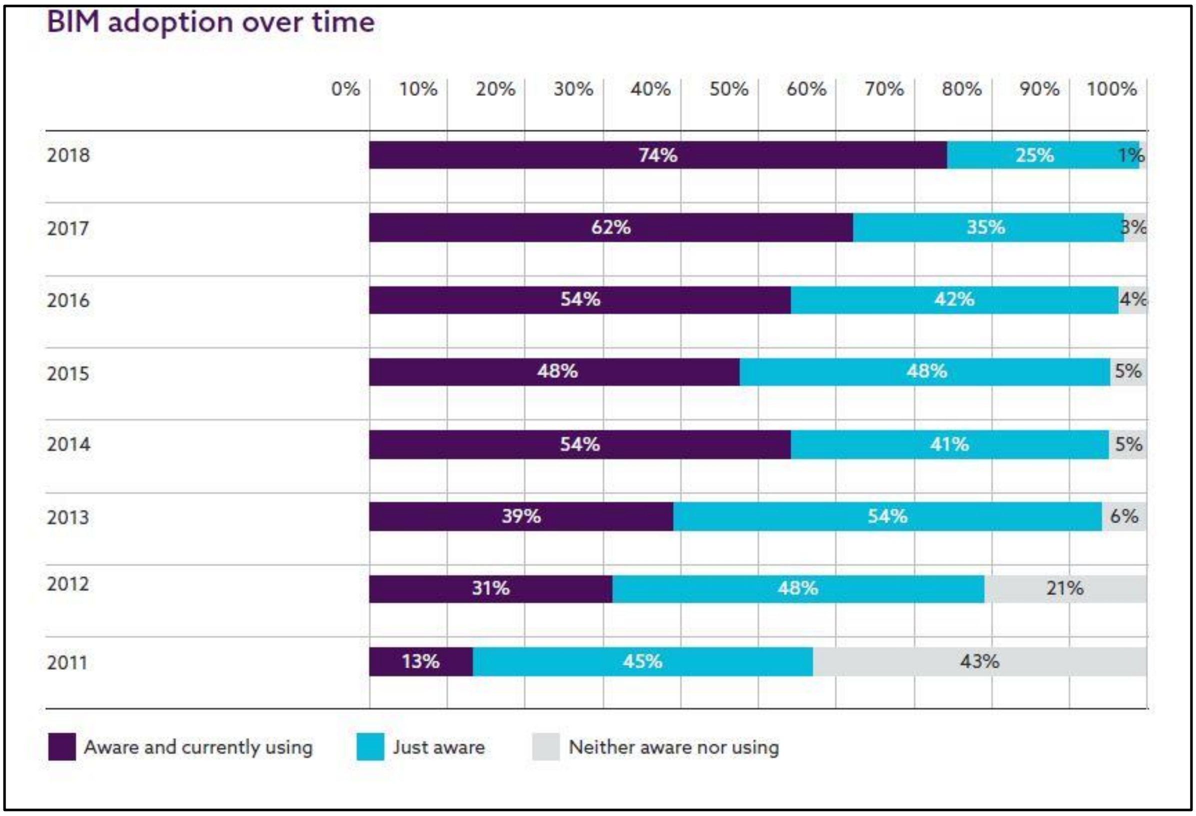

Figure 5.1 UK BIM adoptions 2011-2018 – NBS Report 2018

Figure 5.1 depicts BIM adoption rate by the construction industry in the UK over the span of 8 years since the first BIM implementation strategy was introduced. The BIM awareness in the country saw a steady rise from 2011 to 2014, raising its tally from 13% to 54%. There was minor dip in the BIM usage in 2015. With authority BIM mandate coming into existence in 2016, the BIM awareness has again been in the path of steady increase and the country has achieved 20% increase in BIM awareness from 2016 to 2018. A high percentage of the survey respondents have foreseen the implementation BIM in their practices in time frame of five years. According to the report, 93 per cent of UK small practices (1-15 employees), 98 per cent of medium practices (16-50 employees) and 99 per cent of large practices (51+ employees) will be using BIM come 2024(NBS Report 2018).

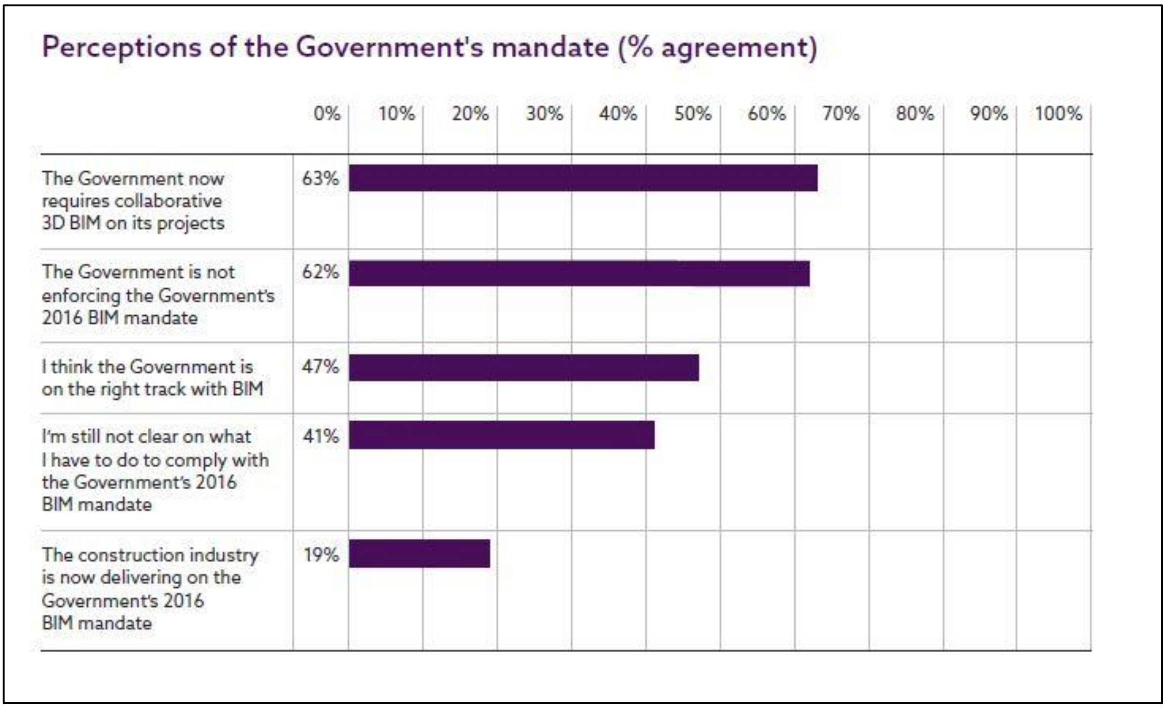

Figure 5.2 Thoughts on UK BIM mandate –NBS Report 2018

Figure 5.2 depicts the thoughts shared by the survey respondents on the topic of the 2016 BIM mandate in the UK. 63% of the respondents found the need for collaborative 3D BIM in their projects, while almost an equal percentage have expressed that the government is not pushing enough for the enforcement of the mandate. Almost half the respondents (47%) felt that the government were on the right track with BIM implementation and mandate. 41% were not clear with requirements from their side to comply with the 2016 mandate. 19% felt that the construction industry is now delivering projects as per 2016 BIM mandate guidelines.

5.1.2 BIM STANDARDS IN THE UK

The AEC (UK) BIM protocol was first released in November 2009. A committee was formed consisting of architects, engineers and construction managers to analyse the steps to be taken to accomplish BIM implementation across the country properly. The protocol works on the guidelines set by UK standards BS1192:2007, PAS1192-2 and BS8541-1. The primary vision of the protocol was to:

- To maximise production efficiency through adopting a coordinated and consistent approach to working in BIM.
- To define the standards, settings and best practices that ensure delivery of high quality data and uniform drawing output across an entire project.
- To ensure that digital BIM files are structured correctly to enable efficient data sharing whilst working in a collaborative environment across multidisciplinary teams both internally and in external BIM environments.

5.1.2.1 LEVELS OF BIM

Levels of BIM are a method recognised by UK authorities on the basis of BIM compliance of a construction project. The method has been instrumental in defining the level of BIM adaptation in government recognised projects. It gives clear guidelines and standards on the amount of deliverables and timeframe for each. The strategy was to have specific contractual agreements and clauses on the BIM deliverables at the end of each stage. The levels of BIM range from Level 0 to Level 3, which gives indication on the level of maturity of the BIM model.

- <u>Level 0</u>

Level 0 represents non-coordinated CAD/2D information. This information can be of the method of traditional paper representations or of PDF format. This normally has the same information spread out in different sheets.

- Level 1

Level 1 represents a mix of 2D and 3D information on basis of BS 1192:2007 with use of a collaboration tool. The collaboration tool provides for a common data environment. This method utilises 3D model for the concept phase and the 2D method for documentation and production purposes.

- Level 2

Level 2 can be defined as a collaborative BIM. This encompasses an information exchange process which is specific to that project and coordinated between various systems and project participants. Any CAD software that each party uses must be capable of exporting to one of the common file formats such as IFC (Industry Foundation Class) or COBie (Construction Operations Building Information Exchange). This is the method of working that has been set as a minimum target by the UK government for all work on public-sector work.

- Level 3

The definition of Level 3 is still under working process; however the main focus of Level 3 would be the following:

- The creation of a set of new, international 'Open Data' standards which would pave the way for easy sharing of data across the entire market.

- The establishment of a new contractual framework for projects which have been procured with BIM to ensure consistency, avoid confusion and encourage, open, collaborative working.
- The creation of a cultural environment which is co-operative, seeks to learn and share.
- Training the public sector client in the use of BIM techniques such as, data requirements, operational methods and contractual processes.
- Driving domestic and international growth and jobs in technology and construction.

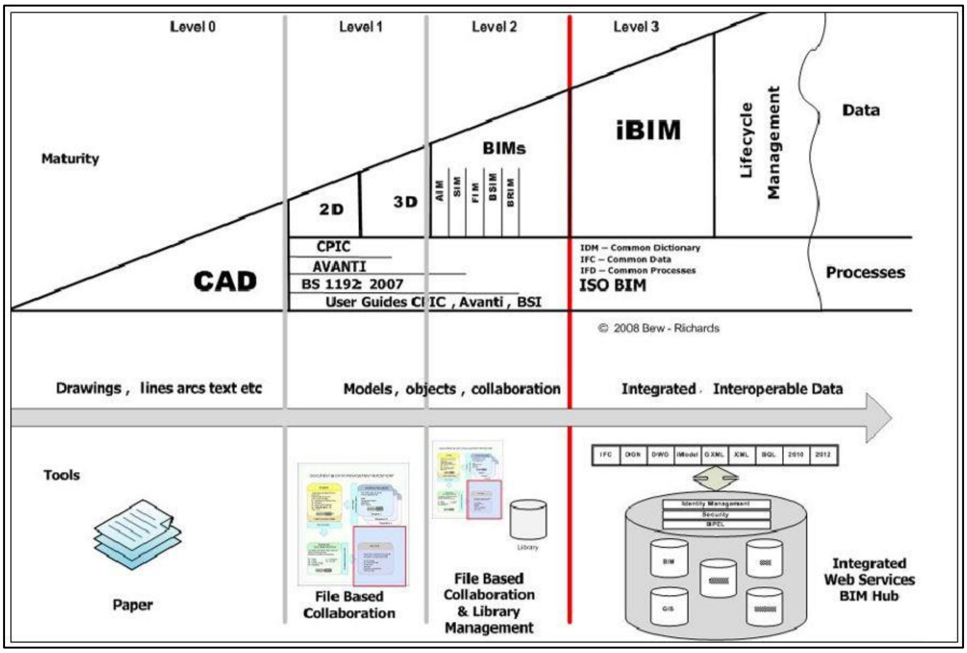

Figure 5.3 BIM Levels Break down

The protocol has guidelines for the BIM execution plan that need to be followed by the design firms and construction companies, set guidelines for the collaborative BIM working environment, Interoperability instructions for the softwares that are being used in the project, data segregation methodology, modelling methodology, folder naming systems, presentation styles, resources and appendix guidelines.

5.1.3 BIM IMPLEMENTATION IN USA

USA was poised to be one of the earliest adapters of BIM methodology as technology was in use from as early as late 1970s. Industry wide BIM adoption in North America surged from 28% in 2007 to 71% in 2012 (49% in 2009). In 2012, 71% of architects, engineers, contractors and owners report that they have become engaged with BIM on their projects, showing a 75% growth over five years (McGraw Hill, 2012). The same study reported the percentages of BIM stakeholder groups (architects, engineers, contractors and owners) who were using BIM in 2009 and 2012 and who were projecting to use BIM in 2014 in more than 60% of their project.

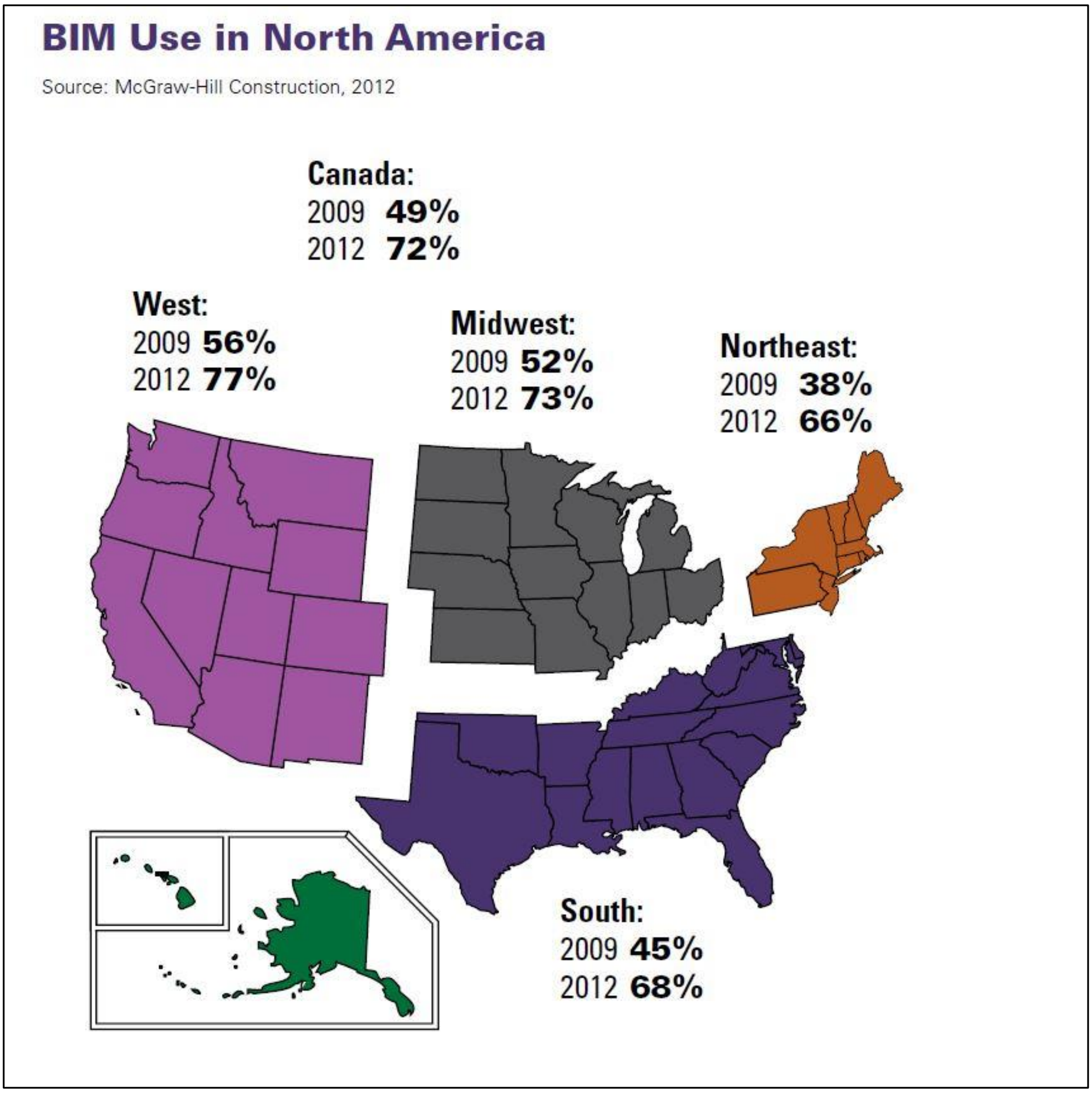

Figure 5.4 BIM Adoption in the US – McGraw-Hill Report 2012

Figure 5.4 shows the different rates at which major regions in North America have been adopting BIM. The lack of mandates and an approved Nation-wide standards have paved way to inconsistent standards in between the states and hence deliverables can been seen not in par with each other in different geographical locations within the country itself.

USA currently has different agencies assigned for undertaking different public construction projects and hence a national BIM mandate is tricky at this position.

5.1.4 BIM STANDARDS IN THE USA

USA still lacks a full central government initiated standards for BIM till date. There have been however standards that have been set across by individual government bodies. In 2003, the US General Services Administration (GSA) formulated the National 3D-4D-BIM program for policy mandating BIM adoption for all Public Buildings Service projects. GSA has published guides for BIM in USA:

- 3D-4D BIM overview
- Spatial Program Validation
- 3D Laser Scanning
- 4D Phasing
- Energy Performance & Operations
- Circulation & Security Validation
- Building Element
- Facility Management

NIBS (National Institute for Building Science), non-profit organization have released guidelines called National Building Information Modelling Standard (NBIMS - US) along with collaboration with Building SMART. The document throws light into the aspects of a BIM project such as Interoperability, BIM roles definition, Collaboration standards, Model Maturity index, BIM execution plans etc.Even though US was the initial adapter of BIM technology, the lack of national level mandates and standards have shown a reduction in the pace at which BIM adoption is happening.

5.1.5 BIM IMPLEMENTATION IN SINGAPORE

Singapore has been keen in recognising the possibilities of BIM from early on. Building and Construction Authority (BCA) first drafted the BIM roadmap in 2010 with an objective to achieve 80% BIM adaptation by 2015. BIM was made mandatory for all public sector buildings in 2012. This was followed up mandating all architectural and engineering projects greater than 20000 sq.m to have BIM complaint e-submission to the authorities in 2014. By 2015 projects having area greater than 5000 sq.m were mandated to have BIM e-submission for regulatory approval.

BIM fund has been allocated by BCA to help enhance the BIM collaboration capability of firms by taking up the costs for training, BIM software and hardware expense, consultation services, etc. However subcontractors who take up smaller works (which do not require BIM e-submission standards) and also don’t fit into the eligibility criteria for allocation of the BIM fund by BCA have been found to stir away from BIM adoption their practices.

5.1.6 BIM STANDARDS IN SINGAPORE

The Singapore BIM guide was initiated by the BIM Steering Committee, set up in 2011. The committee consisted of Architects, Engineers, Government officials and industry experts. BCA released the Singapore BIM guide in 2012 provides detailed description of the BIM execution plan with use of BIM specifications & BIM modelling & collaboration methodology. Modelling, deliverables criteria in each phase of projects are more elaborate and clear than most of the BIM guidelines that exist. Requirements for each discipline namely Architectural, Structural and MEP is listed out separately, hence there is more transparency on the individual deliverables.

Stages	Elements	Modelling Guidelines	Remarks
Conceptual	Existing Buildings (As-Built Condition) for Addition & Alternations.	The Structural Consultants expertise may required when assessing and modelling existing structures, in particular the load-bearing structural system. The scope of Structural BIM model will be agreed upon on a project-specific basis. If the existing Buildings were not in BIM then 2D drawings of existing building can be used to complement the BIM model.	Output: Structural Model of Existing Building or portions thereof.
	New Buildings	The Structural Consultants expertise may be required in special cases in the assessment of the alternatives massing model from Architect and propose framing systems. Structural BIM model is optional at this stage.	Output: Structural concept alternatives.
Preliminary Design Note: Preliminary Design model will be based on Architectural Conceptual Design model. It will be developed further based on the co-ordination during Preliminary Design stage.	General Requirement	Model the elements using the nominal dimension or expected dimension based on precision available at Preliminary Design stage. Model the elements that are critical and required for Preliminary Design co-ordination (based on projects requirement) Connections/Joints and Members can be detailed in the Detail Design stage or Construction stage, depending on the project delivery (traditional or D&B).	Input: Geotechnical information/model, Architectural Conceptual Design Model for intended use (for load assumptions) and geometry of the building (to determine the framing system) Note: The location of load bearing elements and the elevation of the floor will be based on the info from the Architect. Output: ST submission. Refer to BCA's BIM e-Submission requirement and Guidelines. Use BIM e-Submission

Table 5.1 Structural Modelling Guidelines -1– BIM Guide by BCA 2012

			Template. Output: Model for co-ordination with Architects and MEP Engineers
	Piling (Pile Cap and Pile) Diaphragm / Retaining Wall Raft Foundation Pad / Isolated Foundation Strip Foundation	If the BIM authoring tool has relevant objects to represent the foundation elements then place them in the correct level and with the relevant parameter. Alternative is to use Slab, Column and Wall to represent foundation elements. Group them and define the "Type" correctly.	When the design is not confirmed the elements can be modelled as reference to use in the Preliminary Design co-ordination with the Architects and MEP Engineers.
	Slab / Roof Slab	Top of Slab = Structural Floor Level Multiple Slabs need to be placed if the levels, thickness, span direction and material are different. The soffit of the structural slab should be shown. When there is a slope in the Slab or the Slab with a special shape and the BIM authoring tool does not have the functionality to create such Slabs, then create the slab geometry using other tools and define the 'Type' as a "slab".	
	Beam	Top of Beam = As per design (Up stand Beam or Down hang Beam) Create objects for Beams with special shapes and cross sections, e.g. Tapering and haunch.	
	Truss	Model with multiple elements and group them as a truss. Note: Some BIM authoring tools have a function to automate this process.	
	Column	Model from the Structural Floor level to Structural Floor Level of Slab below. Create objects for Columns with special shapes and cross sections.	
	Wall	All Load bearing Walls and concrete Walls (non-load bearing) need to be modelled, e.g. Core Walls, Shear Walls, Retaining Walls, Diaphragm Walls. If the Walls are between floors then model from Structural Floor Level to Structural Floor Level of Slab below else the Walls need to model to the correct levels. When the Wall spans across different heights, if the BIM authoring tool permits model as a single Wall with varying height then model as one Wall. Alternative is to model multiple Walls.	
	Staircase, Step and Ramps	Model only the structure part of the Staircase, Steps and Ramps. Create objects for Staircases, Steps and Ramps with special shapes when it is not available in the BIM authoring tool. If required then the landings and Stair platforms can be modelled as Slabs. In that case define their "Type" accordingly.	
	Opening	Model the structural Opening for the Doors,	

Table 5.2 Structural Modelling Guidelines -2– BIM Guide by BCA 2012

		Windows and Ventilations based on location and size information from the Architects. Model the structural Opening for the MEP elements like Ducts based on the location and size information from the MEP Engineers. Model the Floor openings based on location and Size from the Architects and MEP Engineers.	
	Special Structure Civil defence shelter, Tunnel, Link Way, External structures, Balcony, Canopy, Swimming pool, Temporary structures, Others	Model using Wall, Slab, Column, Beam and Opening or placed as an Object and assign the "Type" accordingly. Check the specific elements for their modelling guideline.	When the design is not confirmed the elements can be modelled as reference to use in the Preliminary Design co-ordination with the Architects and MEP Engineers.
Detailed Design Note: Preliminary Design model is further developed into Detailed Design model	General Requirement	Model all the elements using the actual/accurate dimension. Model all the model elements that are critical and required for the Design co-ordination (based on projects requirement) Detail the Connections/Joints and Members based on the BIM authoring tool's capability. The details can be imported as 2D, which is generated automatically by design tools that can link with BIM authoring tool. Divide the project/building as per various ST's or as per agreed Project Plan. Proceed with the modelling according to the schedule.	Output: ST Submissions. Refer to BCA's BIM e-Submission requirement and Guidelines. Use BIM e-Submission Template. Output: Tender Drawings. Output: Model for co-ordination with Architects and MEP Engineers.
	Refer to Preliminary Design	Develop the Preliminary design with more confirmed parameters like Location, Size and Material. Update the correct Type definition that helps detailed quantity take-off.	The detail can be done only for the agreed portion of the building based on the projects need.
Construction Note: Work together with the contractors and sub contractors to develop the Detailed Design model into Construction model	Refer to Detailed Design model	Model the portions of the buildings that are affected as a result of updates from the Detailed Design models by the other disciplines and variations/RFIs in the design. Deepening of structures should be detailed in shopdrawings, if necessary.	Output: Construction model.
As-Built	Refer to Construction model	When the building is complete, the consultant should check the Detailed Design to correspond with the final implementation (As-Built) based on the information from the Contractor.	Output: Model that can be used for operation, building maintenance and modifications made during occupancy by the FM / Employer.

Table 5.3 Structural Modelling Guidelines -3– BIM Guide by BCA 2012

5.1.7 BIM IMPLEMENTATION IN INDIA

In developing countries like India, BIM implementation is in its early stages. But the forecasted boom in construction industry in India will ensure foreign investors coming to India. This will be instrumental in the wide scale application of BIM in construction projects in India. Even with current absence of BIM standards or implementation plan in India, some of the project infrastructure projects have already adopted BIM work methodology. The projects include:

- Personal Rapid Transit in Amritsar, the scheduling, planning, designing, construction was all done using BIM technology.
- The Bangalore Airport has identified Autodesk BIM 360 as the design and planning of platform for the construction of the Terminal 2.
- The Nagpur Metro Rail Corporation announced for its project the integration of 5D BIM technology.
- Delhi Metro Rail also used BIM technology for construction of the underground track.

Rapid research in the field of BIM implementation is being done in different areas in India by agencies like the India BIM Association. The future looks bright for proper BIM implementation strategies being adopted for public infrastructure projects and high rise buildings.

5.1.8 BIM IMPLEMENTATION IN THE UAE

In the UAE, BIM saw a rise in prominence with the mandate that was introduced by Dubai municipality in 2013. In 2013 the Dubai Municipality issued circular (196), which mandated the use of BIM (Building Information Modelling) for architectural and MEP work on certain projects. This was subsequently widened by circular (207) in 2015 to include architectural and mechanical works for:

- G+20 Buildings
- Areas greater than 200 thousand ft2 for buildings, facilities and compounds.
- Special Buildings such as hospitals and universities
- Government projects.
- Projects done by foreign offices.

The use of BIM in the UAE has been on the rise even before this mandate. For example, BIM has been used in a number of high profile projects, including the Opera House at Downtown Dubai, the Midfield Terminal Complex Development at Abu Dhabi Airport and the Louvre Museum in Abu Dhabi. In addition, the Dubai Road and Transports Authority recently became the first government entity in the world to be awarded a BIM certification by the British Standards Institution. However proper guidelines in the contractual agreements in relation with BIM data exchange in between clients, design firms and contractors along with the universal implementation of BIM mandates across the country is still under working process.

5.2 BIM AWARENESS & CHALLENGES IN THE UAE

As a part of thesis work, a general questionnaire was sent across to different AEC working professionals in the UAE. The questionnaire consisted of 24 questions that gives input on the BIM awareness and future BIM applications and suggestions by the professionals. The survey took place with the help of an online questionnaire, which was sent across to more than 50 working professionals in UAE. Data from the 30 filled questionnaire received back is extracted and analysed below:

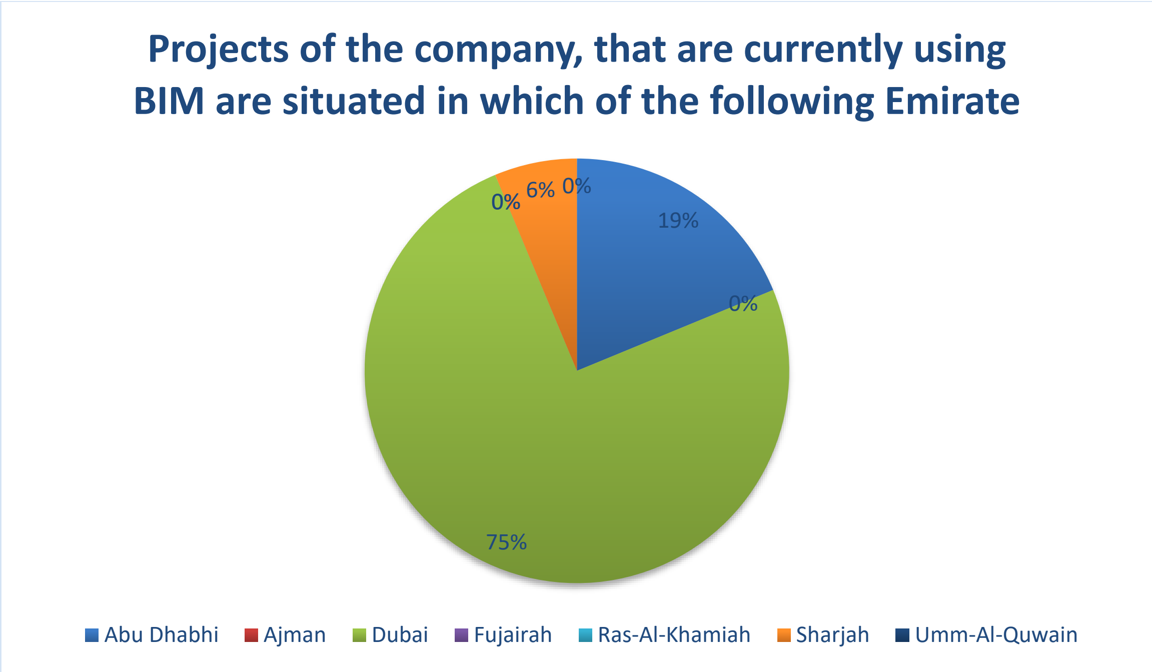

Figure 5.5 BIM Projects Location in UAE

The figure 5.5 shows the location of projects in the UAE that the respondents have been a part of, which has used the possibilities of BIM and BIM workflow. From the data acquired, it is clear that the number of projects in Dubai far outweigh the rest. The set mandates and the contractual client requirements can be considered as the main reason for this trend. Projects in Abu Dhabi also have increasing demand for BIM in consideration with the rest of the Emirates. Certain projects in Sharjah also have shown the adaption of BIM. None of the respondents have mentioned any project (that they have been a part of) in the rest of the Emirates, which have used BIM methodology.

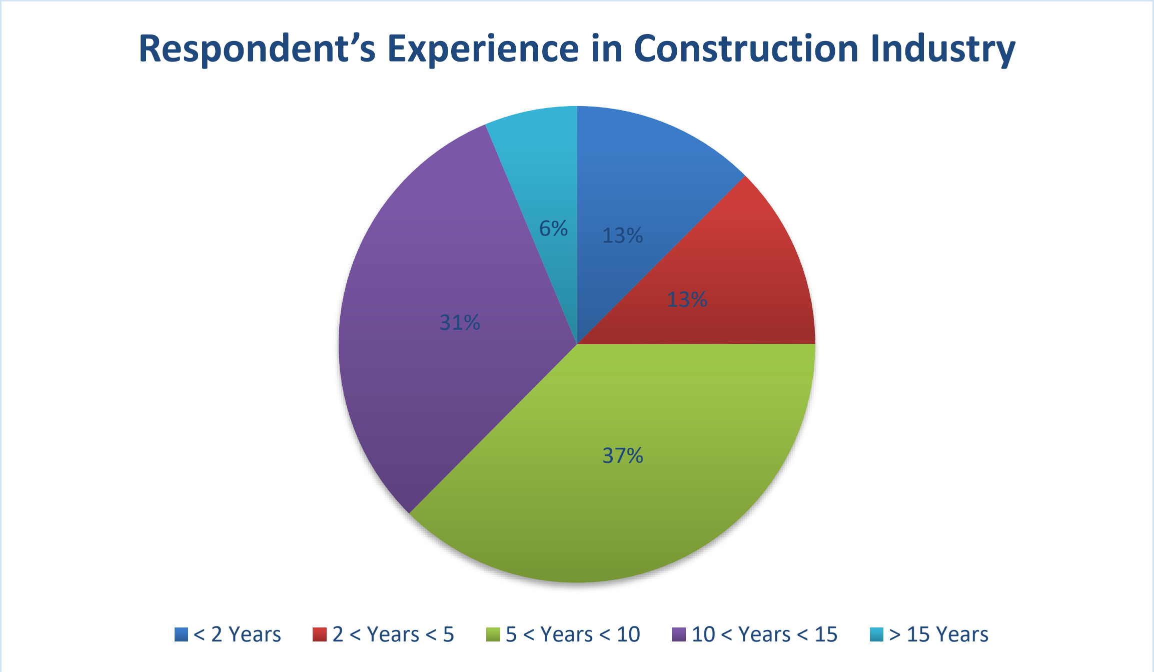

Figure 5.6 Construction Industry Experience

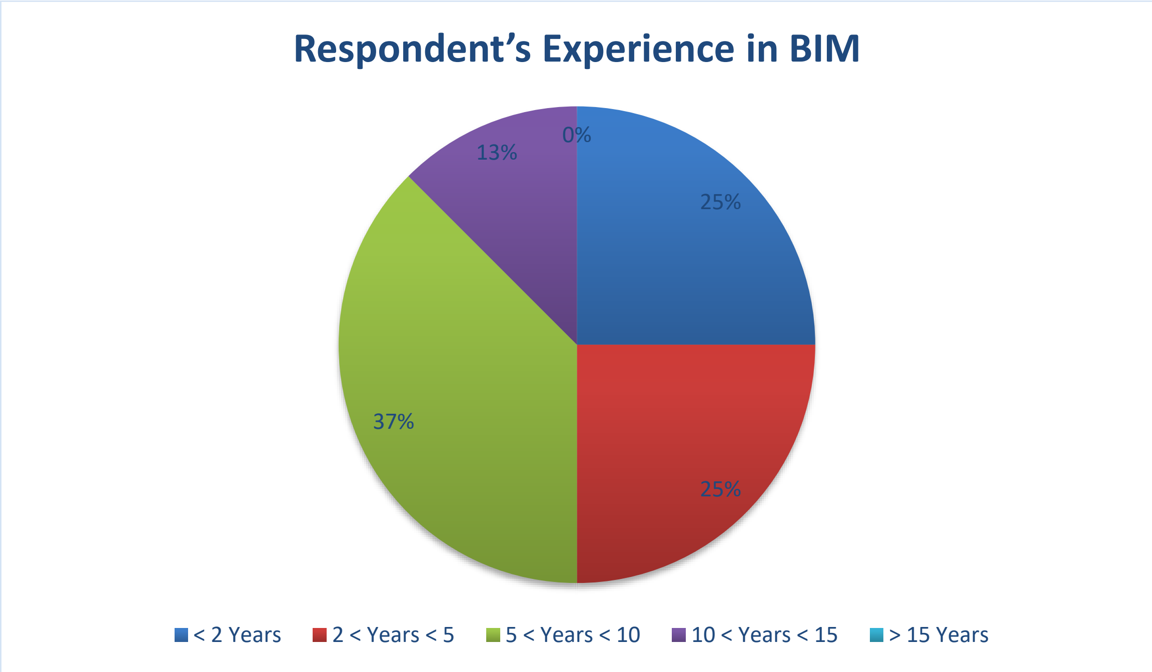

Figure 5.7 BIM Experience

The Figure 5.6 & Figure 5.7 draws a comparison between the actual construction industry experience and BIM experience of the respondents. There is a gap in between the actual number of construction experience and related BIM experience. This shows the relatively new nature of the concept of BIM in the construction industry. But the increasing number of personnel making use of the BIM workflow and methodology shows the increasing trend of adaptation of BIM due to various factors and industry demands.

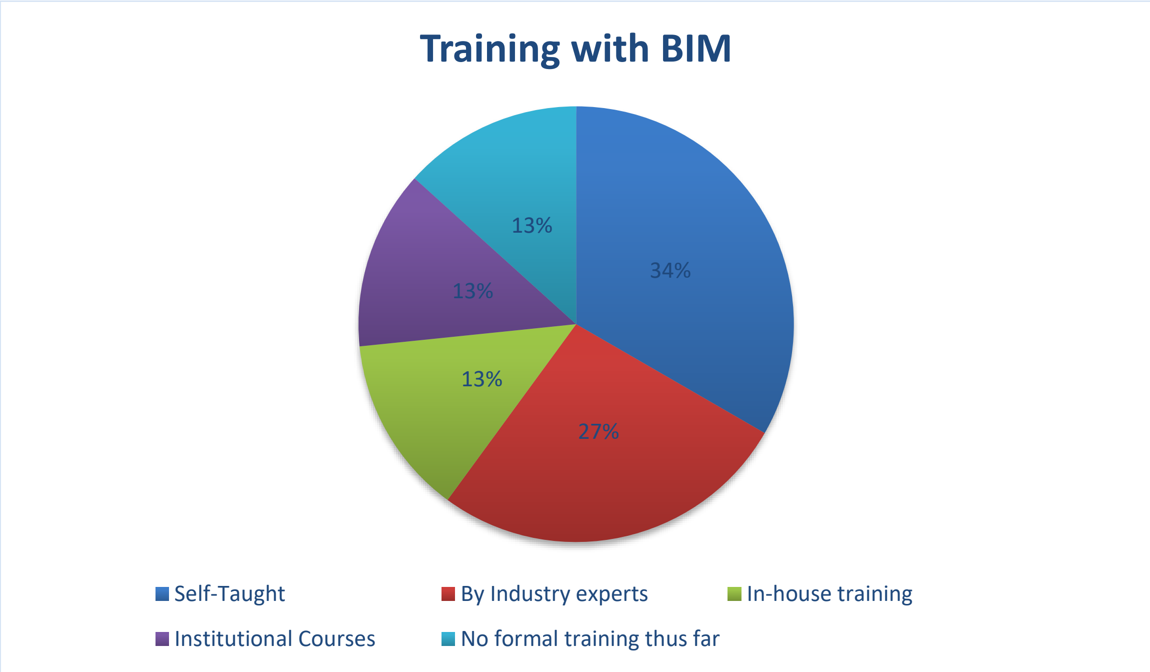

Figure 5.8 BIM Training

The figure 5.8 above shows data on the training methods of the respondents in relation to BIM. The training with the BIM and BIM softwares have been mainly self-taught or by industry experts for the respondents. People who have had in-house training from their respective offices, people who had taken up institutional courses and people who had no formal training thus far remains in the same ratio.

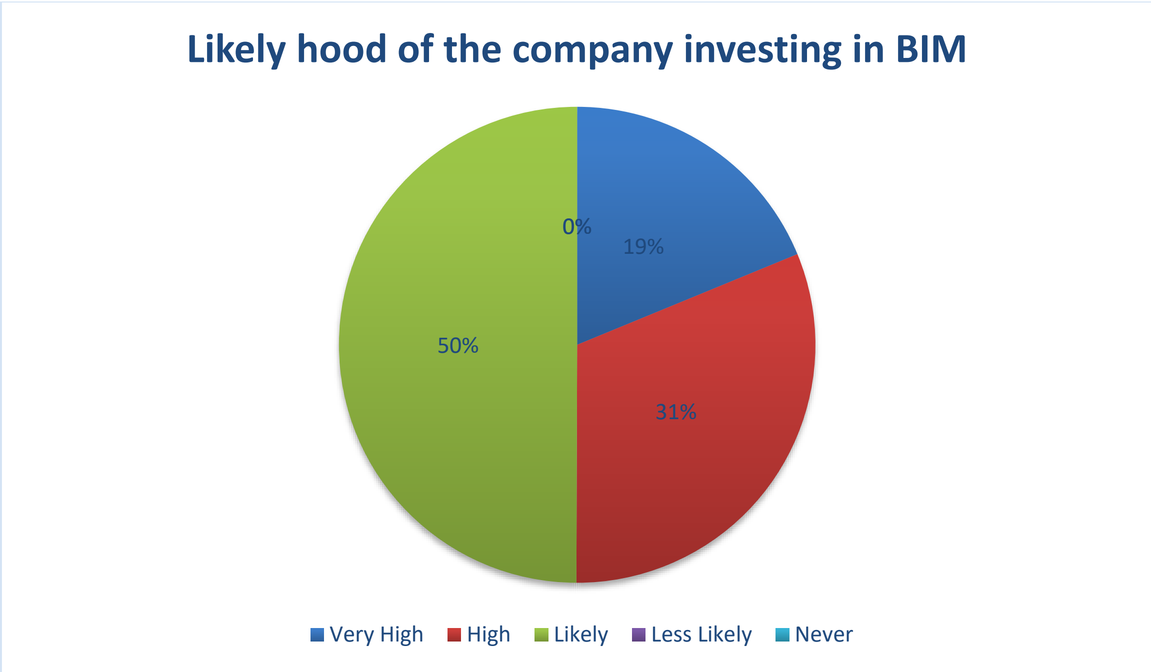

Figure 5.9 Investing in BIM

Figure 5.9 shows the likelihood of their current employer/ company in investing in BIM and training of their staff. Every respondent felt that the company will eventually invest in BIM eventually. The likelihood of the employer investing in BIM was rated likely by half of the respondents, more than quarter of them felt a high chance of the company investing in the process, while the rest had a very high feeling of the company investing in BIM.

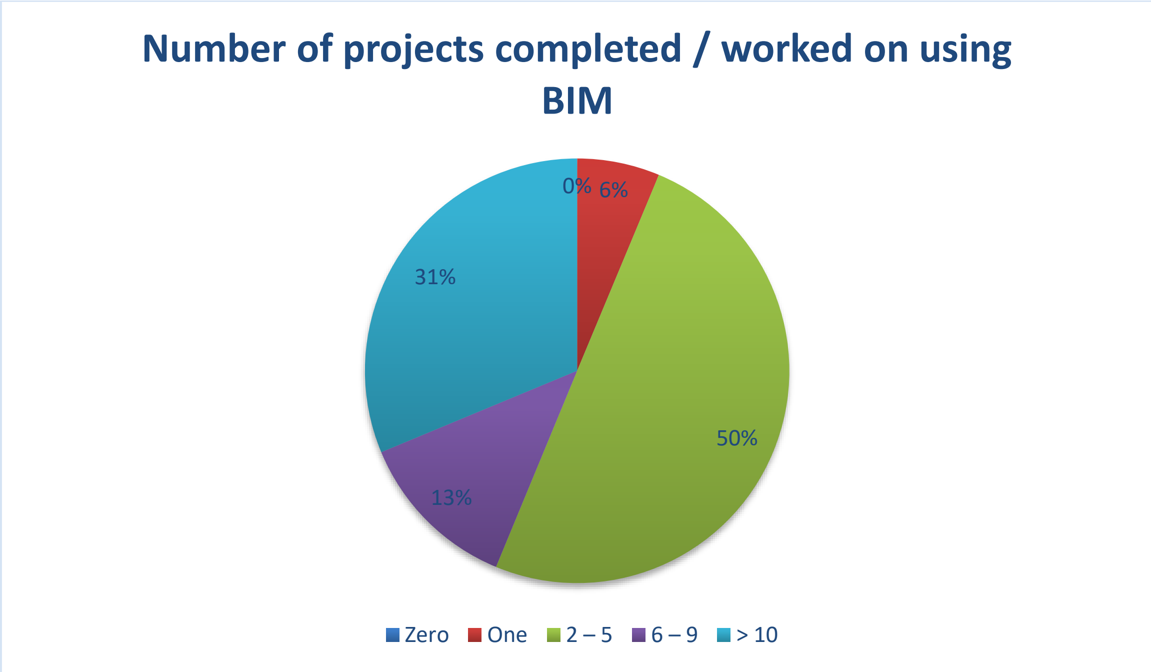

Figure 5.10 Number of BIM Projects Completed

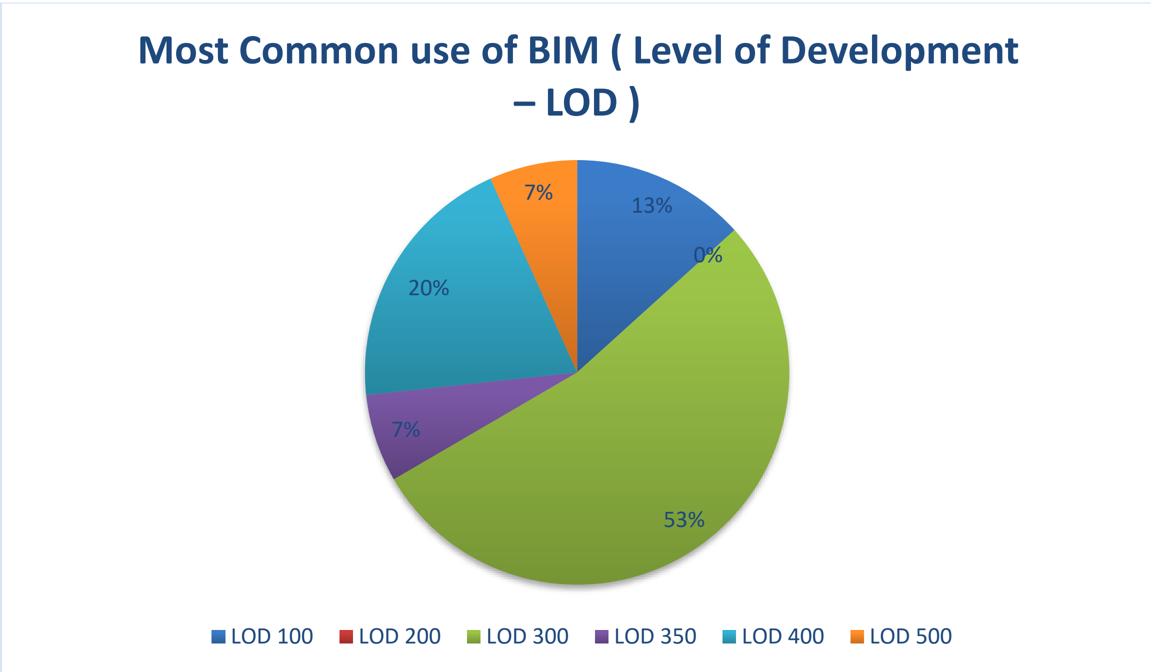

Figure 5.11 Most Common LOD used

The Figure 5.10 & Figure 5.11 shows the number of projects that were completed using BIM and the most common BIM LOD model that was used for them. Half of the respondents were only 2-5 projects old in the adaptation of BIM into their project workflow. More than quarter of the respondents has more than 10 completed projects in BIM. Only a marginal percentage of the respondents had experience of just a preliminary project in BIM.

The most common usage of BIM is for LOD 300 models for the respondents. This shows the vast inclusion of BIM into design practices and consultants alike. Construction / clash detection models such as LOD 350, LOD 400 and LOD 500 make up just more than a quarter of the common use of BIM. There is also marginal use for LOD 100 models for the respondents. This shows the inclusion of BIM into concept design documents.

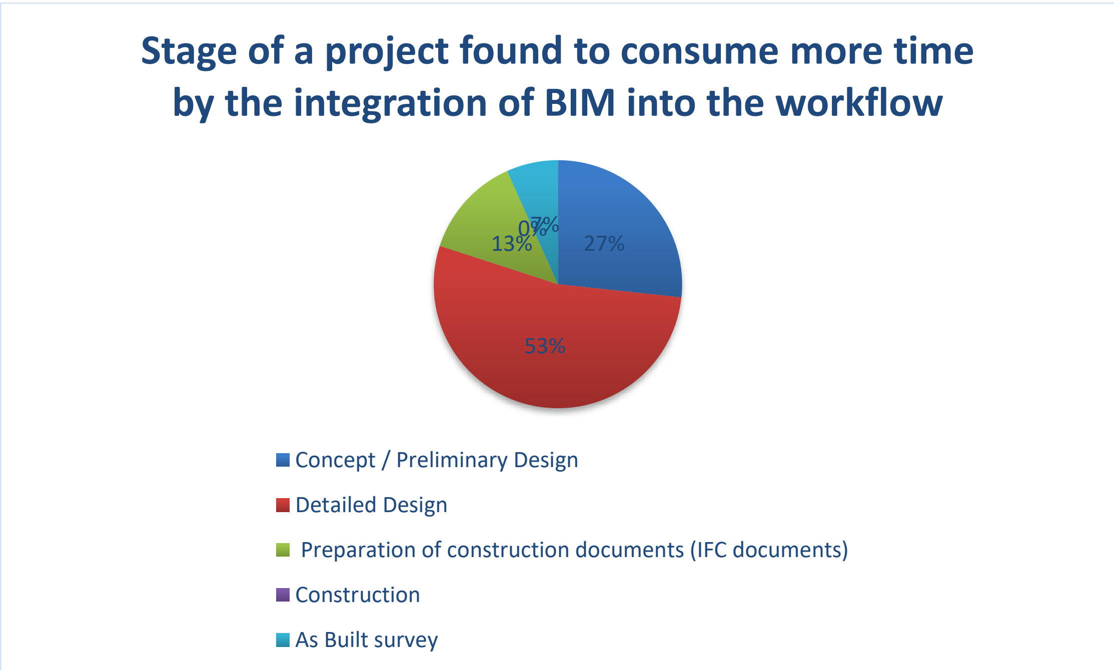

Figure 5.12 Stage of Project Where BIM is More Time Consuming

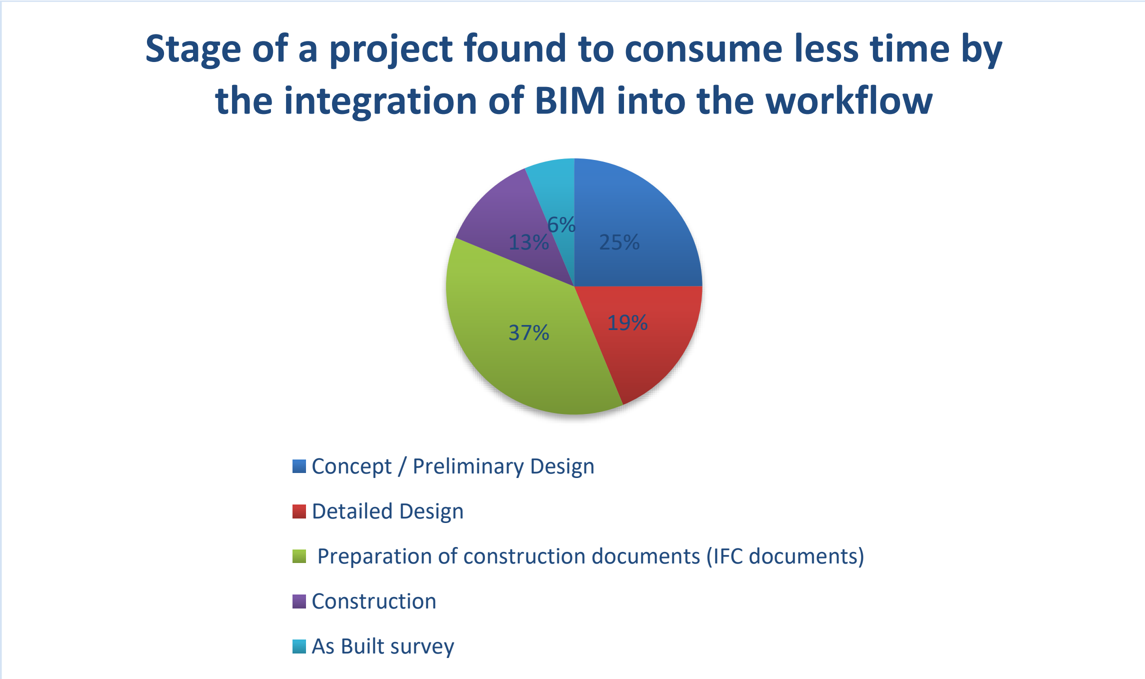

Figure 5.13 Stage of Project where BIM is less time consuming

The Figure 5.12 & 5.13 shows the time distribution of BIM in project phases from concept to 'As-Built' survey. More than half of the respondents felt that BIM is responsible for taking up more time in the detailed design phase. More than quarter of them felt that setting up of a BIM model in the concept stage will consume more time than the traditional workflow and methods.

By the production of BIM models, the time taken for the production of construction documents, shop drawings and 'as-built' survey has shown to reduce. Thus the implication of BIM for the long run is established as the documents become more transparent and error free as the project phases develop.

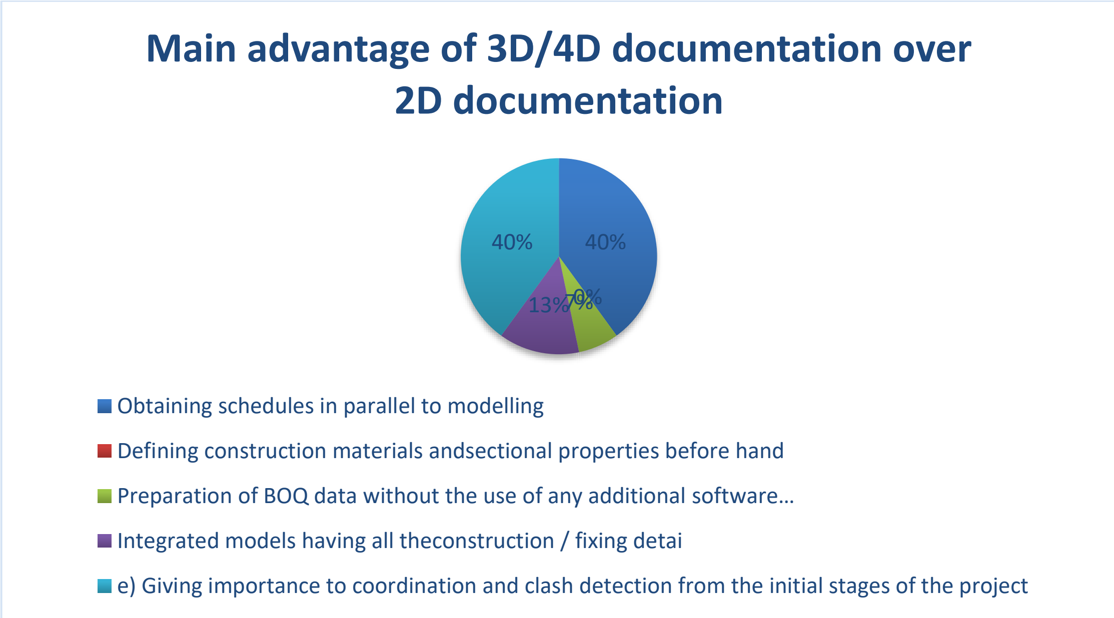

Figure 5.14 Main Advantage of BIM over 2D Documentation

Figure 5.14 depicts the advantages of BIM documentation methods over the traditional 2D documentation techniques and methods. An equal amount of respondents felt that the BIM way of clash detection/ coordination checks from the early stages of the project by the concept of virtual construction and the production of timely schedules along with the modelling process contributed as the main advantage of BIM documentation process. The rest felt the preparation of BOQ data and the data rich models with all construction and fixing detail in-cooperated by the BIM softwares directly, had the major advantage over the traditional methods.

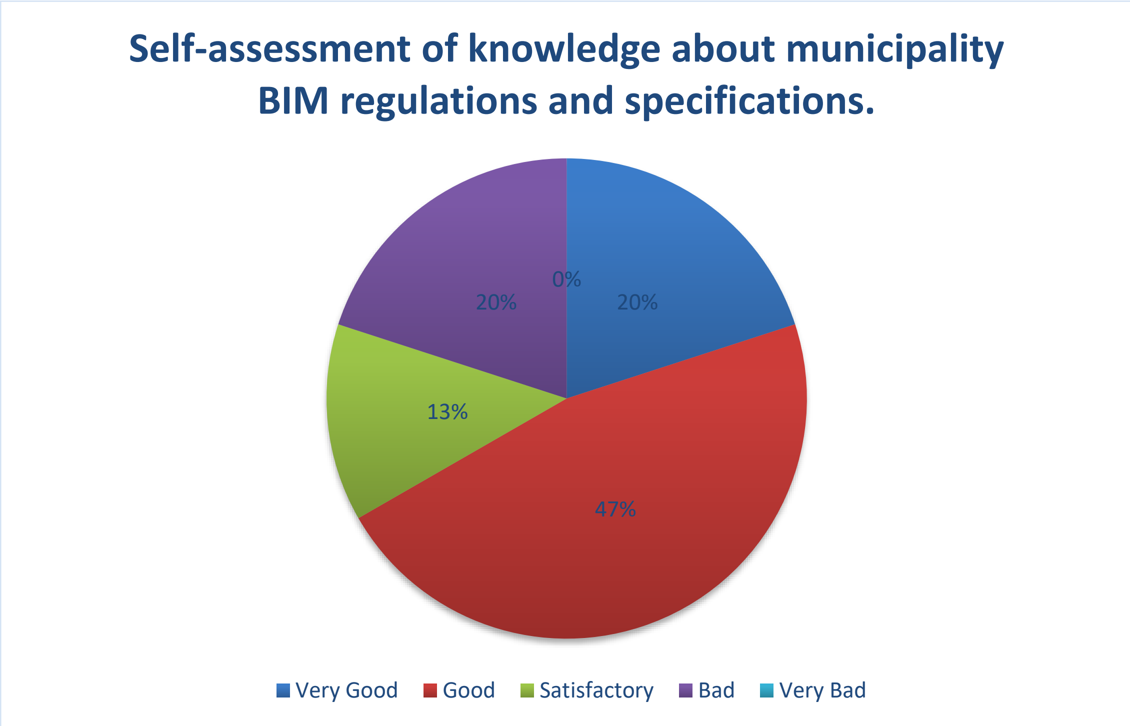

Figure 5.15 Knowledge about BIM mandates in UAE

The figure 5.15 shows the respondent's self-evaluation of the BIM mandates set up by the concerned authorities in UAE. Almost half of them felt that they had very good knowledge about the BIM regulations and mandates in UAE. 20 % of the respondents felt they had very good knowledge about the standards while another 20 % felt that they had bad or dismissal knowledge about the same. A small percentage felt they had about satisfactory knowledge on the matter.

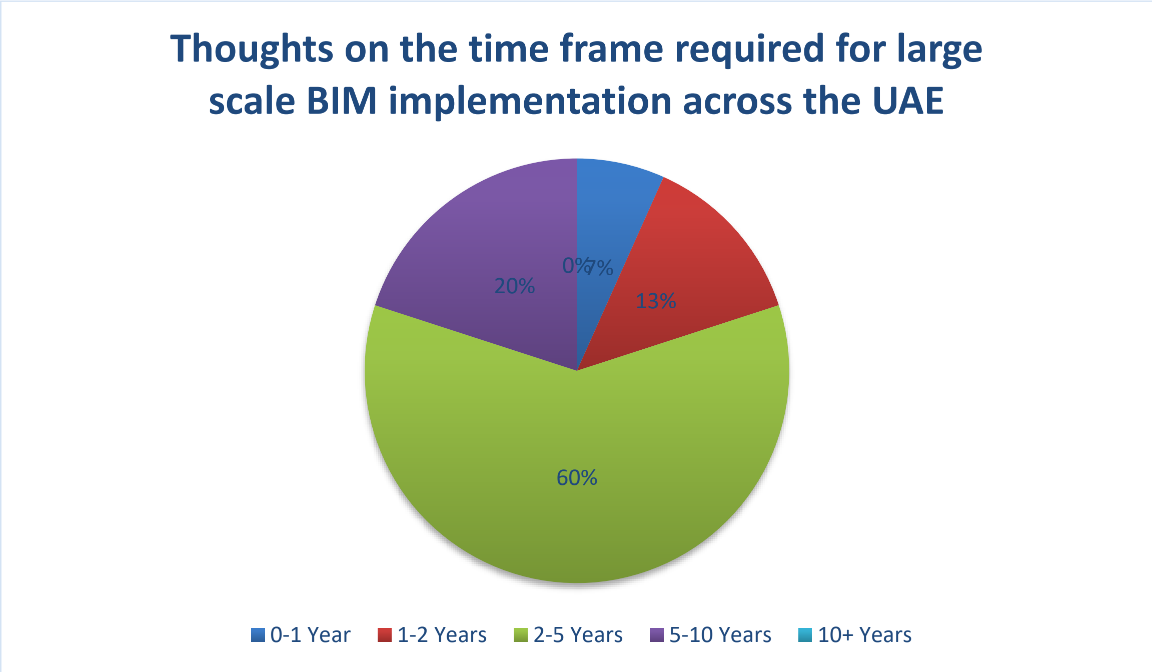

Figure 5.16 Time required for large scale BIM implementation in UAE

The figure 5.16 shows the thoughts of the respondents about the time frame required for the large scale BIM implementation in the UAE. More than half of the respondents thought that a time frame of 2- 5 years will be more realistic in the large scale implementation of a proper BIM strategy into the UAE market as of the current scenario. Almost a quarter of the respondents felt that the implementation will only take place in a time frame of 5-10 years from now, while a marginal percentage felt that it could go well beyond 10 years. A small percentage also felt that the process can be done in 1-2 years as well.

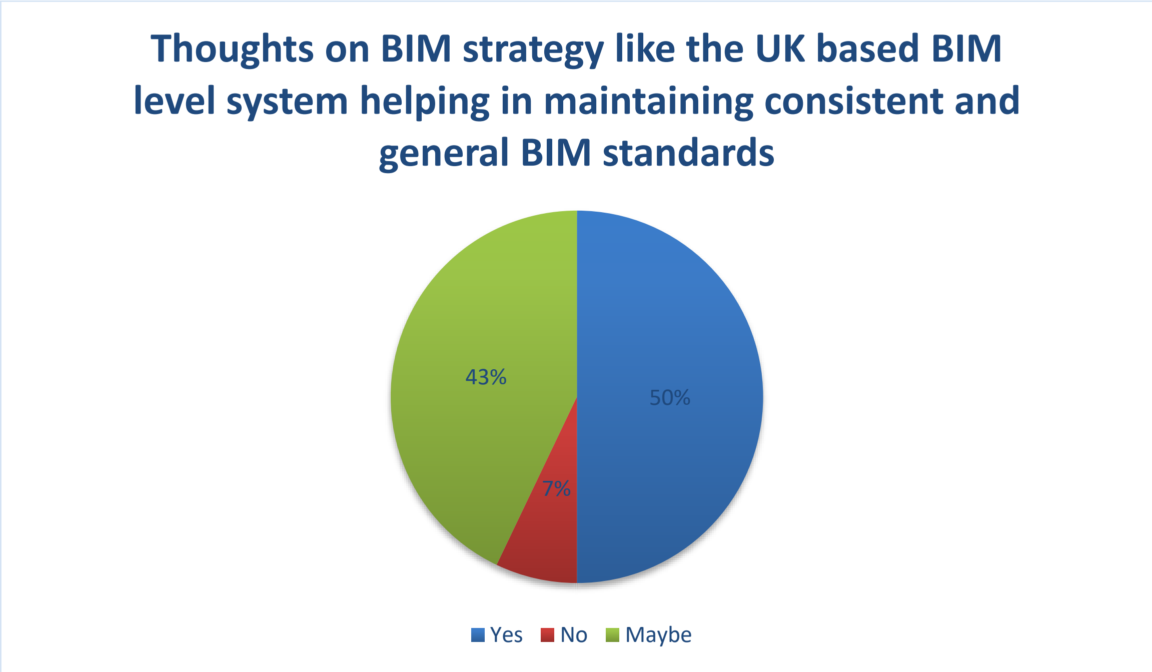

Figure 5.17 Thoughts on implementing UK based BIM standards in UAE

The figure 5.17 shows the thoughts of the respondents on setting up a national BIM strategy in UAE similar to the industry pioneers like UK based BIM level system. Half of the respondents felt that it will make a positive impact in the large scale BIM adaptation in the country. A marginal percentage of them felt that it will not have any impact of the current scenario. The rest was unsure on the applications and impacts of adopting a similar strategy in the UAE.

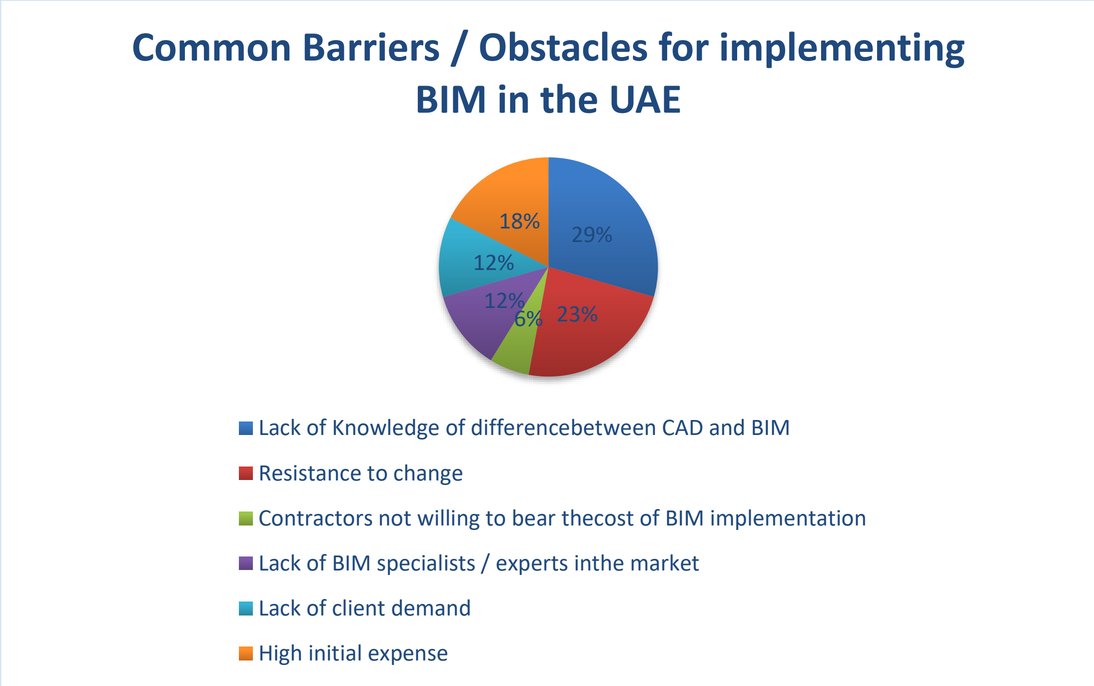

Figure 5.18 Common barriers in BIM implementation in UAE

The figure 5.18 shows the common concerns in the implementation of BIM in the UAE. More than a quarter of the respondents felt that the lack of general awareness on the difference between traditional 2D based CAD workflow and the BIM workflow as the major obstacle in BIM implementation. The resistance to change away from the traditional methods is a close second obstacle that was rated. High initial expenses are another major concern because of the cost of BIM softwares and training requirement for the same. Lack of BIM specialists in the market and the lack of client demand is rated equally among the concerns listed. The unwillingness of the contractors to bear the additional cost of BIM implementation and hiring of BIM personnel also has marginal concerns.

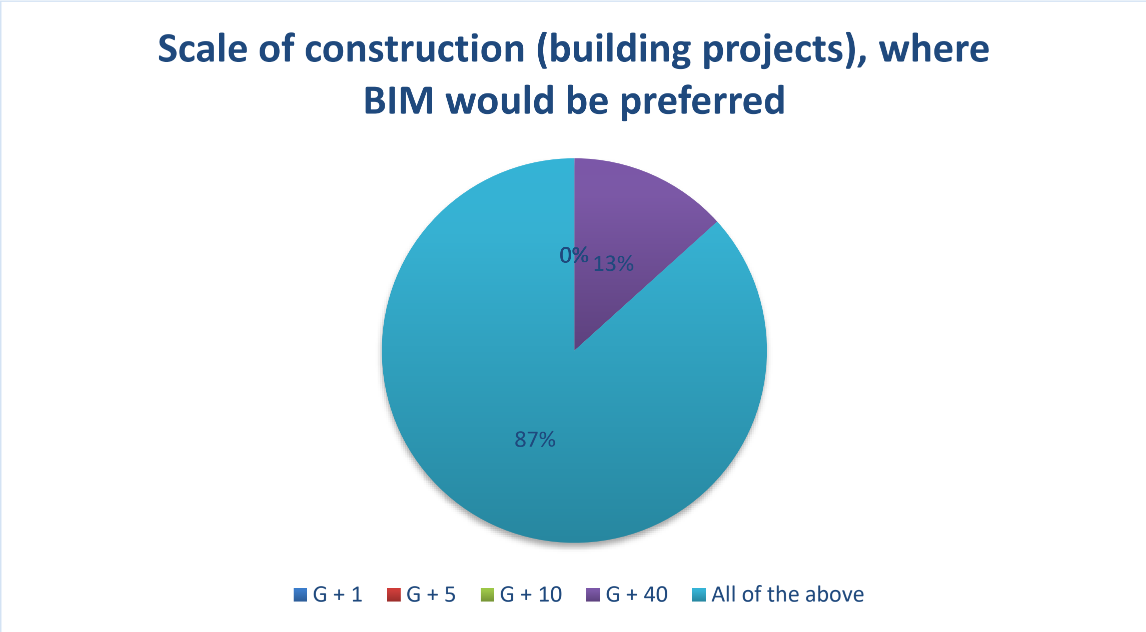

Figure 5.19 Scale of projects where BIM is preferred

The figure 5.19 shows the preferences of the respondents for the scale of the building projects where BIM workflow would be preferred by them. Vast majority of the respondents felt that BIM should be implemented in all scale of building projects ranging from G+1 to G+40. A small percentage felt that BIM is better preferred for only large scale projects at the time being.

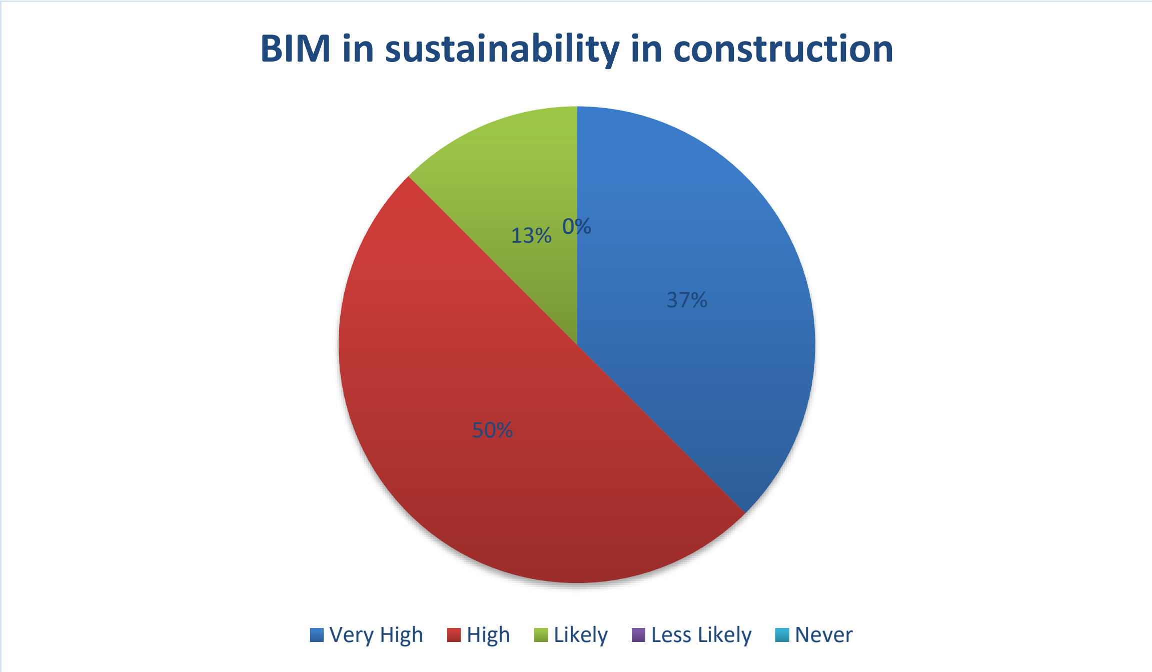

Figure 5.20 BIM in sustainability

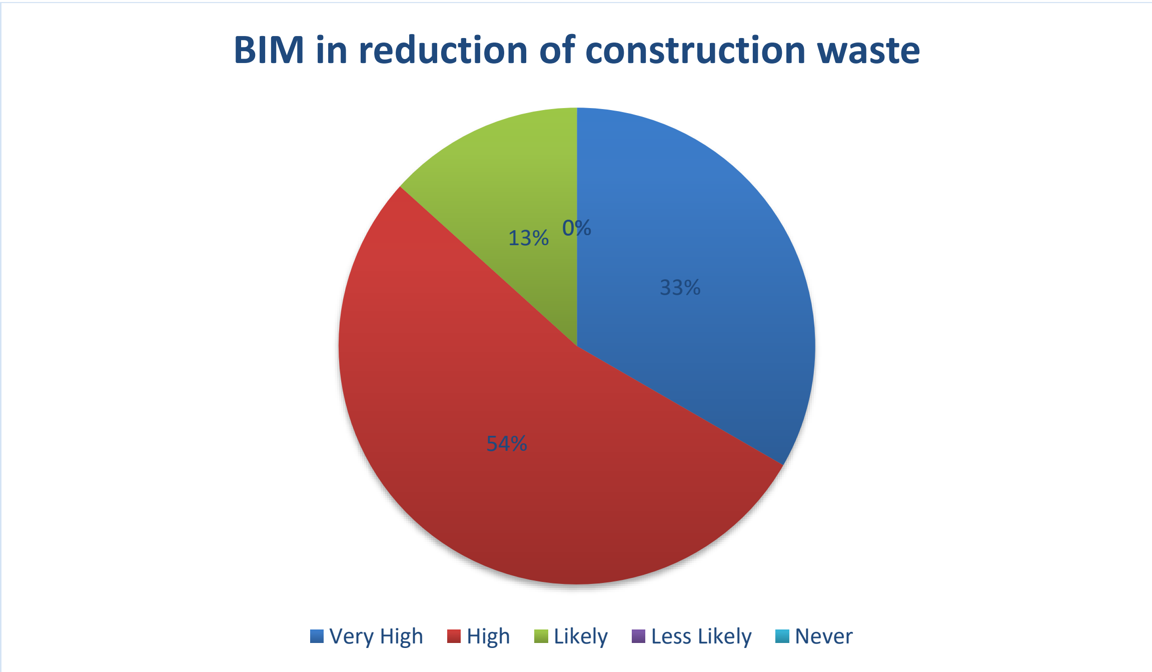

Figure 5.21 BIM in Waste reduction

The figure 5.20 & figure 5.21 shows the thoughts of the respondents on the applicability of BIM in sustainability and overall reduction of construction waste in the industry. Half of them felt very high contribution of BIM towards sustainability in construction. More than a quarter felt very high contribution towards sustainability by the proper implementation of BIM in project workflow. A small percentage felt a likely contribution of BIM towards the overall contribution of BIM in sustainability front.

More than half of the respondents felt that there will be high reduction of construction waste, if BIM is applied to design and construction phase of a project. More than quarter felt a very high chance of this happening. A small percentage felt that it is likely that BIM also contributes to the reduction of construction waste by the proper applications of the same.

There have been numerous opinions that were proposed by the respondents for the increase of BIM usage and the need for setting up BIM standards for the country. Some of the opinions involve making strict regulations on submission of BIM models in the municipality for projects of all scale.

CHAPTER-6

SUMMARY & CONCLUSION

In this section, we take summarised look into the 3 phases of the research work. The findings found regarding difference of Structural BIM workflow over traditional workflow, the impact of national BIM standards and mandates on nation-wide BIM adaptation and the BIM awareness and challenges currently existing in UAE is discussed below:

6.1 STRUCTURAL BIM WORKFLOW OVER TRADITIONAL WORKFLOW

In this research, the applications for BIM in structural engineering were evaluated in both theoretical and practical approach by the use of case study. The BIM approach was found to produce more error-free data, since there was no loss of information when the analytical data from the design software was transferred to the modelling software, thus enhancing the Structural work flow and design optimisations were found to be simplified. The 3D representation of reinforcement data gave more space for coordination issues in line with the concept of virtual designs. However the skill sets of the Design Engineer and the BIM modeller should be relative to each other as data exchange through softwares is found to be more transparent and hence technical information should be carefully assigned with intention to transfer the same information across the design and modelling phase. Time taken for the design, modelling, coordination and production of drawings were found to be decreased due to the BIM compliance of the modelling and design software.

6.2 BIM ADOPTION IN DIFFERENT COUNTRIES

On accessing the BIM implementation status in the different countries, it can found that BIM mandates play a huge role in determining the pace at which BIM adaptation happens nation-wide. National BIM mandates and standards introduced in the UK, was helpful in maintaining consistency among authority based submissions and working standards among architects, engineers and contractors. The mandate and subsequent protocol introduced was helpful in achieving a gradual but consistent increase of 61 % (13 % to 74%) BIM adoption in the country over the span of 8 years. Long-time goals set across by the government with a vision to exploit the full potential of BIM including construction waste reduction by 1/3rd of the current scenario, shows the enthusiasm in investing in BIM.

The lack of national BIM mandates and also different BIM standards set up by different regulatory bodies across the country in the USA is slowly affecting the national BIM adoption percentage. Standards set up by the contractors and clients individually goes unchecked by the authority as 3D collaborative authority submission is not mandated in many parts of the country. The fact that different public projects fall under different authorities and the lack of initiation by the central government to develop a consistent BIM standard and mandate can be found as the main hindrance to implement BIM in all public projects, even though the technology was in use for a longer time in consideration to other countries.

There is limited availability of data regarding the current status of BIM adoption in Singapore. But the early recognition of the potentials of BIM by the government and implementation of BIM mandates and standards across the country can be found as the positive impacts of BIM adoption in the country. BIM fund released by the government and also roadmaps developed for future BIM implementations and applications in the country is helping making BIM more accessible to a larger part of the construction industry. India is a relatively new adapter of BIM. There have been public infrastructure projects done in India using BIM methodology, however no mandate or standards that haven set by any government authorities for this. This will be deteriorating the chances of having a BIM implementation strategy for the whole country.

6.3 BIM ADOPTION IN UAE - CHALLENGES

In UAE, Dubai Municipality has been the pioneer in introducing a set mandate for adaption of BIM in projects of specific functions (as listed in 5.1.8). However mandates in other emirates are still under working progress and hence there is an absence of BIM national mandate. The need for national BIM standards and protocols is evident from the in-consistent work methodology among different consultancies and contractors within the country.

From the market survey conducted, it can be found that the BIM awareness in UAE is on the raise. The use of BIM technology based work has been increasing in consultancies and contractors in the UAE. But most of the time, the companies work on their individual set standards and hence there is inconsistency among the deliverables and LOD standards.

Number of experienced professionals and the companies ready to invest in BIM has also been on the raise. This can be attributed to the recognition of the advantages of BIM workflow over the traditional workflow. This includes cost and time saving for the projects, production error-free construction documents by the principal for virtual construction, co-ordination and involvement of all stake-holders in all stages of project, the ease of information transfer, reduction in construction waste management, sustainability aspects, etc.

The need for a large scale BIM implementation strategy across UAE was expressed by most of the respondents. BIM adoption strategies adopted from countries that have done successful implementation of mandates and standards like UK was preferred by most of the respondents, as it will ensure consistent standards across the country. The lack of knowledge between the traditional workflow and BIM workflow and the resistance to change among the construction industry in general, has been found as the most concerning aspect in large sale BIM adaptation in the country.

The cost implications of BIM were also raised as an issue among the respondents. The lack of contractual clauses regarding the proper BIM deliverables can only be overcome by national BIM guidelines/ protocol development. National level roadmap of BIM implementation like in Singapore can be helpful in spreading BIM awareness across the construction industry and also allocate for the proper BIM training for professionals.

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APPENDICES

APPENDIX A: THESIS–QUESTIONNAIRE MODEL

1. Respondent's Profession
    a) Structural Design Engineer (Jnr.) (< 5 Year Experience in Consultancy)
    b) Structural Design Engineer (Snr.) (> 5 Year Experience in Consultancy)
    c) Site Architect / Consultant Architect
    d) Civil Engineer (Resident / Site)
    e) Project Manager
    f) Quantity Surveyor
    g) BIM Engineer
    h) BIM Manager
    i) BIM Coordinator
    j) General Draftsman

2. Projects of the company, that are currently using BIM are situated in which of the following Emirate
    a) Abu Dhabi
    b) Ajman
    c) Dubai
    d) Fujairah
    e) Ras-Al-Khamiah
    f) Sharjah
    g) Umm-Al-Quwain

3. Respondent's Experience in Construction Industry
    a) < 2 Years
    b) 2 < Years < 5
    c) 5 < Years < 10
    d) 10 < Years < 15
    e) > 15 Years

4. Respondent's Experience in BIM
    a) < 2 Years
    b) 2 < Years < 5
    c) 5 < Years < 10
    d) 10 < Years < 15
    e) > 15 Years

5. Number of projects completed / worked on using BIM
   a) Zero
   b) One
   c) 2 – 5
   d) 6 – 9
   e) > 10

6. Most Common use of BIM (Level of Development – LOD)
   a) LOD 100
   b) LOD 200
   c) LOD 300
   d) LOD 350
   e) LOD 400
   f) LOD 500

7. Softwares used / preferred for BIM Projects
   a) Autocad
   b) Archicad
   c) Revit
   d) BENTLY
   e) Tekla Structures
   f) Navisworks
   g) Others (Please Specify)

8. Please make a self-assessment of your particular knowledge about municipality regulations and specifications of BIM implementation into projects.
   a) Very Good
   b) Good
   c) Satisfactory
   d) Bad
   e) Very Bad

9. Common Barriers / Obstacles for implementing BIM in the Middle East
   a) Lack of Knowledge of difference between CAD and BIM
   b) Resistance to change
   c) Contractors not willing to bear the cost of BIM implementation
   d) Lack of BIM specialists / experts in the market
   e) Lack of client demand
   f) High initial expense
   g) Not suitable for the projects in hand

10. Respondent’s training with BIM
    a) Self-Taught
    b) By industry experts
    c) In-house training
    d) Institutional Courses
    e) No formal training thus far

11. Likely hood of the company investing in BIM
    a) Very High
    b) High
    c) Likely
    d) Less Likely
    e) Never

12. Specific BIM duty of the respondent
    a) Analyse models for coordination / clash detection
    b) Train others in BIM usage
    c) Extract Estimates from BIM models
    d) Creation of 2D – Autocad plans
    e) Creation of 4D – Schedule Sequencing
    f) Managing BIM personnel and activities
    g) Create site logistics plans and models

13. Do you feel the usage of BIM has contributed to time saving for the projects
    a) Yes
    b) No
    c) Marginal

14. Do you feel the usage of BIM is cost effective in the long run
    a) Yes
    b) No

15. Which stage of a project has been found to consume more time by the integration of BIM into the workflow
    a) Concept / Preliminary Design
    b) Detailed Design
    c) Preparation of final construction documents (IFC documents)
    d) Construction
    e) As Built survey

16. Which stage of a project has been found to consume less time by the integration of BIM into the workflow

a) Concept / Preliminary Design
b) Detailed Design
c) Preparation of final construction documents (IFC documents)
d) Construction
e) As Built survey

17. Main advantage of 3D/4D documentation over 2D documentation
    a) Obtaining schedules in parallel to modelling process
    b) Defining construction materials and sectional properties before hand
    c) Preparation of BOQ data without the use of any additional software / personnel
    d) Integrated models having all the construction / fixing detail
    e) Giving importance to coordination and clash detection from the initial stages of the project

18. What kind of projects have been benefited more since the introduction of BIM into the workflow
    a) Building Design / Construction projects
    b) Infrastructure projects
    c) Water / Irrigation projects
    d) Transport Engineering projects
    e) Special Constructions (Airport / Metro rail / Harbours etc)

19. Scale of construction (building projects), where BIM would be preferred
    a) G + 1
    b) G + 5
    c) G + 10
    d) G + 40
    e) All of the above

20. Do you feel a similar BIM strategy like the UK based BIM level system will be helpful in maintaining consistent and general BIM standards
    a) Yes
    b) No
    c) Maybe

21. Your thoughts on the time frame required for large scale BIM implementation across the UAE
    a) 0-1 Year
    b) 1-2 Years
    c) 2-5 Years
    d) 5-10 Years

e) 10+ Years

22. How much do you rate the contribution of BIM in sustainability in construction
    a) Very High
    b) High
    c) Likely
    d) Less Likely
    e) Never

23. What are the chances of reduction of construction waste, by proper implementation of BIM in design and construction
    a) Very High
    b) High
    c) Likely
    d) Less Likely
    e) Never

24. Have got any suggestions for improving BIM workflow in UAE. Please note below: