GREEN TECHNOLOGY APPLICATION IN CONSTRUCTION USING BUILDING INFORMATION MODELLING

Master Thesis

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GREEN TECHNOLOGY APPLICATION IN CONSTRUCTION USING BUILDING INFORMATION MODELLING

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This thesis titled "GREEN TECHNOLOGY APPLICATION IN CONSTRUCTION USING BUILDING INFORMATION MODELLING" has been prepared and submitted by Khwaja Mohammad Ashraf NOORI in partial fullfillment of the requirements in "Eskişehir Technical University Directive on Graduate Education and Examination" for the Degree of Master of Science in Civil Engineering Department has been examined and approved on 22/03/2019.

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ABSTRACT

GREEN TECHNOLOGY APPLICATION IN CONSTRUCTION USING BUILDING INFORMATION MODELLING

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March 2019

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Building industry greatly contribute to global warming and CO_2 emission. Power plants providing energy for buildings are mostly operated by fossil fuels. With invention of BIM (Building Information Modelling) and possibility of building analysis prior to construction, it is possible to reduce building impact on environment using different alternatives.

This study mainly focuses on green technology and sustainability analysis using BIM. An already built residential building is considered for analysis and is compared with an alternative design using ecofriendly materials. The results show that going green and implementing green technology and sustainability on building industry costs little bit more in the beginning but is effective in the long run. Alternative design significantly saves energy and water during building lifecycle which also lowers building impact on environment. Green technology and using ecofriendly design helps in qualifying for LEED which helps toward standardizing building industry.

The findings of this study will provide the platform aimed at exploring the technological benefits, and operational flexibility that green technology application in construction with BIM had created.

Keywords: BIM, Green technology application, sustainability, construction industry.

ÖZET

İNŞAAT SEKTÖRÜNDE YAPI BİLGİ MODELLEMESİ İLE YEŞİL TEKNOLOJİ UYGULAMASI

Khwaja Mohammad Ashraf NOORI

İnşaat Mühendisliği Anabilim Dalı
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Mart 2019

Danışman: Dr.Öğr.Üyesi Serkan KIVRAK

İnşaat sektörü küresel ısınmaya ve CO_2 emisyonuna büyük ölçüde katkıda bulunmaktadır. Binalar için enerji sağlayan enerji santralleri çoğunlukla fosil yakıtlarla işletilmektedir. BIM'in icadı ve inşaat öncesinde yapı analizi yapma olasılığı ile farklı alternatifler kullanarak çevre üzerindeki inşaat etkisini azaltmak mümkündür.

Bu çalışmanın temel odak noktasını yeşil teknoloji ve sürdürülebilirlik analizinde BIM kullanımı oluşturmaktadır. Bu çalışmada analiz için yapımı tamamlanmış bir konut binası seçilmiş ve çevre dostu malzemeler kullanılarak bu bina alternatif bir tasarım ile karşılaştırılmıştır. Çalışmanın sonuçlarına göre yeşil teknolojinin ve sürdürülebilirliğin sağlanması inşaat sektöründe başlangıçta biraz daha maliyetli olsa da uzun vadede etkili olduğunu göstermektedir. Alternatif tasarım bina ömrü boyunca enerji ve su tasarrufu sağlar. Bu ise çevre üzerinde inşaat etkisinin azalmasına neden olur. Çevreci görünmek ve çevreye duyarlı tasarım kullanmak LEED'i seçmeye hak kazandırır. Dolaysıyla bina endüstrisinin standartlaşmasına yardımcı olur.

Bu çalışmanın bulguları BIM ile inşaat projelerinde yeşil teknoloji uygulamasının getirdiği teknolojik faydaları ve operasyonel esnekliği keşfetmeyi amaçlayan platformu sağlamaktadır.

Anahtar Kelimeler: BIM, Yeşil Teknoloji Uygulaması, Sürdürülebilirlik ve İnşaat Sektörü.

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I would like to thank my dear family for their always and kind support during this Masters study. I would like to dedicate this research to my kind parents.

Khwaja Mohammad Ashraf NOORI

March 2019

22/03/2019

STATEMENT OF COMPLIANCE WITH ETHICAL PRINCIPLES & RULES

I hereby truthfully declare that this thesis is an original work prepared by me; that I have behaved in accordance with the scientific ethical principles and rules throughout the stages of preparation, data collection, analysis and presentation of my work; that I have cited the sources of all the data and information that could be obtained within the scope of this study, and included these sources in the references section; and that this study has been scanned for plagiarism with "scientific plagiarism detection program" used by Anadolu University, and that "it does not have any plagiarism" whatsoever. I also declare that, if a case contrary to my declaration is detected in my work at any time, I hereby express my consent to all the ethical and legal consequences that are involved.

Khwaja Mohammad Ashraf NOORI

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AEC	Architecture, Engineering & Construction
AIA	American Institute of Architects
BAS	Building Automation System
BEAM	Building Environmental Assessment Method
BEPAC	Building and Environmental Performance Assessment Criteria
BIM	Building Information Modeling
BOQ	Bill of Quantity
BREEAM	Building Research Establishment Environmental Assessment Method
CAD	Computer Aided Drafting
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
CO_2	Carbon dioxide
DGNB/BNB	Deutsche Gesellschaft für Nachhaltiges Bauen / Bewertungssystem Nachhaltiges Bauen für Bundesgebäude
EPA	Environmental Protection Agency
FM	Facility Management
GBCA	Green Buildiing Council of Australia
gbXML	Green Building Extensible Markup Language
GHG	Greenhouse Gas
GIS	Geographic Information System
GLIDE	Graphical Language for Interactive Design
GRIHA	Green Rating for Integrated Habitat Assessment
HR	Human Resource
IFC	Industry Foundation Classes
JSBC	Japan Sustainable Building Consortium
LEED	Leadership in Energy and Environmental Design

LoD	Level of Develeopment
MEP	Mechanical, Electrical, Plumbing
NZGBC	New Zealand Green Building Council
O&M	Operation and Maintanance
PtD	Prevention through Design
RFID	Radio Frequency Identification
TPP	Technology, Process and Policy
UNEP	United Nations Environment Program
USGBC	United States Green Building Council

1. INTRODUCTION

1.1. Background

Construction is a labor industry which has been remained unchanged for years. With improvements of technology, many business and production areas are being improved but construction process is still the same as it was thousands of years ago, from a bunch of drawings, a building is erected and mostly the drawings are not free of errors (Kuehmeier, 2008). Insufficient information sharing and weak communication between stakeholders results in increasing possibilities of risks and errors (Salah, 2014).

With the advent of BIM (Building Information Modelling) software the architects and designers design the building with minor errors (Kuehmeier, 2008). The concept of BIM and development of 3D modelling started in early 1970s. However, the term BIM didn't become popular for some 10 years (Eastman et al., 2011). In 2002 Autodesk company released a white paper entitled BIM, and then other firms started involvement in this field (Autodesk Inc, 2011).

Buildings and structures differ in types of use, age and ownership which are influencing the BIM application, level of details and its supporting functionalities regarding processes of design, construction, maintenance and deconstruction due to stakeholders needs (Kuehmeier, 2008). According to surveys, BIM is suitable for complex buildings and it has been applied in many complex building types (Azhar et al., 2012). The emerging of BIM with green building has revolutionized the build environments in the western world in recent years and is referred as Green BIM (Lu et al., 2017).

Nowadays climate changes and its rate of effect on the environment is alarming worldwide. Furthermore, constructed projects and buildings also contribute to the global warming because they need power which most of them are powered by power plants using highly polluted fossil fuels like oil and coal (Swarnkar and Singh, 2015). These issues forces designers, researchers and companies to use energy efficient design structures within the construction industry to stand against global warming challenges.

Even though green technology seems something new but the existance of green technology refer to 1900s and green technology has been taken serious as recently as the 1990s (Mueller, 2017).

1.2. Research objective

The aim of this study is to implement building sustainability analysis using BIM. The findings of this study will provide the platform aimed at exploring the technological benefits and operational flexibility that green technology application in construction with BIM had created.

Furthermore, a case study is implemented using BIM softwares (Revit and Green Building Studio) and possibilities of implementation of green technology application in construction in above mentioned BIM softwares are studied.

1.3. Scope of the research

The scope of this study covers doing research on BIM and green technology application in construction and possibilities of implementing green technology application in construction using BIM.

Following delimitations define the scope of work:

- The 3D BIM model is created in Autodesk Revit
- Structural, mechanical and electrical design is not considered because the aim of study is implementation of green technology application in construction and sustainability analysis using BIM for which 3D model is enough.
- Sustainability analysis is done using Autodesk Green Building Studio.

2. LITERATURE REVIEW

2.1. History, benefits and challenges of BIM

The term BIM is the short form of Building Information Modeling. It is one of the most important developments in AEC (Architecture, Engineering & Construction) industry. Its origin goes back to 1970s when Professor Eastman described Building Description System in one of his papers. He described BIM long time before foundation of Autodesk and release of Autodesk Revit (Eastman et al., 2011). Later in 1977 he created GLIDE (Graphical Language for Interactive Design) which exhibited most of the BIM platform characteristics. BIM definition developments by time are BPM – Building Product Model in 1989, GBM – Generic Building Model in 1995 and BIM – Building Information Modelling in 2000. The term BIM was first discussed on a research paper in 1992, but its implementation in AEC industry started to take place in mid 2000s (Azhar et al., 2012).

BIM model allows users to control current status and all progress of a building. It uses intelligent objects to design projects which means all components of the project have relationship with each other and knows how to get connected to each other. It is mistakenly thought that BIM is just a software, in fact it is more than a software, it is a process which depends on accurate and detailed information models (Criminale and Langar, 2017). Contractors and project managers believe that BIM technology is an intelligent database management system that directly analyze data from CAD (Computer Aided Drafting) for cash flow modelling, time sequence and risk scenario planning during the lifecycle of a project while engineers and architechts believe that BIM is an extention to CAD (Gu and London, 2010).

BIM has multidimensions which combines multi issues of design information such as 3D modeling, construction scheduling, costing and project estimation, sustainability, energy saving, facility management, safety and health (Kamardeen, 2010). Another characteristics of BIM is its level of details or Level of development (LOD). It is required detail amount in a BIM system (AMS Admin, 2014). It is a step by step progress of BIM element from conceptual stage to highest level of detail (Salah, 2014). According to American Institute of Architect there are six LOD as LOD100, LOD200, LOD300, LOD350, LOD400 and LOD500 (Denis, 2015) which are briefly discussed in this study. Figure 2.1 and Figure 2.2 below describe BIM use details and purposes of using BIM.

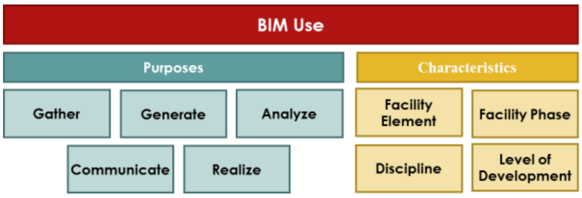


Figure 2.1. *BIM use details (Kreider and Messner, 2013)*

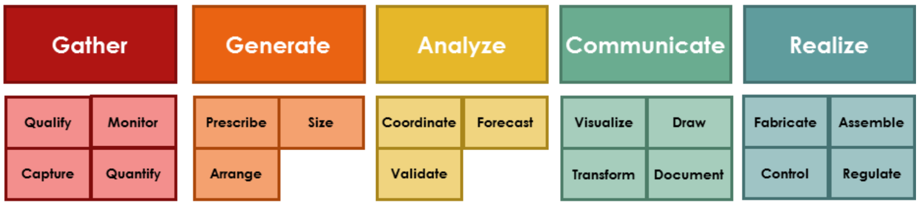


Figure 2.2. *Purposes of BIM use (Kreider and Messner, 2013)*

As discussed previously BIM technology is more than a software and it has significant advantages in construction industry. One of its greatest benefits is creation of accurate model which can be used in entire life of project starting from concept design to operation & maintenance. Interoperability is another benefit of BIM which means data exchange between softwares which helps to reduce transfer errors and prevents waste of time (Criminale and Langar, 2017). It saves data into it which is accessible anytime. It also allows changes in design at anytime which helps design team for less cost and accurate control of the project which has significant impact on outcome of the project. Implementation of BIM using improved design and construction process helps in reduction of (material, resource and cost) waste (Eadie et al., 2013). BIM is widely used by the building industry, architects, engineers, contractors, owners and Green BIM professionals. In general its benefits in construction industry are divided into pre-construction benefits, design benefits, during construction benefits and post construction benefits (Eastman et al., 2011).

BIM like any other technology has challenges and barriers in implementing it. Initial barriers for implementing BIM are time and money required for training individuals to use it. Interoperability at the same time could be a barrier for implementing BIM as well. As exchange of data need suitability between softwares which sometimes softwares supporting each others data could not be available. Cost of software license, unfamiliarity of customers with BIM and multiple stakeholders cooperation can be named as other challenges of implementing BIM (Criminale and Langar, 2017).

2.2. Review of Green Technology

Green technology includes the word “green” which does not mean the color, and using of knowledge for practical issue is called technology (Das, 2015). Concept of green technology has been in use long time ago. Electric taxi and windmill of 1900s are examples of basic green technology (http-11). This technology is used to reduce GHG (Greenhouse Gas) effect and global warming and prevents emission of CO_2 (Monokova et al., 2017). As per EPA (Environmental Protection cAgency) report Figure 2.3 shows GHG emission in different fields.

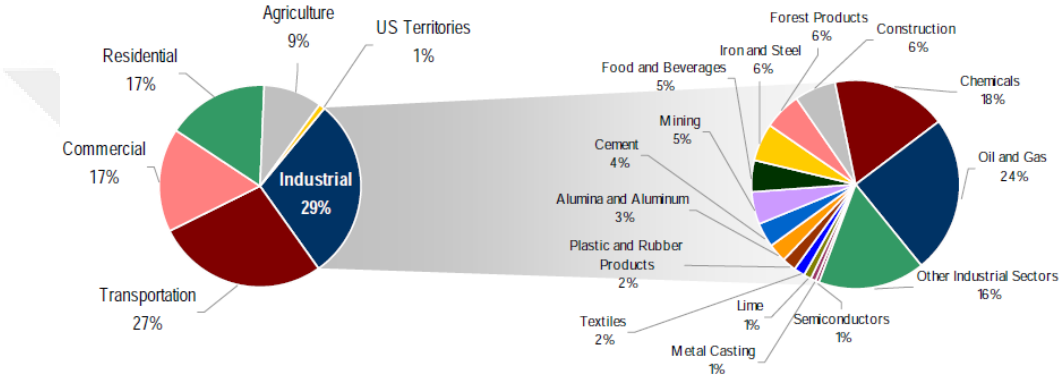


Figure 2.3. *GHG emission in different fields (JEONG, 2011)*

The goals of green technology are sustainability, eco-friendly design, reduction of built environment impact on environment and human health. It uses renewable natural resources which are eco-friendly to environment and these resources never finish. Green technology changes waste in a way which is not harmful for the planet. Applications of green technology can be listed as solar array, reusable water bottle, solar water heater, wind generator, rain water harvesting system and insulating houses (Das, 2015).

Buildings benefiting from green technology is called green building. Green technology in construction industry is used to reduce impact of buildings on environment and human health via improved design, construction and O&M (operation and maintenance) (Feltes, 2007). The main goal of green building is to implement sustainability norms in AEC sector (Wu, 2010). In terms of green building, green characteristic and project stages can define green buildings (Lu et al., 2017). Parameters like sustainable site, atmosphere and energy, material and sources, water resources and indoor environment quality are considered to make buildings green (Meher et al., 2016).

2.3. Green rating standards

Building rating systems are used to measure sustainability. First and oldest rating system was created in UK called BREEAM (Building Research Establishment Environmental Assessment Method) which surved as foundation for other rating systems. It measures building rating levels as Pass, Good, Very Good, Excellent and Outstanding (Kibert, 2013).

USGBC (United States Green Building Council) was then established in 1993 in US by David Gottfried which is widely used all around the world. The council created rating system for building sustainability in 1998 which is LEED (Leadership in Energy and Environmental Design) system (Kim and Anderson, 2013). LEED rating system is point based. Points are being added and then rating level is being issued as Certified, Silver, Gold or Platinum (Ehmida, 2011).

Most of the countries have their own building rating system which most of them are briefly introduced here. GBCA (Green Building Council Australia) was first launched in 2002 in Australia. The council created rating system named Green Star (Kubba, 2017) which has much similarities to BREEAM and LEED (Kibert, 2013). It is also point based rating system which evaluates building sustainability from one to six star (JEONG, 2011). DGNB/BNB is building assessement system of Germany which developed standard for sustainable buildings in 2009. Allocation of points and evaluation of buildings via this system is by consideration of ecology, economy and socioculture. It evaluates building rating as Gold, Silver and Bronze. JSBC (Japan Sustainable Building Consortium) is green building council of Japan which developed CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) system later. Evaluation of buildings via this system is done by the ratio of quality to environmental loading. The system then provides numeric score for buildings and gives one to five star rating (Kibert, 2013).

GRIHA of India, NZGBC of New Zealand, GBC of South Africa are other green building councils around the world (Kubba, 2017).

2.4. Implementing BIM in Green Building

A building is erected from a bunch of drawings. There are a lot of softwares which have ability of providing 2D or 3D drawings of a project with unintelligent objects which means objects are not connected and recognizable by each other and mostly these drawings are not free of error.

With the advent of BIM software, architects and designers design the building with minor errors. The emerging of BIM with green building has revolutionized the build environments in the western world in recent years and is referred as Green BIM. It is obvious that construction industry has direct impact on environment. BIM software provides solution to these issues. It can be used in design, construction, operation and renovation process of green buildings (Lu et al., 2017). Revit as a BIM software helps in project drawings and easily communicate with other BIM software for analysis issues (Wu, 2010). Figure 2.4 briefly describes BIM life cycle of green projects.

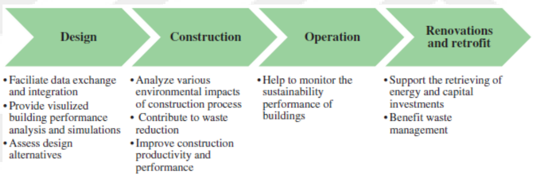


Figure 2.4. *BIM lifecycle of green projects (Lu et al.,2017)*

Traditional design method can not cover all aspects of projects including of sustainability analysis. BIM software gives the possiblity of green buildings analysis in 6 aspects which are provided in Table 2.1.

Table 2.1. *BIM software for green analysis (Lu et al., 2017)*

BIM Software	Green Analysis*						Users**	Users***
	E	CE	NV	SD	A	W		
Green Building Studio	●	●	●	●		●	A/D	De/OM
Integrated Environmental Solutions® Virtual Environment	●	●	●	●		●	A/E/O/D	De
Bentley Hevacomp	●	●	●				C/E/D	De
AECOsim	●	●		●			C/E/D	De
EnergyPlus	●	●		●		●	A/E	De
HEED	●	●					A/C/D/O	De
DesignBuilder Simulation	●	●	●	●			A/C/E	De
eQUEST	●		●	●			A/C/E	C/De/OM
DOE2	●		●	●			A/C/E/G/U	De
FloVENT			●				E	De
ODEON Room Acoustics Software					●		A/E	De
TRNSYS	●		●	●			A/E	De

*E – Energy, CE – carbon emission, NV – Natural Ventilation, SD – solar and day lighting, A – Acoustic, W – water
**A – architect, D – designer, E – engineer, O – Owner, C – consultant, U – utility company, G – government
***De – design, C – construction, OM – operation & maintenance

There are lots of studies conducted in the field of BIM as well in green technology application in construction but few researches and studies include both of these phenomena. Wong and Fan (2013) in their journal under the title of "Building information modelling (BIM) for sustainable building design" implemented a case study about achieving energy efficiency via solar analysis application in building design. They used ECOTECT application for their research. Wong and Zhou (2015) in their journal reviewed and compared about 84 green BIM related papers and provided their opinions about defects in the scope of green BIM literatures. They found that lack of extensive BIM-based environmental sustainability simulation tool, limited research effort for managing environmental performance at the building and inadequate attention given to the current cloud computing technology are the defects of the existing green BIM literature. According to another study implemented by Jalaei and Jrade (2014), they proposed an integrated methodology that connects energy analysis tools and BIM with green building certification systems and indicates to apply this methodology at the early design stage of project's life. Ampratwum (2017) implemented a study about adaptation of green building design concept with BIM into a new construction market in Ghana and investigated about green BIM concept in the UK and Scandinavia as well. Lu et al., (2017) implemented a study under the title of BIM for green buildings. The main structure of the study includes reviews and future instructions. Based on review of journals published between 1999 and 2016 and some widely used BIM software, they proposed "Green BIM Triangle" to assist in noticing challenges and advantages of implementing green BIM. They also have noticed gaps which needs further research to help promoting green BIM.

As per reviews, similar study has not been implemented in construction industry in Afghanistan and it could be a good start for implementing sustainability analysis and implementing of green BIM in construction industry in Afghanistan.

3. BUILDING INFORMATION MODELLING (BIM)

3.1. What is BIM ?

The concept of Building Information Modelling has been existed since 1970s. It is one of the most challenging developments in the AEC (Architecture, Engineering & Construction) industry (Eastman et al., 2011). It is a 3D digital representation of functional and physical features of a project and parameters related to it such as material, cost, structure type, equipments and much more which are necessary for designers, architects, contractors, and owners (Hardin, 2009). In fact BIM is moving from analog to digital construction and design (Kuehmeier, 2008).

Creating a Building Information Modelling is different than making a 2D or 3D CAD (Computer Aided Drafting) drawing. 2D or 3D CAD drawing is equivalent to conventional drafting. It includes unintelligent points, lines, or symbols in drawings and designs. To create a BIM, intelligent objects are used to build the model. Intelligent objects represent the geometry needed to demonstrate the assembly graphically by including much more information about the object associated with it (ASHRAE, 2009). BIM model allows users to control current status and all progress of a building. It is seen as "*an intelligent model based design process that adds value across the entire lifecycle of building and infrastructure projects*" (Autodesk Inc, 2011).

As a result, it is obvious that Building Information Modeling is not equivalent to 3D CAD. The building's lifecycle and its stakeholders as per BIM are shown in Figure 3.1.

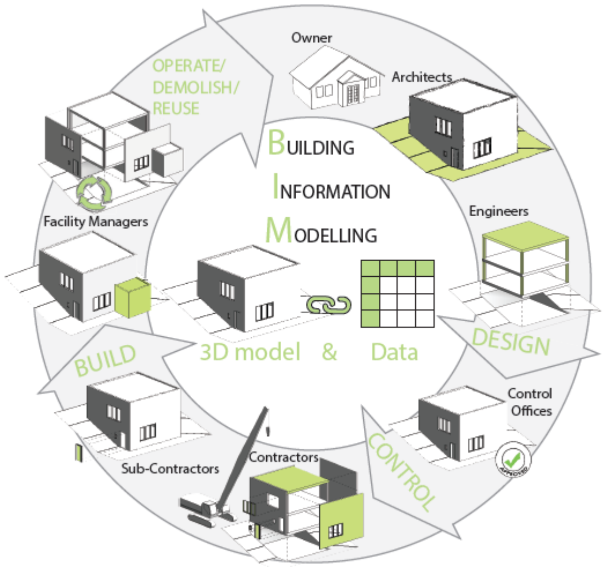


Figure 3.1. *The building's lifecycle and its stakeholders (Denis, 2015)*

Visual representation of BIM is shown in Figure 3.2.

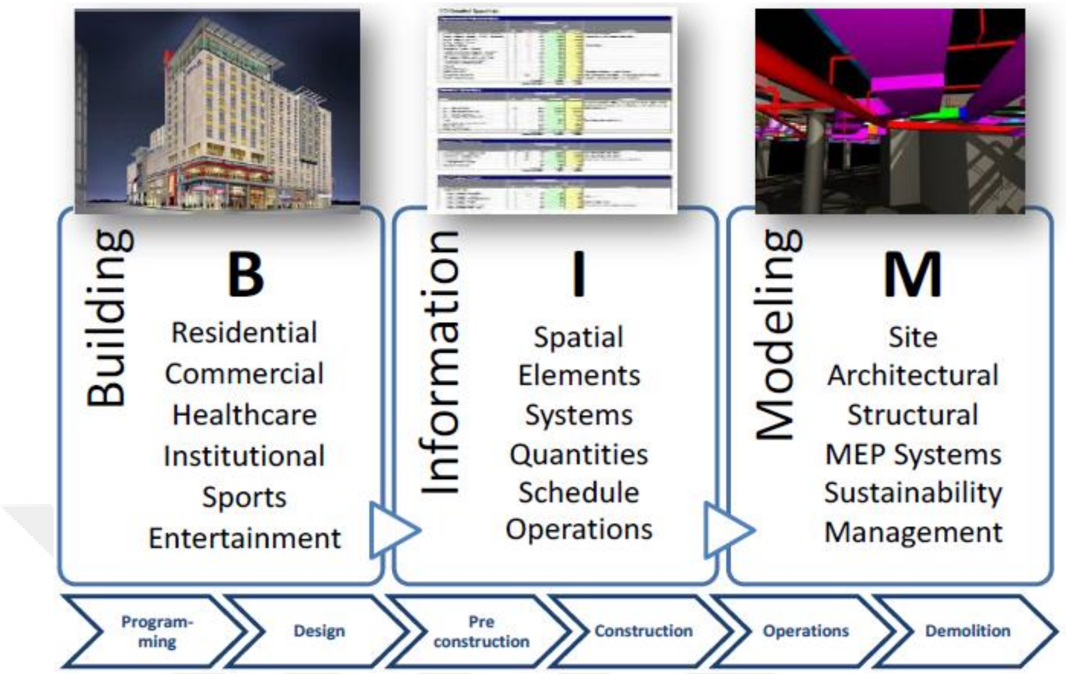


Figure 3.2. *Visual representation of BIM (Azhar et al., 2012)*

Architects, project managers and contractors have different point of views about BIM. Contractors and project managers believe that BIM technology is an intelligent database management system that directly analyze data from CAD for cash flow modelling, time sequence, simulations and risk scenario planning during the lifecycle of a project while engineers and architects believe that BIM is an extention to CAD (Gu and London, 2010). Building process of a project using BIM is shown in Figure 3.3 below.

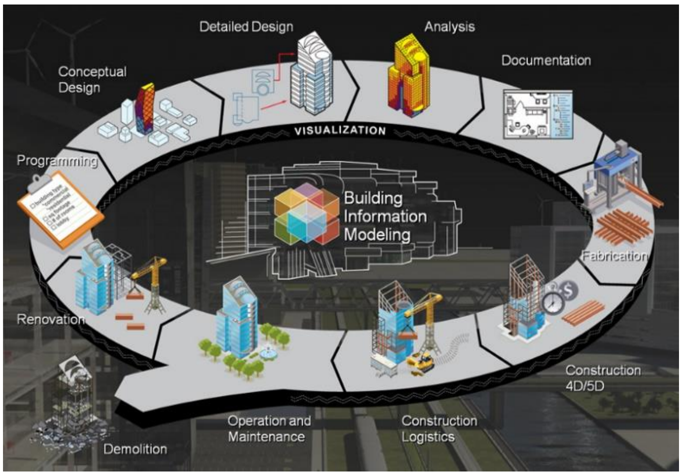


Figure 3.3. *Building process of a project using BIM (http-1)*

Figure 3.4 describes development of BIM definition by time (Ampratwum, 2017).

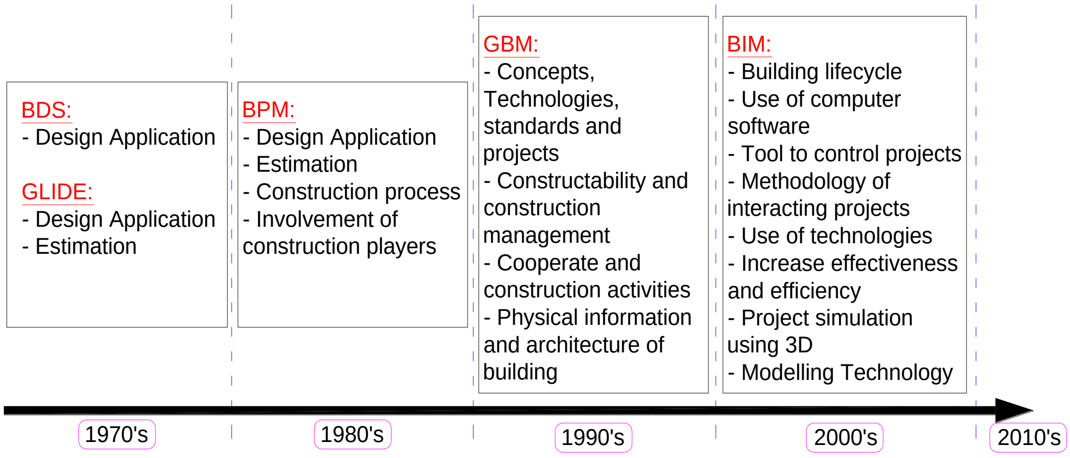


Figure 3.4. *Development of BIM definition (Ampratwum, 2017)*

BDS – Building Description System (1975)

GLIDE – Graphical Language for Interactive Design (1977)

BPM – Building Product Model (1989)

GBM – Generic Building Model (1995)

BIM – Building Information Modelling (2000)

Security of confidential data to the BIM model for all project members are needed in order to successfully implement BIM processes during the project lifecycle (Eadie et al., 2013). Lifecycle phases for most of the projects are as concept, feasibility, evaluation, authorization, implementation, completion, operation and maintenance (O&M) and termination. Lifecycle phases of different projects can be different and it is good that each organization develop their own lifecycle diagram for their projects (Lester, 2014). BIM project execution plan (PEP) is required for implementation of BIM. The BIM PEP is used to identify and gain maximum benefits of BIM during the project lifecycle phases (Eadie et al., 2013).

3.1.1. What is not BIM ?

Eastman et al., (2011) describes below points which are not BIM:

- Models that only contain 3D data and no object attributes.
- Models with no behaviour support.

- Models that are composed of mutliple 2D CAD reference files that must be combined to define the building.
- Models that allow dimension changes in one view and is not automatically changed in other views

3.2. The purposes of BIM

The purposes for implementing BIM are described in Figure 3.5.

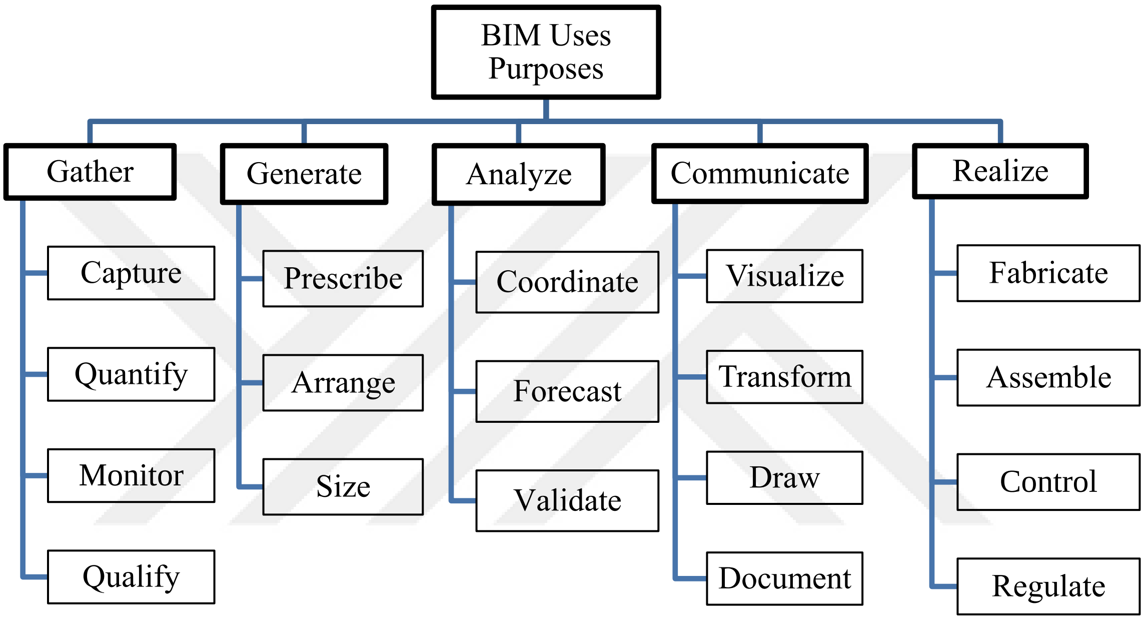


Figure 3.5. *Purposes of BIM (Kreider and Messner, 2013)*

3.3. Application areas of BIM

As discussed in the definition of BIM, building models in BIM are full of information. Building models created by BIM can be used in entire life of building starting from conceptual design to demolition of building which means the gathered and stored data and information in the model can be reused and refreshed in any stage of the project and can be shared with all project participants (Salah, 2014).

Application areas of BIM can be discussed as below (Eastman et al., 2011):

Design modelling: The design team including of architects, mechanical, electrical and structure engineers can use BIM tool to visualize and create the building project model as it is the most capable technology for design and implementation. Figure 3.6 is an example of a project using BIM tool.

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

Figure 3.6. *Different design models of Hilton Aquarium using BIM tool (Azhar et al., 2011)*

Modelling of new and existing buildings are possible with BIM. Figure 3.7 describes new and existing buildings creation process using BIM.

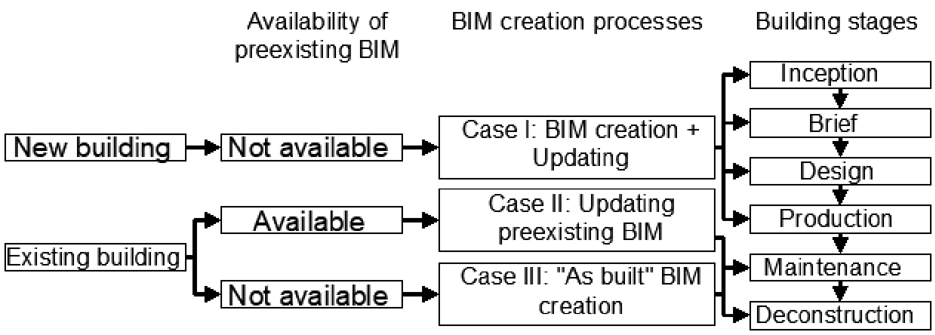


Figure 3.7. *New and existing buildings creation process using BIM (Volk et al., 2013)*

<u>Coordination:</u> BIM has the ability to detect clashes in architectural, structural and plumbing models which means after generation of BIM model, every change will be reflected in all views which can decrease time consumption and facilitates the coordination of design between documentation and project information.

Two types of clash detection can be classified:

- Hard clash: When two or more objects occupy same physical space.
- Soft clash: It refers to permissible space or tolerances and occurs when objects are placed close enough to each other, like rebars which are close enough to let proper concrete placing (Eastman et al., 2011)

Figure 3.8 shows an example of clash detection.

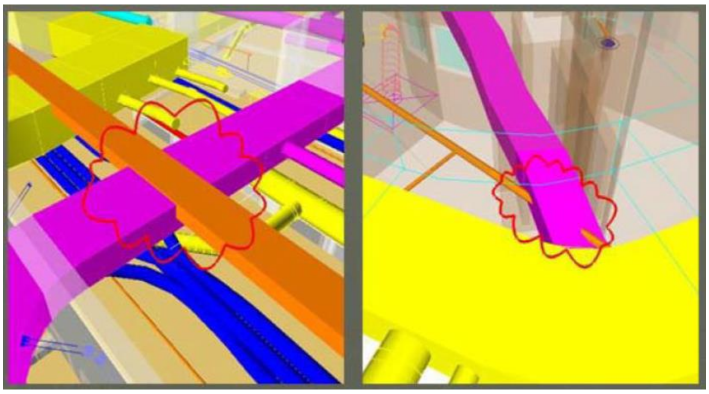


Figure 3.8. *Clash detection between structural and MEP models (Salah, 2014)*

<u>Construction scheduling:</u> BIM can be connected to schedule of work to show the range of work. 4D BIM defines construction scheduling in BIM. It helps schedulers to develope series of the work and analyze the suggested job (Jiang, 2011).

<u>Cost estimating:</u> BIM can be useful for estimation of quantities and budget of projects by providing and calculating quantities from the model (Salah, 2014). BIM softwares are programmed to calculate the cost automatically from inputs in the model, this can prevent time lost in estimating project (Kuehmeier, 2008).

Although BIM softwares can calculate the amount of material used for project, it is not able to calculate the number of labor for implementing complicated designs (Kuehmeier, 2008). Estimation engineers or different estimating platforms are supposed to do precious cost estimation of project (Eastman et al., 2011). BIM estimating process is shown in Figure 3.9.

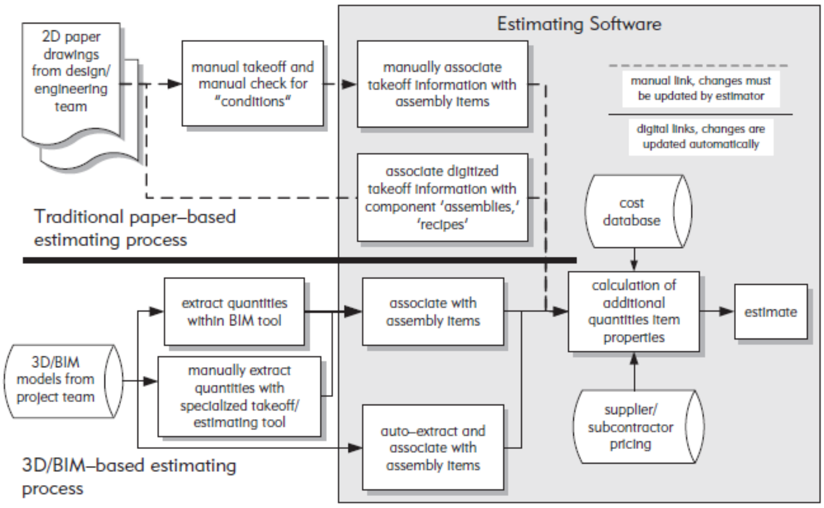


Figure 3.9. *BIM estimating process (Eastman et al., 2011)*

Energy analysis: Connection of energy analysis to building model lets energy usage evaluation during design phase (Eastman et al., 2011). 6D BIM is sustainability which includes energy analysis, fire and smoke modeling, heat load calculations and waste estimation.

Facility Management (FM): 7D BIM is facility management. It is a new session in business which contains broad range of tasks involved in productive management of building assets. It includes the overall management of all duties which support the business of organization (Amaratunga et al., 2000). BIM software provides efficient space planning, easy operation and maintenance and processing technical issues for facility managers (Salah, 2014). A comparison of traditional facility management and BIM aided facility management is presented in Table 3.1 below:

Table 3.1. *Comparison of traditional facility management and BIM aided facility management (Su et al., 2011)*

	BIM imported mode	Traditional mode	
		Management information system	Paper works
Presenting information	• 3D visual mode • External related information file	• Screen display • 2D CAD based • Related information files	• 2D Figures • Related paper report
Recording information	• BIM based model to save information • Save in external related information files	• E-system to save information	• Paper works to save information
Searching information	• Searching by integration functions of model & software • Linking to external related information files • Searching by standard report which was exported by BIM model and software	• Searching the information in the system	• Searching the information in paper reports

3.4. Benefits of BIM

BIM provides effective advantages over CAD. One of the greatest benefits of BIM is creation of accurate model which can be used in entire life of project starting from concept design to operation & maintenance (Lindblad, 2013). It also supports data exchange between softwares which helps in reducing transfer errors and prevents waste of time (Fischer and Kund, 2004). BIM allows changes in design at anytime which helps design team for accurate control of the project, this results for higher quality of work and prevents time waste due to manual changes in design (http-1). Another benefit of BIM is having cost efficiency for facility management (FM), and Architecture, Engineering and Construction (AEC) industry as it decreases waste & increases profitability (Ampratwum, 2017). Implementation of BIM using improved design and construction process helps in reduction of (material, resource and cost) waste (Eadie et al., 2013). Some other benefits of BIM are reduced risks, streamlined production, improved productivity and design intent maintenance (Kuehmeier, 2008).

http-3 describes top ten benefits of BIM as below:

- Capture Reality
- Waste Not, Want Not
- Maintain Control
- Improve Collaboration
- Simulate and Visualize
- Resolve Conflict
- Sequence Your Steps
- Dive into Detail
- Present Perfectly
- Take It with You

Eastman et al., (2011) describes BIM benefits as below:

Preconstruction benefits

- Realistic presentation of building project in feasibility and design phase lets the owner to decide whether the design meets the financial requirements or no.
- Providing of schematic model enables for careful evaluation of provided models. This way building quality can be enhanced.

Design benefits

- BIM can generate 3D model without requirement of any 2D view. Dimensional consistency is also suppported by 3D models.
- 3D models will be free of any error if objects are checked by parametric rules. This way need for design change will be reduced.
- Accurate drawing of objects or views can be accessed any time. This helps in prevention of time waste.
- Provision of earlier 3D visualization which allows for accurate and earlier estimation of costs.
- Extraction of accurate BOQ (Bill Of Quantity) is possible with BIM at any design stage. In the preliminary design stage a draft BOQ can be provided, which by improvement of design, more accurate BOQ can be provided. This way BIM can provide better design decision regarding cost rather than paper based system.
- Energy usage evaluation in early design phase is possible by connecting model to energy analysis tools. This connection capability provides opportunity to develop quality of building.

Construction and fabrication benefits

- Accurate building model representation for construction and fabrication is possible if design model is shifted to a building information modelling fabrication tool.
- Design update and change can be done automatically, visually or via clash detection using BIM which prevents time consumption and error.
- Design errors and faults are discovered and deleted before construction begins.
- 4D BIM defines construction scheduling in BIM. Linking of construction scheduling with 3D model lets us know the condition of site and building at any required time.
- Execution of lean construction methods with detailed building design model and material resources.
- Detailed 3D model provides accurate specifications and quantities or required materials in the project. This helps to speed up the procurement process and prevent time waste.

Post construction benefits

- As BIM includes accurate information about all objects in the project, this can be used for better operation and maintenance after handovering of the project.

Briefly benefits of BIM process can be shown in Figure 3.10.

Figure 3.10. *Benefits of BIM process (http-1)*

3.5. BIM numeric labels dimensions

BIM has multidimensions which combines multi issues of design information such as scheduling, sustainability, costing, accessibility, energy saving and so on which are required during lifecycle of a project (Kamardeen, 2010). Further BIM dimensions would be raised in the future as development of BIM has not been completed yet. Till now 8D BIM has been introduced which are briefly discussed below.

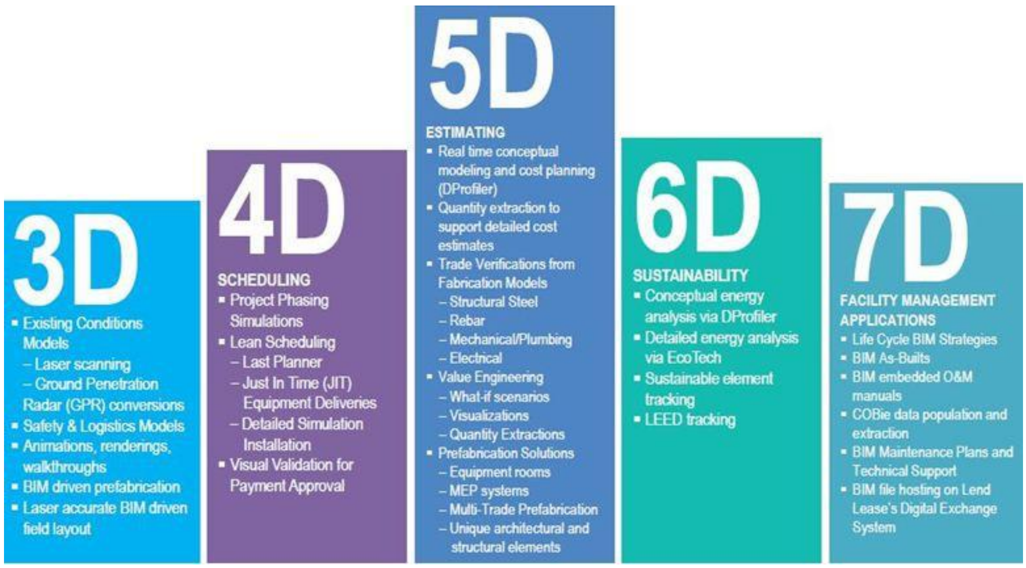


Figure 3.11. *BIM dimensions (http-1)*

3.5.1. 3D BIM

3D BIM is virtual and intelligent model that includes project information (Kamardeen, 2010). These information included models can generate shop drawings automatically. One of the main profits of 3D BIM is clash detection which enables to detect design faults and solve them prior to construction phase (Eastman et al., 2011). Creating a 3D BIM is different from making 3D CAD (Computer Aided Drafting) drawing. 3D CAD drawing is equivalent to conventional drafting. It includes unintelligent points, lines or symbols in drawings and designs (ASHARE, 2009). To create a 3D BIM, intelligent objects are used to build the model (Autodesk Inc, 2011) which means change in any part of the model effects entire project while editing 3D CAD requires to check and update all project manually which is an error prone process (Azhar et al., 2012). Comparison between Traditional process and BIM process is shown in Figure 3.12 and 3D BIM softwares are shown in Table 3.2 below.

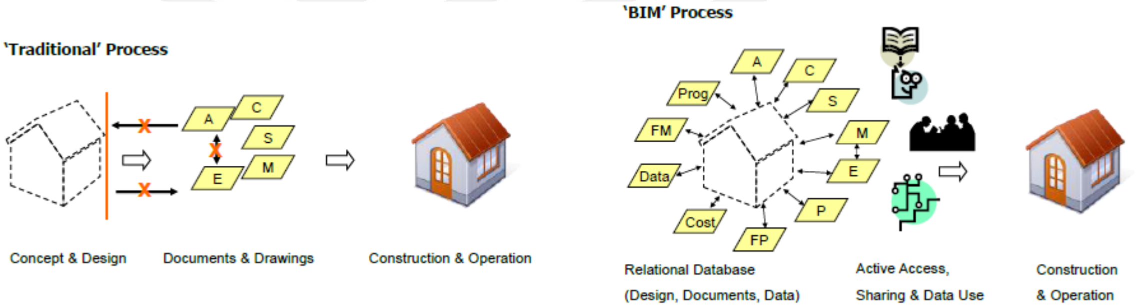


Figure 3.12. *Tradition and BIM process comparison (Azhar et al., 2012)*

Table 3.2. *3D BIM software*

Architecture Section		
Software Name	**Manufacturer**	**Software LOGO**
Revit Architecture	Autodesk	
ArchiCAD	Graphisoft	
Infraworks 360	Autodesk	
Allplan Architecture	Nemetschek	
Vectorworks architect	Nemetschek	
Sketch up pro	Trimble	

Table 3.2. (Continued) *3D BIM software*

Bentley Architecture (Microstation)	Bentley	
Digital project designer	Gehry Technology	
Structure Section		
Software Name	**Manufacturer**	**Software LOGO**
Tekla structures	Tekla	
Revit Structure	Autodesk	
STAAD & Pro steel	Bentley	
Mechanical, Electrical, Plumbing (MEP) Section		
Software Name	**Manufacturer**	**Software LOGO**
Bentley Hevacomp	Bentley	
Revit MEP	Autodesk	
4MSA Fine HVAC	4M	

3.5.2. 4D BIM

4D defines construction scheduling and site planning in BIM and is time element. In fact it is time added to 3D BIM (3D + time) (Eastman et al., 2011). It is used to show actual or planned status of work in 3D model for any requested period of time (Kuehmeier, 2008) which helps to visualize the status of work and is evaluated to be helpful for projects with many stakeholders (Fischer and Kund, 2004).

Critical path method and line of balance are two general 4D BIM scheduling methods. Level of details of 4D BIM differs from design to construction phase (Salah, 2014). 4D BIM can be implemented in all phases of project which are pre-design, detailed design, proposal and construction phase (http-2). Figure 3.13 shows 4D BIM illustration.

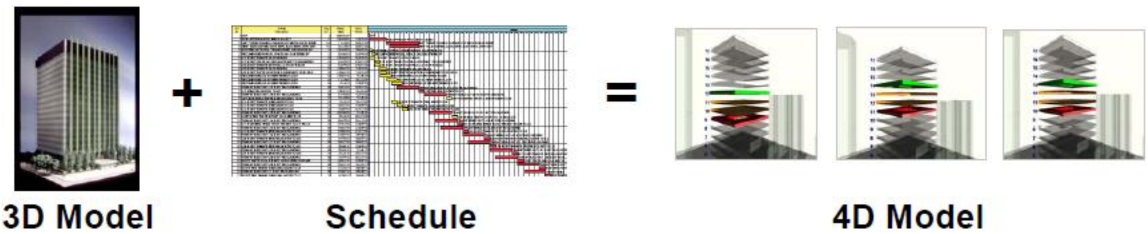


Figure 3.13. *3D BIM model + Time = 4D BIM (http-2)*

Difference between 4D CAD and 4D BIM is the "Information" element in BIM which is added from 3D models to 4D models automatically, but 4D CAD is just element of time added to 3D CAD. Comparison of 4D CAD and 4D BIM is shown in Figure 3.14 and 4D BIM softwares are shown in Table 3.3.

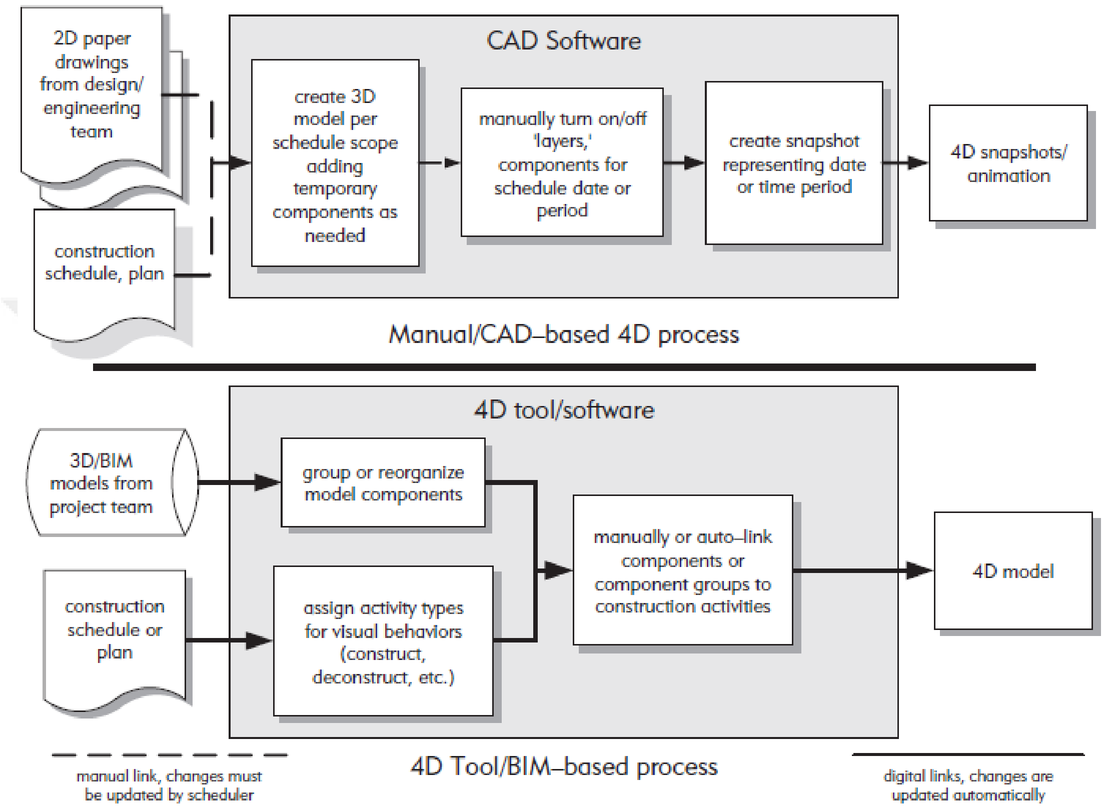


Figure 3.14. *Comparison of 4D CAD and 4D BIM (Eastman et al., 2011)*

Table 3.3. *4D BIM software*

Software Name	Manufacturer	Software LOGO
Navisworks	Autodesk	
iTWO	RIB Software	
Vico office suite	Vico	
Bentley Navigator	Bentley	
Visual simulation	Innovaya	
Synchro professional	Synchro LTD	

3.5.3. 5D BIM

5D defines construction estimation in BIM and is the cost element. It is used to represent the model financially and generate cost budget against time (http-1). In fact it is cost added to 4D BIM (4D+cost). Figure 3.15 shows 3D and 4D BIM effects on 5D BIM.

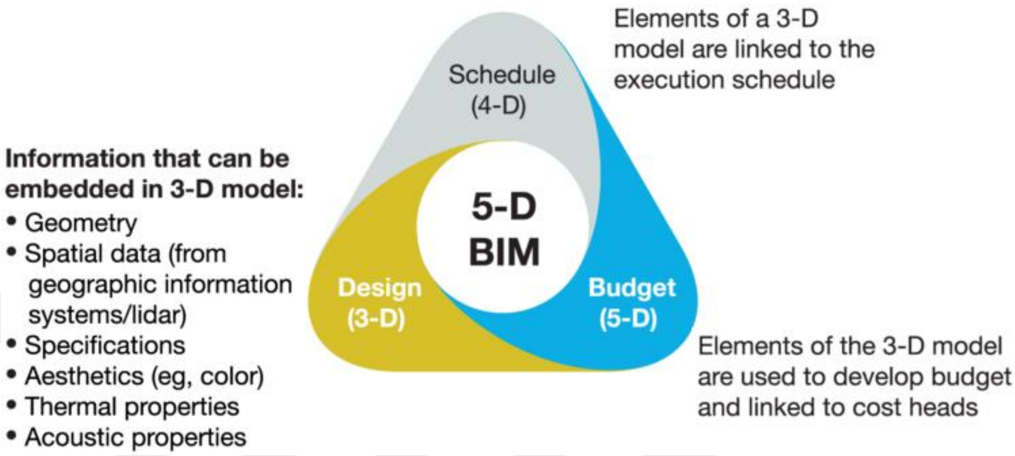


Figure 3.15. *Effect of 3D and 4D BIM on 5D BIM (http-1)*

After defining of cost to each object of the model, 5D BIM model will be automatically updated upon changes in the model (Jiang, 2011). Traditional paper-based estimation versus 3D BIM estimation process is shown in Figure 3.16 and list of 5D BIM software is shown in Table 3.4.

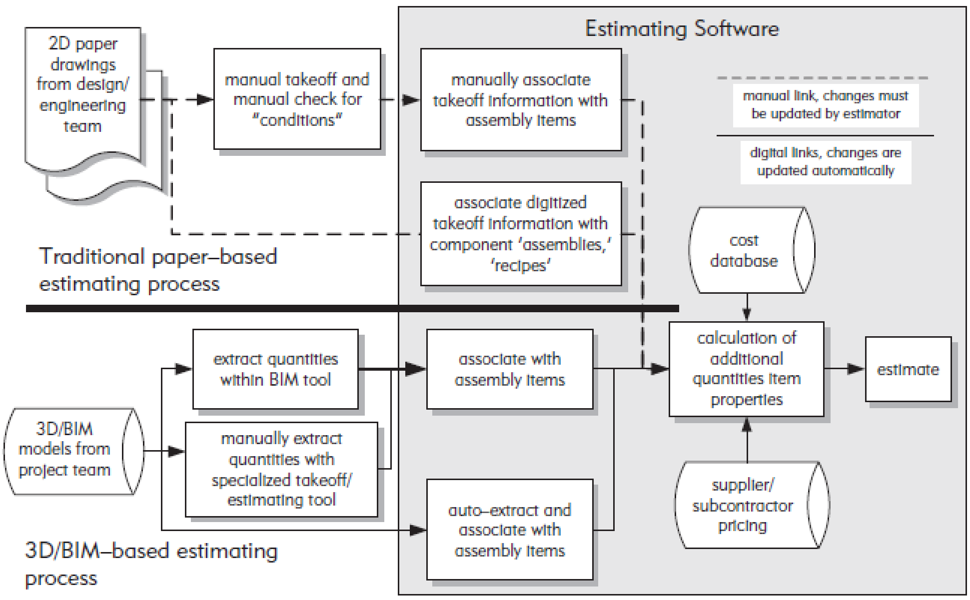


Figure 3.16. *Traditional paper based and 3D BIM based estimation process (Eastman et al., 2011)*

Table 3.4. *5D BIM software*

Software Name	Manufacturer	Software LOGO
Graphisoft estimator	Graphisoft	
Quantity Takeoffs QTO	Autodesk	
Nevaris	Nemetschek	
Visual simulation	Innovaya	
DESTINI Estimator	Beck technology	
Vico office suite	Vico	

3.5.4. 6D BIM

6D defines sustainability in BIM. Buildings which use less energy and produce less waste and pollution are defined as sustainability in building industry (Wong and Fan, 2013). With 6D BIM, analysis of energy, carbon emission, natural ventilation, solar and day lighting, acoustic and water can be carried out (Lu et al., 2017). Softwares for 6D BIM are shown in Table 3.5.

Table 3.5. *6D BIM software*

Software Name	Manufacturer	Software LOGO
Vintocon Archi FM	Graphisoft	
Onuma system	ONUMA Inc	
Hevacomp	Bentley	
FM-systems	FM: Systems	
Sefaira	Trimble	
Green Building Studio	Autodesk	
Ecotect Analysis	Autodesk	
Eco designer	Graphisoft	
Tas simulation	Bentley	
Design Builder	Design Builder	

3.5.5. 7D BIM

7D defines facility management in BIM. Facility management is a session which includes a group of tasks involved in productive management of building assets. It includes the overall management of all duties which support the business of organization (Amaratunga et al., 2000). It can be used in feasibility and design, construction and operating phase of a building project. Better planning, operation and maintenance (O&M) of buildings are carried out easily and faster using 7D BIM (CommScope, 2017). Most common technologies used by facility managers to manage buildings efficiently are BAS (Building Automation Systems), RFID (Radio Frequency Identification), GPS (Global Positioning Systems) and GIS (Geographic Information Systems) (Eastman et al., 2011). Softwares for 7D BIM are shown in Table 3.6.

Table 3.6. *7D BIM software*

Software Name	Manufacturer	Software LOGO
Building OPS	Autodesk	B
Assetwise	Bentley	ASSETWISE
Gestproject	Micad Global group	GP
YOUBIM	YOUBIM	YOU BIM

3.5.6. 8D BIM

Safety and health is newly discussed as 8D BIM. Elimination of hazard and risk through design is called Prevention through Design (PtD) which is possible via BIM (Kamardeen, 2010). 8D modelling schematic concept for prevention through design (PtD) is represented in Figure 3.17.

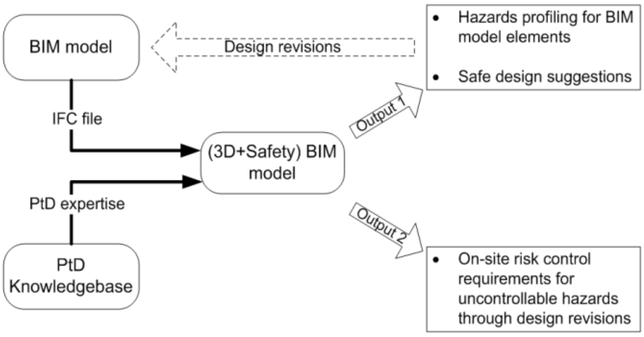


Figure 3.17. *8D modelling schematic concept (Kamardeen, 2010)*

3.6. BIM software applications

Autodesk Revit and Autodesk Green Building Studio are used in the case study of the current research which are briefly explained below:

3.6.1. Autodesk Revit

Revit is an Autodesk product which is introduced in 2002 (Eastman et al, 2011). It supports drawings, designs and schedules required for BIM (Revit Help). It includes 3 different products which are Autodesk Revit Architecture, Autodesk Revit Structure and Autodesk Revit MEP. Revit has completely different file structure than AutoCAD. Revit has the ability to import models from different softwares which export DXF files. Multiple file formats (DWF/DWFx, DWG, DXF, DGN, ACIS (SAT), html, IFC, SKP, gbXML, FBX, JPG, ADSK, TGA, OBDC, JPG, PNG, TIFF) are supported by Revit. Due to in-memory system of Revit, it will slow down for projects larger than 300 MB (Eastman et al., 2011). Figure 3.18 describes the user interface of Revit.

3.6.2. Autodesk Green Building Studio

Currently there are dozens of energy analysis software for calculating and analyzing buildings energy and power. Complete list of sustainability analysis software is provided in Table 3.5.

Green Building Studio is a web based service which uses gbXML uploaded file for sustainability analysis. It is used for analyzing of energy, carbon emission, natural ventilation, solar and day lighting and water usage of buildings. It is freely offered for Education Community members. (GBS Help).

All the building geometry including of rooms, their connections, areas and volumes of the model and all other neseccary information required for analyzing is prepared in BIM software preferably Revit and imported as gbXML file format for GBS web based software. In order to do analysis, few questions are responded to GBS to specify building type, location of building and weather station of the project. (Autodesk , 2011). GBS web based service then provides complete analysis report of the project.

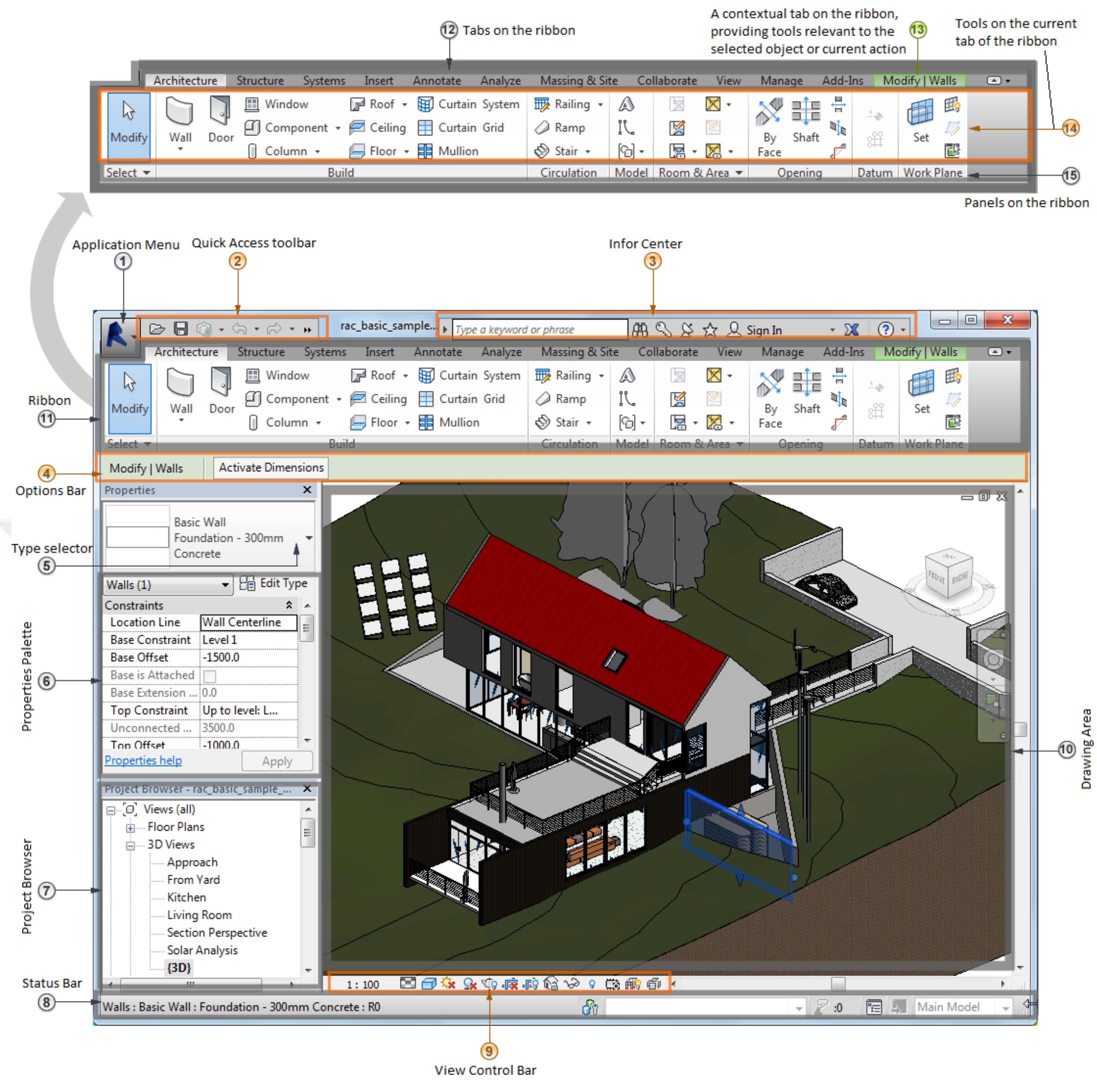


Figure 3.18. *User interface of Revit (Revit Help)*

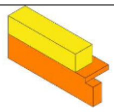
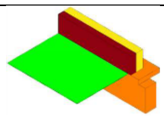
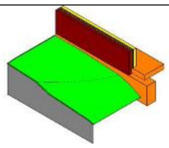
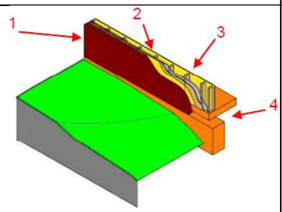
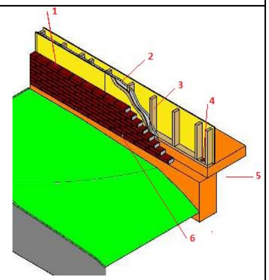
3.7. Level of Development

American Institute of Architects (AIA) firstly defined Level of Development in 2008 in E202^{TM} – 2008 BIM protocol document (BIMFORUM, 2015). Level of details or Level of development (LOD) is required detail amount in a BIM system. It is a step by step progress of BIM element from conceptual stage to highest level of detail. For instance, during the design process, the level of details increases from concept design to detailed design (AMS Admin, 2014). LOD depends on the details provided in 3D model and scheduling (GSA, 2009). There are six LOD according to American Institute of Architects and BIM Forum as LOD100 (Conceptual Design), LOD200 (Design Development), LOD300 (General construction documents), LOD 350 (The compromise), LOD400 (Fabrication information) and LOD 500 (As-built model) (Denis, 2015) which are briefly described in Table 3.7 (Kreider and Messner, 2013). A step by step example of LOD is shown in Table 3.8.

Table 3.7. *Definitions of different LoD (Kreider and Messner, 2013)*

Level of Development	Description
LoD 100	The Model Element may be graphically represented in the Model with a symbol or other generic representation but does not satisfy the requirements for LoD 200. Information related to the Model Element (i.e cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements.
LoD 200	The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.
LoD 300	The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.
LoD 350	The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element.
LoD 400	The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element.
LoD 500	The Model Element is a field verified representation in terms of size, shape, location, quantity, and orientation. Non-graphic information may also be attached to the Model Elements.

Table 3.8. *Step by step example of LoD (BIMFORUM, 2015)*

Exterior Wall veneer				
LoD100	**LoD200**	**LoD300**	**LoD350**	**LoD400**
			 1- wall veneer element 2- skin layers 3- core framing 4- concrete slab edge	 1- masonry unit 2- skin layers 3- core framing 4- bolt 5- concrete slab edge 6- weep holes
Note: LoD500 is not addressed in this specification. No graphic detail will be attached to the model because it is a field verified representation in term of shape, size, location, quantity and orientation.				

3.8. BIM Framework

All suitable BIM issues can be addressed by extensive BIM framework (Jung and Joo, 2010). BIM framework is multi dimensional comprising of BIM fields of activity, BIM stages and BIM lenses as shown in Figure 3.19 (Sucar, 2008). Hierarchical structure of BIM framework is shown in Figure 3.20 (Jung and Joo, 2010).

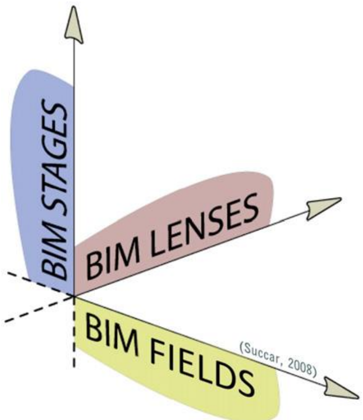


Figure 3.19. *BIM framework model (Sucar, 2008)*

Figure 3.20. *BIM framework (Jung and Joo, 2010)*

The variables in the Figure 3.20 BIM framework try to be independent of each other in order to facilitate further analyses and applications (Jung and Joo, 2010).

BIM field of activity is divided into three interlocking parts of Technology, Process and Policy (TPP) Figure 3.21 (Sucar, 2008).

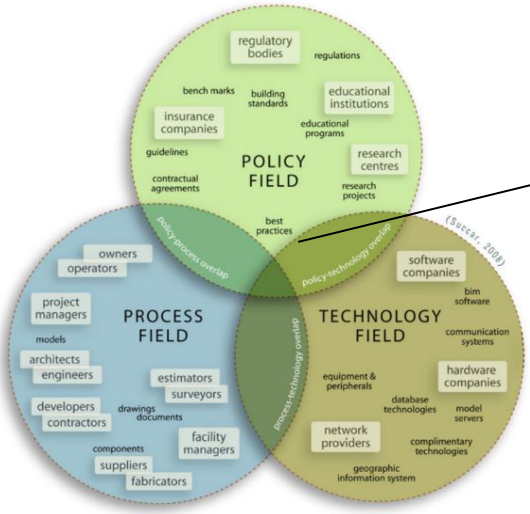


Figure 3.21. *Three interlocking parts of BIM field of activity (Succar, 2008)*

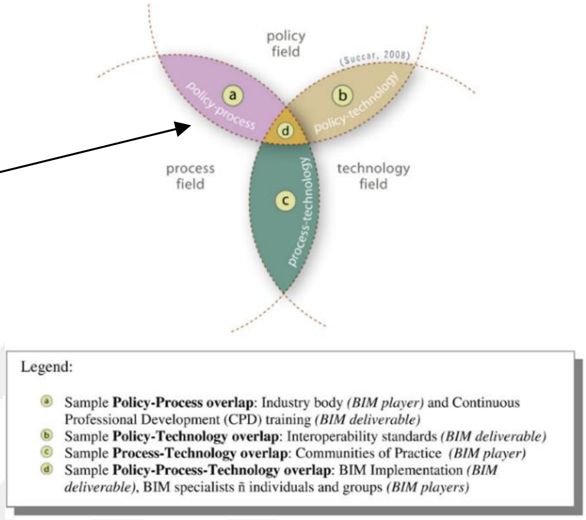


Figure 3.22. *BIM filed of activity overlaping (Succar, 2008)*

Before implementing BIM there are three stages named modelling, collaboration and integration which are shown in Figure 3.23 and briefly discussed below.

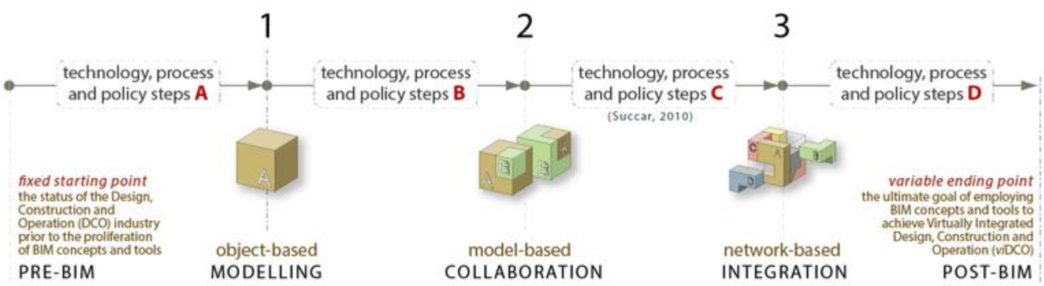


Figure 3.23. *BIM stages (Succar, 2008)*

3.8.1. Stage One: Object based MODELLING

In this stage single – disciplinary models are generated within project lifecycle (design, construction, operation) phases using object based 3D software tools such as

Revit ®, Digital project®, ArchiCAD® and Tekla®. In this stage communications between stakeholders are disjointed and data exchanges are unidirectional (Succar, 2008).

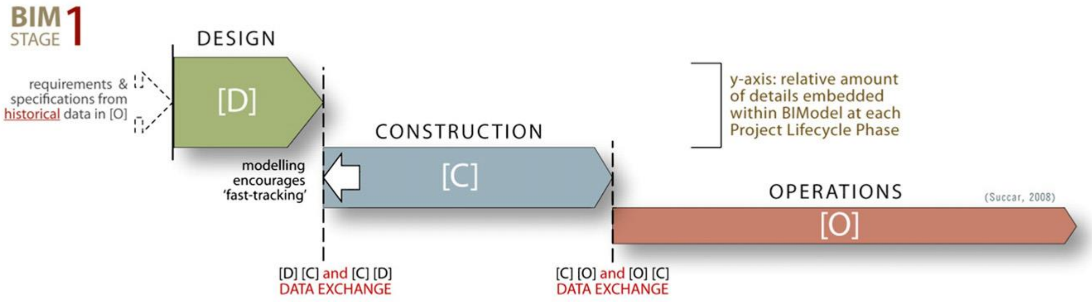


Figure 3.24. *BIM stage 1 project lifecycle phases (Succar, 2008)*

3.8.2. Stage Two: Model based COLLABORATION

In this stage players cooperate with other players after single disciplinary models are generated in stage one. Interchange of models through proprietary formats and non proprietary formats are two examples of model based collaboration. Interchange of models using the .RVT file format between Revit Architecture and Revit Structure is an example of proprietary format and interchange of models through the IFC file format between Tekla and ArchiCAD is an example of non proprietary format.

Stage two of BIM can occur within one or among two phases of project lifecycle. For instance the Design – Design interchange [D-D], the Design – Construction interchange [D-C] and the Design – Operations interchange [D-O] but only one of these collaborating models can have 3D geometric data for letting semantic interchange between disciplines (Succar, 2008).

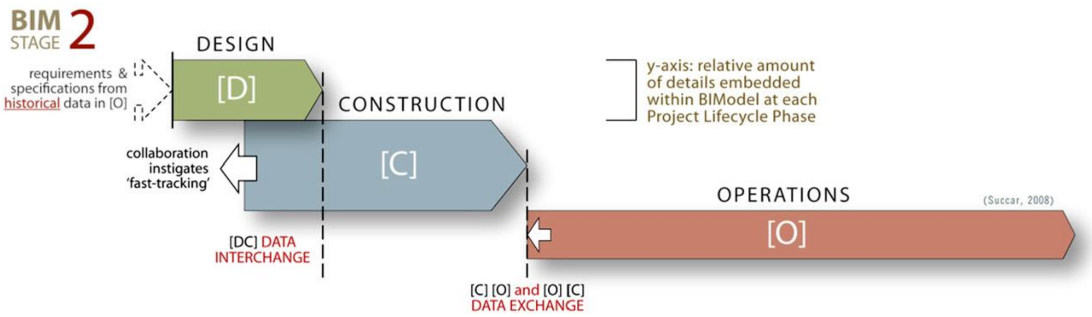


Figure 3.25. *BIM stage 2 project lifecycle phases (Succar, 2008)*

3.8.3. Stage Three: Network based INTEGRATION

Creating, sharing and maintaining of semantically rich integrated models across project life cycle phases are done in stage 3. Models in stage 3 become interdisciplinary nD which in virtual design and construction stages allows complex analysis.

Implementations of this stage requires reconsideration of contractual relationships, procedural flows and risk allocation models (Succar, 2008).

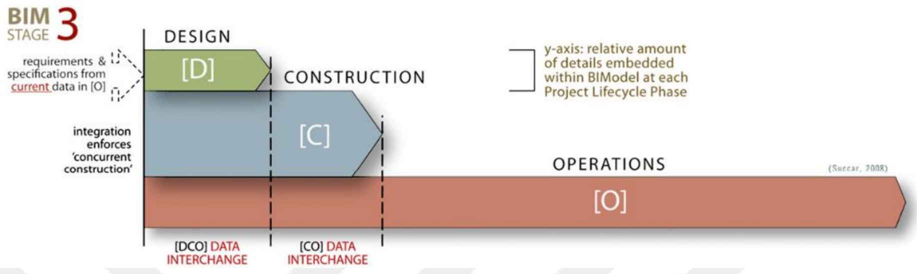


Figure 3.26. *BIM stage 3 project lifecycle phases (Succar, 2008)*

Third dimension of BIM framework is BIM lenses which is shown in Figure 3.27. They generate depth of inquiry of BIM framework. They are used to generate knowledge views by applying to stages and fields. They remove unnecessary details and control complexity of BIM domain (Succar, 2008). Complete overview of BIM framework is shown in Figure 3.28.

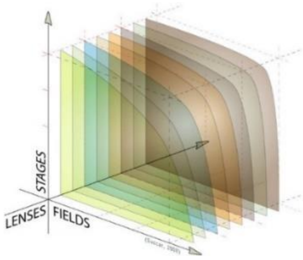


Figure 3.27. *BIM lenses (Succar, 2008)*

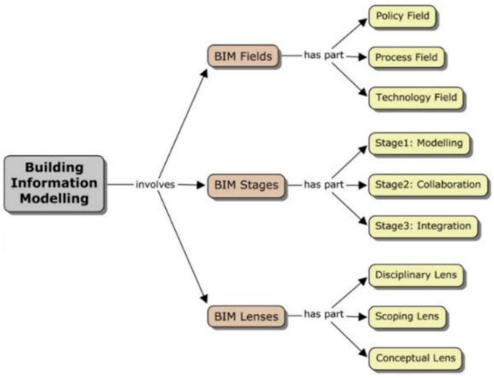


Figure 3.28. *BIM framework overview (Succar, 2008)*

4. GREEN TECHNOLOGY APPLICATION IN CONSTRUCTION

4.1. What is Green Technology?

Technology has been in use in different forms since human being started living and it's hard to give an exact date of technology invention. Technology meant different things in different eras. For example, tools for hunting in Stone Age, later metallic weapons and tools and so on can be named as very beginning technologies (Mueller, 2017).

Green technology includes the word "green" which does not mean the color, and using of knowledge for practical issues is called technology (Das, 2015). Many people think green technology is completely a new concept, while it started to be used long time ago than many people think of it. Electric taxi and windmill of 1900s are examples of green technology existence long time ago (http-11). It is eco-friendly technology which does not damage environment and natural resources. It is used to reduce greenhouse effect and global warming (Monokova et al., 2017) . It includes group of materials and methods for producing non toxic cleaning products and energy. The goals of green technology are sustainability, eco-friendly design and viability (http-4). It also aims to reduce built environment impact on environment and human health (Bai and Ravindra, 2014). Wind turbines, geothermal energy, solar power technology and hydro-power technology are examples of green technology.

Figure 4.1. *Green technology parameters (Bai and Ravindra, 2014)*

Green technology's key parameters are sustainability, economic feasibility and social equitability. It complements durability, economy, utility and comfort concerns of building design.

Planet earth is environmentally getting damaged day by day. Construction industry consumes about 40% of energy in some countries (Wan et al., 2012) and construction projects contribute to the global warming because they use fossil fuels such as oil and coal which are harmful to both environment and humans. These activities lead to the greenhouse gases emission especially CO_2. (Swarnkar and Singh, 2015). Figure 4.2 shows CO2 emissions per capita in different countries of the world.

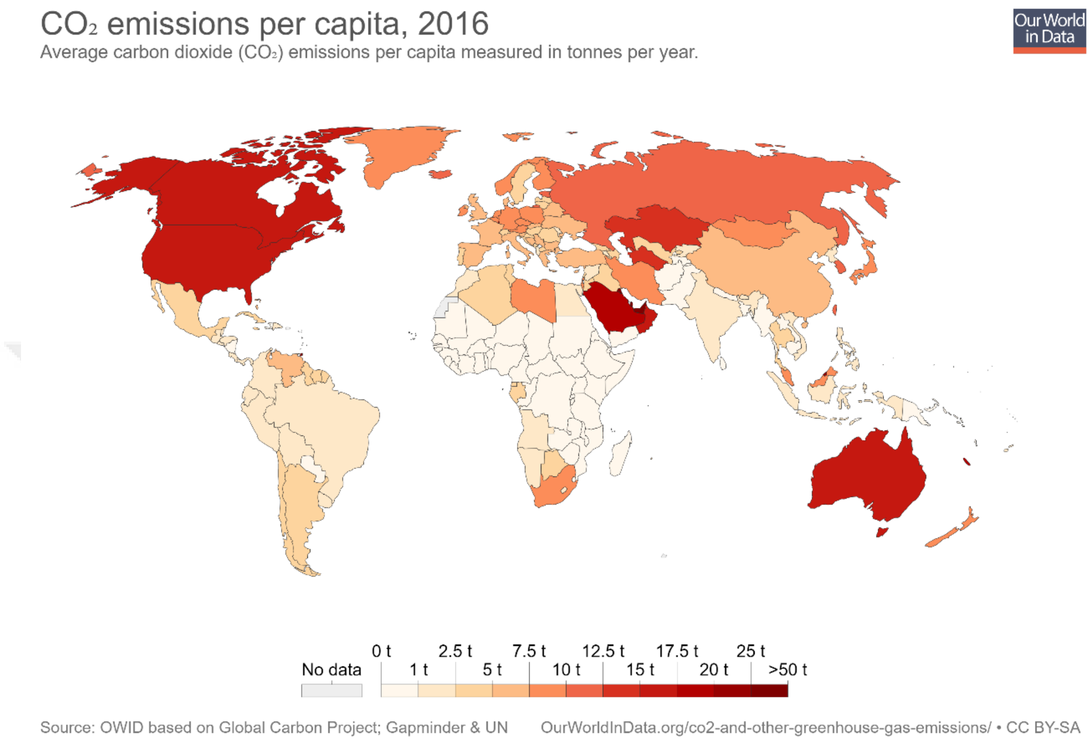


Figure 4.2. *CO_2 emissions per capita (Ritchie and Roser, 2018)*

Table 4.1 defines numeric ton/capita emission of CO_2 in year 2016 which is increasing rapidly if any fundamental solution is not found for it (Ritchie and Roser, 2018).

Table 4.1. *CO_2 emission / capita*

Entity	Code	Ton/year		Entity	Code	Ton/year
Afghanistan	AFG	0.338		Colombia	COL	1.739
Albania	ALB	2.093		Comoros	COM	0.201
Algeria	DZA	3.787		Congo	COG	0.638
Andorra	AND	6.34		Costa Rica	CRI	1.682
Angola	AGO	1.24		Cote d'Ivoire	CIV	0.5
Antigua and Barbuda	ATG	5.547		Croatia	HRV	4.405
Argentina	ARG	4.764		Cuba	CUB	3.2
Armenia	ARM	1.966		Curacao	CUW	38.938
Aruba	ABW	8.777		Cyprus	CYP	6.042

Table 4.1. (Continued) *CO_2 emission / capita*

Australia	AUS	16.496		Czech Republic	CZE	9.952
Austria	AUT	7.747		Congo	COD	0.062
Azerbaijan	AZE	4.119		Denmark	DNK	6.536
Bahamas	BHS	6.518		Djibouti	DJI	0.796
Bahrain	BHR	24.509		Dominica	DMA	1.904
Bangladesh	BGD	0.506		Dominican Republic	DOM	2.119
Barbados	BRB	4.702		Ecuador	ECU	2.464
Belarus	BLR	6.345		Egypt	EGY	2.259
Belgium	BEL	8.922		El Salvador	SLV	1.043
Belize	BLZ	1.417		Equatorial Guinea	GNQ	4.765
Benin	BEN	0.602		Estonia	EST	12.184
Bermuda	BMU	9.337		Ethiopia	ETH	0.116
Bhutan	BTN	1.416		Faeroe Islands	FRO	13.03
Bolivia	BOL	1.938		Fiji	FJI	1.446
Bosnia and Herzegovina	BIH	6.657		Finland	FIN	8.262
Botswana	BWA	2.955		France	FRA	5.134
Brazil	BRA	2.347		French Polynesia	PYF	3.212
British Virgin Islands	VGB	6.197		Gabon	GAB	2.733
Brunei	BRN	23.701		Gambia	GMB	0.26
Bulgaria	BGR	6.35		Georgia	GEO	2.525
Burkina Faso	BFA	0.159		Germany	DEU	9.696
Burundi	BDI	0.044		Ghana	GHA	0.538
Cambodia	KHM	0.48		Gibraltar	GIB	16.275
Cameroon	CMR	0.317		Greece	GRC	6.614
Canada	CAN	15.515		Greenland	GRL	9.611
Cape Verde	CPV	0.945		Grenada	GRD	2.423
Cayman Islands	CYM	9.38		Guatemala	GTM	1.164
Central African Republic	CAF	0.067		Guinea	GIN	0.206
Chad	TCD	0.053		Guinea-Bissau	GNB	0.154
Chile	CHL	4.868		Guyana	GUY	2.754
China	CHN	7.363		Haiti	HTI	0.278
Hong Kong	HKG	5.914		Mongolia	MNG	8.634
Hungary	HUN	4.893		Montenegro	MNE	3.757
Iceland	ISL	10.232		Morocco	MAR	1.691
India	IND	1.836		Mozambique	MOZ	0.304
Indonesia	IDN	1.918		Myanmar	MMR	0.46
Iran	IRN	8.17		Namibia	NAM	1.573
Iraq	IRQ	4.529		Nauru	NRU	3.832
Ireland	IRL	8.437		Nepal	NPL	0.315
Israel	ISR	7.776		Netherlands	NLD	9.897
Italy	ITA	5.928		New Caledonia	NCL	18.201
Jamaica	JAM	2.717		New Zealand	NZL	7.627

Table 4.1. (Continued) *CO_2 emission / capita*

Japan	JPN	9.521		Nicaragua	NIC	0.834
Jordan	JOR	2.734		Niger	NER	0.104
Kazakhstan	KAZ	13.011		Nigeria	NGA	0.55
Kenya	KEN	0.301		North America		17.637
Kiribati	KIR	0.612		North Korea	PRK	1.993
Kuwait	KWT	25.813		Norway	NOR	8.597
Kyrgyzstan	KGZ	1.662		Oman	OMN	15.09
Laos	LAO	0.309		Pakistan	PAK	0.978
Latvia	LVA	3.8		Palau	PLW	13.486
Lebanon	LBN	3.934		Palestine	PSE	0.615
Lesotho	LSO	1.021		Panama	PAN	2.293
Liberia	LBR	0.21		Papua New Guinea	PNG	0.874
Libya	LBY	9.567		Paraguay	PRY	0.894
Liechtenstein	LIE	4.248		Peru	PER	2.133
Lithuania	LTU	4.578		Philippines	PHL	1.242
Luxembourg	LUX	16.467		Poland	POL	8.406
Macao	MAC	2.352		Portugal	PRT	4.902
Macedonia	MKD	3.805		Qatar	QAT	47.829
Madagascar	MDG	0.121		Romania	ROU	3.966
Malawi	MWI	0.071		Russia	RUS	11.325
Malaysia	MYS	8.492		Rwanda	RWA	0.073
Maldives	MDV	3.593		Saint Kitts and Nevis	KNA	4.378
Mali	MLI	0.082		Saint Lucia	LCA	2.416
Malta	MLT	4.165		Samoa	WSM	1.127
Marshall Islands	MHL	2.261		Sao Tome and Principe	STP	0.6
Mauritania	MRT	0.656		Saudi Arabia	SAU	19.655
Mauritius	MUS	3.253		Senegal	SEN	0.584
Mexico	MEX	3.645		Serbia	SRB	5.614
Micronesia (country)	FSM	1.62		Seychelles	SYC	5.492
Moldova	MDA	1.453		Sierra Leone	SLE	0.184
Singapore	SGP	11.171		Tunisia	TUN	2.725
Sint Maarten (Dutch part)	SXM	19.498		Turkey	TUR	5.08
Slovakia	SVK	6.281		Turkmenistan	TKM	13.473
Slovenia	SVN	6.722		Turks and Caicos Islands	TCA	6.304
Solomon Islands	SLB	0.384		Tuvalu	TUV	0.901
Somalia	SOM	0.045		Uganda	UGA	0.129
South Africa	ZAF	8.365		Ukraine	UKR	5.365
South Korea	KOR	11.618		United Arab Emirates	ARE	25.794
South Sudan	SSD	0.128		United Kingdom	GBR	5.933
Spain	ESP	5.621		United States	USA	16.438
Sri Lanka	LKA	0.998		Uruguay	URY	2.064
Sudan	SDN	0.404		Uzbekistan	UZB	3.418

Table 4.1. (Continued) *CO_2 emission / capita*

Suriname	SUR	3.761	Togo	TGO	0.356
Swaziland	SWZ	0.871	Tonga	TON	1.307
Sweden	SWE	4.581	Vanuatu	VUT	0.629
Switzerland	CHE	4.504	Venezuela	VEN	5.601
Syria	SYR	1.716	Vietnam	VNM	2.013
Tajikistan	TJK	0.625	Yemen	YEM	0.819
Tanzania	TZA	0.217	Zambia	ZMB	0.275
Thailand	THA	4.753	Zimbabwe	ZWE	0.69
Timor	TLS	0.418			

According to United Nations Environment Program (UNEP) if new technologies (green technologies) are not implemented during rapid growth of construction projects, the annually emission of 9 billion tons of CO_2 can be doubled by 2050. This way green technology is an approach toward saving earth. Green technology is using renewable natural resources which are eco-friendly to environment. Environment is mostly polluted by waste disposal. Green technology changes waste in a way that is not harmful for the planet. Applications of green technology can be listed as solar array, reusable water bottle, solar water heater, wind generator, rain water harvesting system and insulating houses (Das, 2015). All green technologies can be classified as:

1- Technologies to solve the issue of global warming
2- Technologies for sustainable growth

Table 4.2 describes objective of green technology in different fields which green building or construction sector is one of them.

Table 4.2. *Green technology objectives (Aithal and Aithal, 2016)*

No	Field	Objective
1	Construction	Building ecofriendly green buildings compatible to environment
2	Sustainable Energy	Process and production of energy without harming environment
3	Automobiles	Production of energy efficient, ecofriendly automobiles
4	Food process	Elimination of toxic contents of food and prevention of environmental degradation in process of food packaging
5	Water	Filtration of water via green process.
6	Agriculture	Increasement in harvesting process, economic profitability

4.2. BIM and Green Building

Green building can be defined as reduction of building impacts on environment and human health via improved design, construction and O&M. Concept of green building is not new. It's beginning date can be mentioned as 19th century (Feltes, 2007) but its history of existence can go back to ancient Egyptians and Babylonians where people used accessible natural materials to build shelters for them (Ampratwum, 2017).

Construction projects have direct impact to environment as they consume raw material and quite high energy, therefore, project designers and owners should highly concern energy performance and sustainability of building projects. Mostly energy analysis tools to design energy efficient buildings have been conducted after design stage. However, such analysis is helpful for designers at the initial design phase to select most effective alternative (Jalaei and Jrade, 2014). The traditional design format has been changed after development of CAD software and BIM (Wong and Zhou, 2015). BIM gives the possibility of selecting different energy efficient design alternatives at the conceptual design phase (Jalaei and Jrade, 2014). Figure 4.3 describes managing of sustainable projects via BIM.

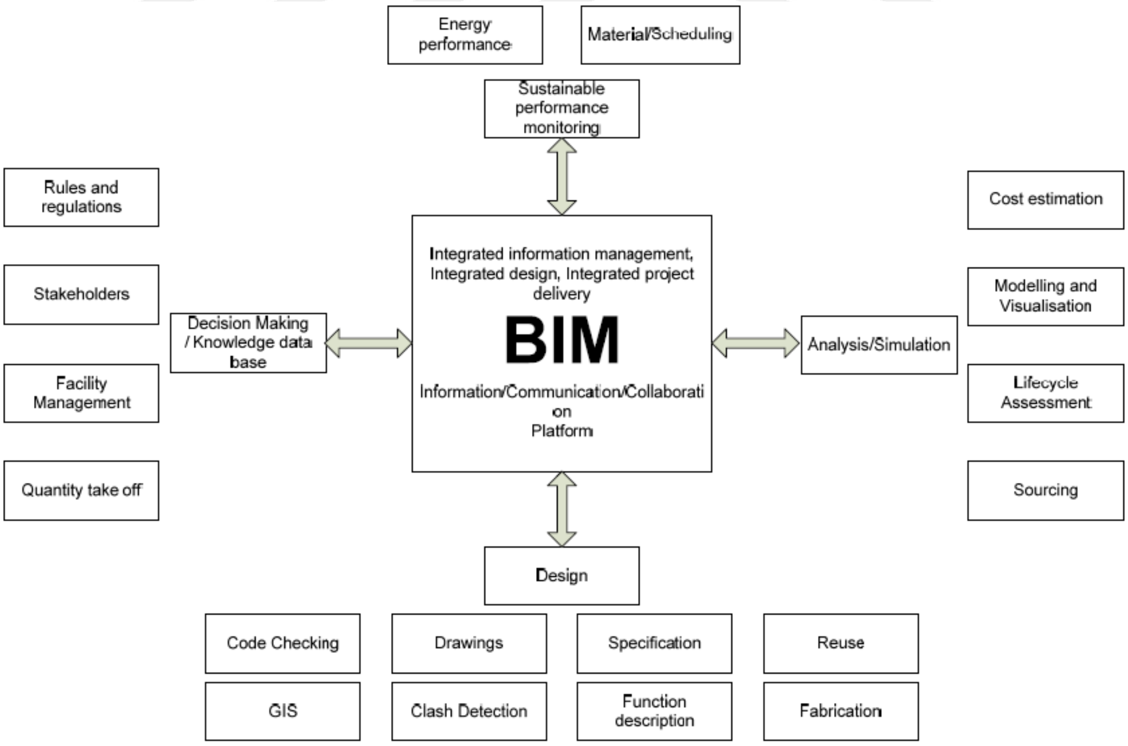


Figure 4.3. *Sustainable projects management via BIM (Liu et al., 2011)*

BIM gives the possibility of building analysis in different aspects. Figure 4.4 describes sustainability analysis of BIM.

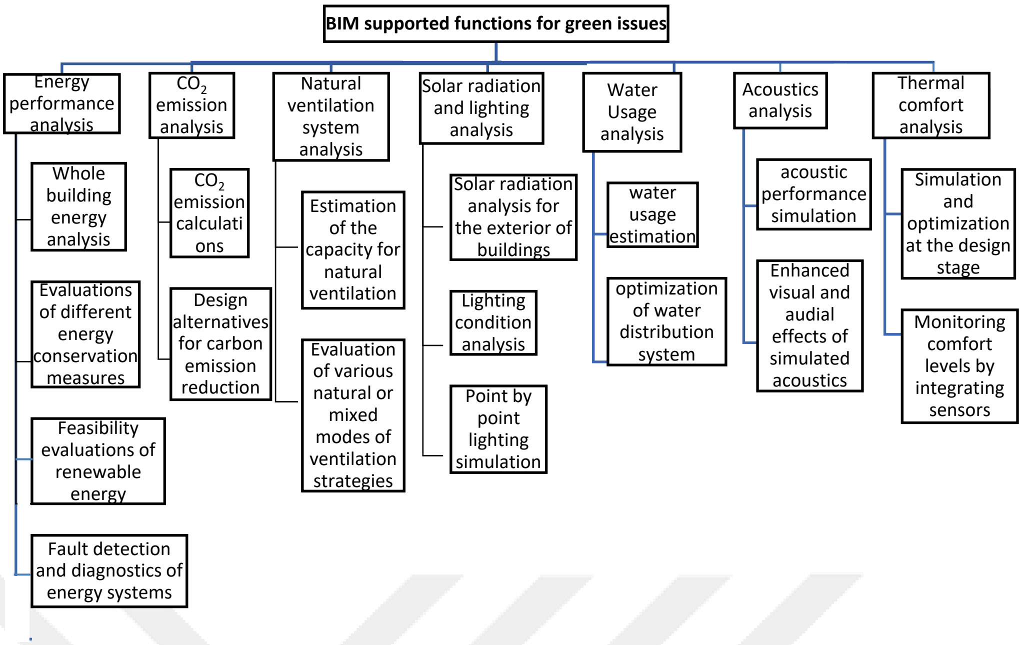


Figure 4.4. *Sustainability analysis of BIM (Lu et al., 2017)*

Environmental sustainability's concept in construction industry has been around for many years while major energy consumers are AEC (Architecture, Engineering & Construction) industry. The main goal of green building is to implement sustainability norms in AEC sector (Wu, 2010). BIM as a revolutionary technology has been taken into account as considerable opportunity in the AEC industry (Lu et al., 2017).

Green BIM tools includes 3 R's concept (recycle, reuse and reduce) in sustainability analysis of projects (Wong and Zhou, 2015).

Figure 4.5. *3 R's concept (http-5)*

Green BIM is divided into two, namely green buildings and BIM. In terms of green building, green characteristic and project stages can define green buildings while in terms of BIM, it demonstrates functions which BIM software provides to the project. Its obligatory properties are summarized as (Lu et al., 2017):

1- Combining with different databases
2- Simplifying document management
3- Visualizing analytical process and result
4- Provision of sustainability analysis

Figure 4.6 briefly describes green BIM triangle which is used to assist in noticing challenges and advantages of implementing green BIM (Lu et al., 2017).

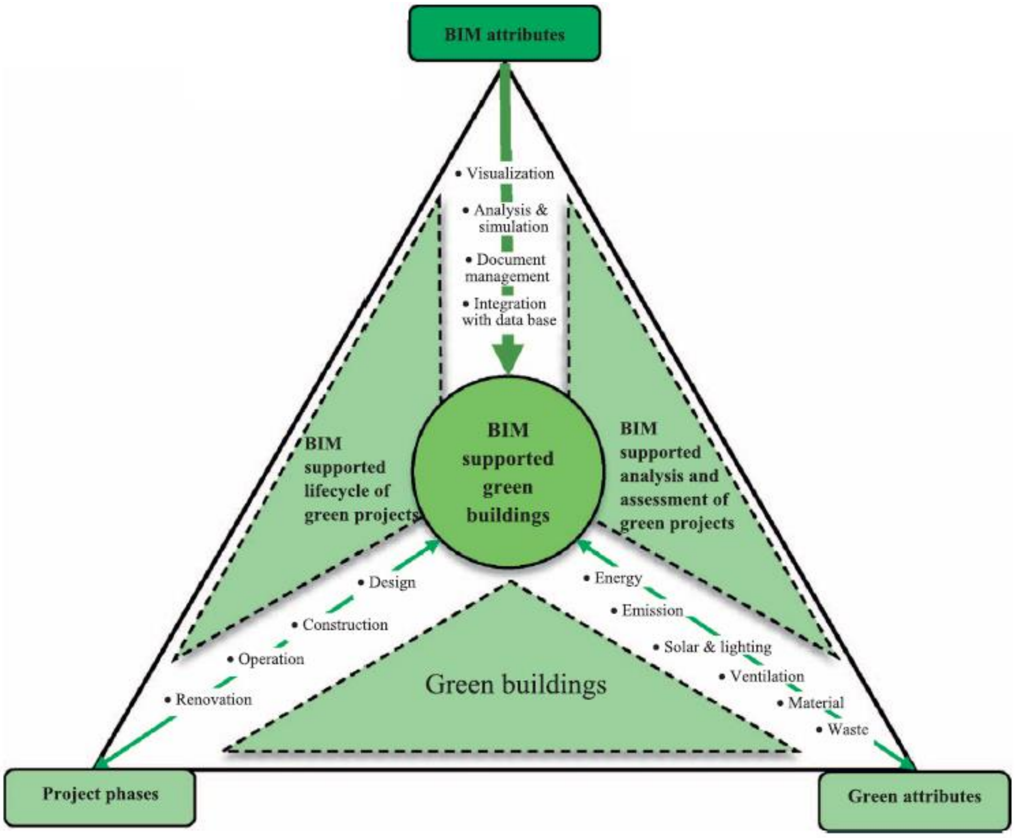


Figure 4.6. *Green BIM triangle (Lu et al., 2017)*

Green building strategies in construction industry can be adopted by the increase in sustainability concerns like reduction in carbon dioxide emission (Lu et al., 2017). Figure 4.7 describes sustainability and life cycle of sustainable buildings (Kim, 1998).

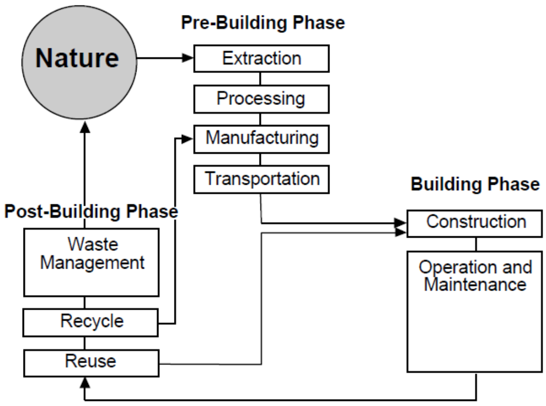


Figure 4.7. *Life cycle of sustainable building*

Parameters like sustainable site, atmosphere and energy, material and sources, water resources and indoor environment quality should be considered to make green buildings (Meher et al., 2016).

Buildings consume energy resources and they have a huge role on emission of CO_2, heating and cooling system of buildings play the key role in emission. Designers and planners work on minimizing these impacts and excess consumption of building energy via green ideas and improved designs. As per a report from McGraw Hill in 2008, traditional buildings have around 14% higher operating cost than green buildings (Wong and Zhou, 2015). Figure 4.8 describes common points of different stakeholders regarding green building (World Green Building Council, 2013).

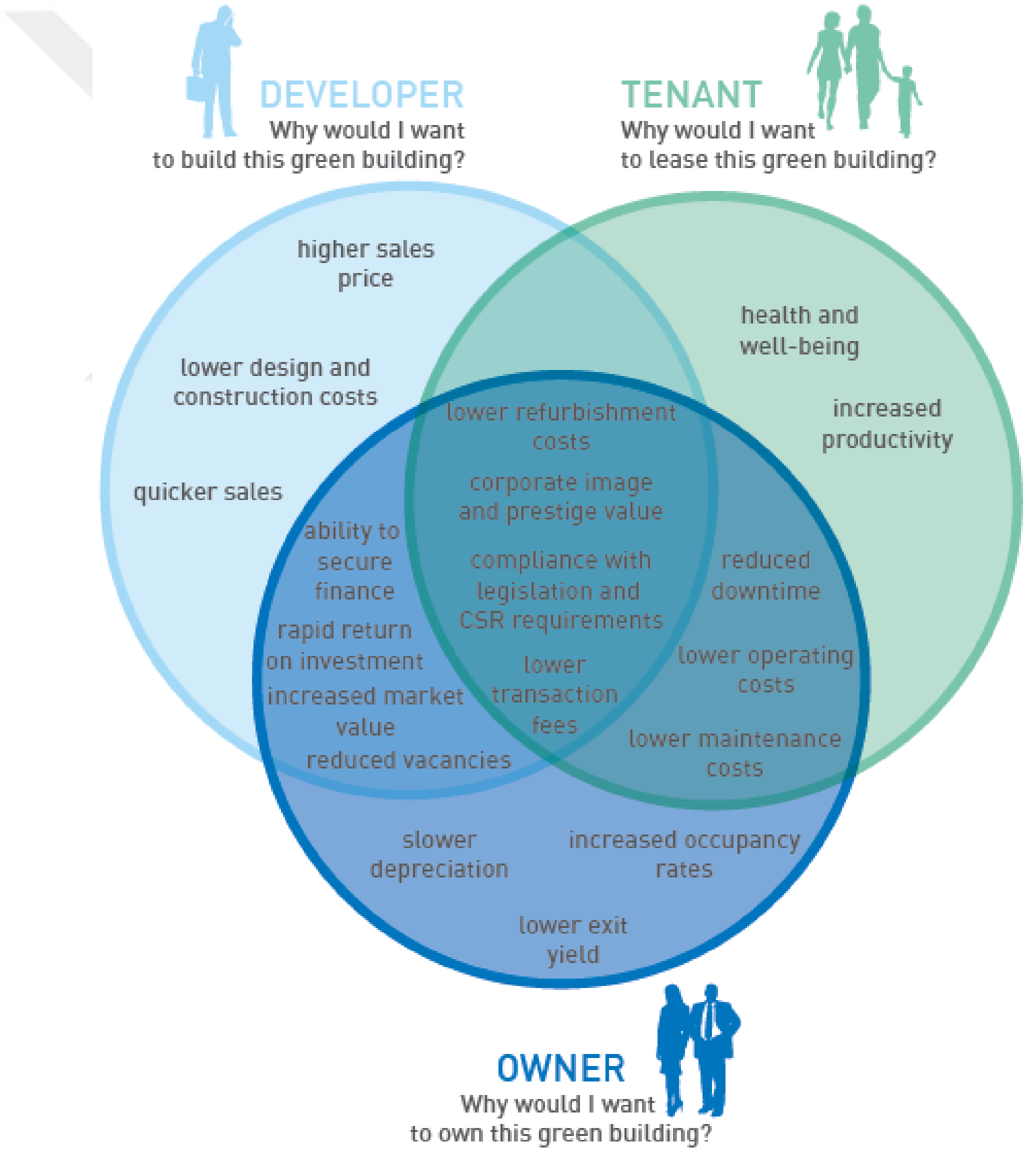


Figure 4.8. *Common points of different stakeholders regarding green building*

4.3. Common myths & realities of Green Building

Even though owners and designers are aware of benefits of green and sustainable buildings, but still there are some myths which are completely against reality. Some of the myths and their realities are mentioned below (Kubba, 2017).

Myth No 1: Green buildings are expensive than traditional buildings. Reality is that construction cost of green buildings might be little bit higher than traditional buildings, but research shows that LEED certified buildings prevent CO_2 emission, decrease water consumption and has about 25% lower operation cost.

Myth No 2: Green buildings are not as much attractive as conventional buildings. Reality is that green buildings does not have any difference from conventional buildings by their view, the only difference is in design not elevation views.

Myth No 3: Green buildings just use eco-friendly material. Reality is, the way of thinking green and designing the building. Using of eco-friendly material in design is a minor and important part of overall green building design.

Myth No 4: Rental rates of green buildings are lower than traditional buildings. Reality is completely against the myth. Due to lower cost of O&M, green buildings have higher rental rate than traditional buildings.

Myth No 5: Comfort level of green buildings are not as per demand. As discussed previously green building helps in prevention of greenhouse gas emission and also materials used in green building design helps in reduction of humidity, lighting and temperature control which is healthier and comfortable.

Myth No 6: It is hard to find products of green building. This myth could be true in past decades, but nowadays green technology products have been produced and distributed almost everywhere.

Myth No 7: Green building follows traditional techniques, technology and tools. Reality is that while designing green buildings, all stakeholders of the project including architects, consultants and owners gather into a team and architect plays team leader role. Commonly, local techniques and materials are used along with latest technology.

Myth No 8: Its complicated and difficult to build green. Reality is that sustainable building is matter of common sense. Many labors and builders nowadays claim green buildings are easy as they don’t require rocket science for implementation.

Myth No 9: Green buildings can not be built as skyscrapers. Reality is that all techniques and technologies which are implemented in traditional buildings can be implemented with green buildings too. “Condé Nast Building” and “Bank of America Tower” in Midtown Manhattan New York are its examples.

Myth No 10: Its quite hard to convert traditional building into green building. The truth is that it is not quite hard to do so, but there are some checklist and procedures to follow in order to meet green building standards.

4.4. Advantages of Green Technology

We have already discussed about origin and main features or green technology and green building. In this part we would like to go deeper to them and discuss about advantages of this technology. Mainly green technology is used for environment protection or repair of damaged ecosystem (http-6). For example, solar cells, they change energy to electricity through a specified process which helps in reduction of GHG emission and use of fossil fuels (Iravani et al., 2017).

Green or sustainable building can be defined as implementation of green technology in construction field. Some of the green building features can be named as: 1) Ecofriendly material like fly ash which can be used in production of bricks, mixed with cements to prepare concrete and used in production of aggregates. Other ecofriendly materials can be named as ply board, bamboo, gypsum board etc. 2) Ecofriendly construction like construction of cavity wall which helps in reduction of heating costs. 3) Green power like using of solar and wind energy. 4) Water use efficiency: Harvesting rain water which is a very effective way of collecting and reusing of rain water. Via this system excess rain water is collected in tanks, filtered and reused (Uparwat et al., 2013). Figure 4.9 describes collection of rainwater (Noori, 2015).

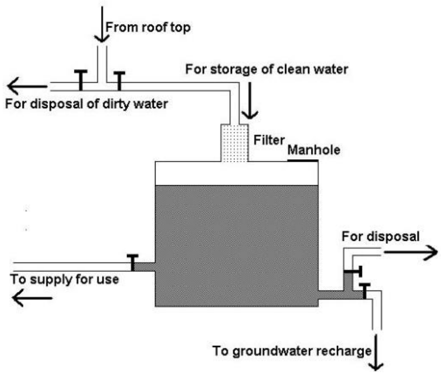


Figure 4.9. *Collection and reuse of rainwater (Noori, 2015)*

Green building technology like any other technology has both advantages and disadvantages. Maintenance, renovation and operation cost of green buildings are lower than standard buildings as it is claimed that investing on these buildings are 10 times more beneficial than traditional buildings. Water, energy and material efficiency are other advantages of these buildings (http-7). Reduction of water wastage, improvement in water and air quality and protection of ecosystem can be listed as environmental advantages while reduction of operating cost and market creation for green products are economical advantages of green buildings (http-8). As per researches, LEED certification achieved buildings use 11% less water and 25% less energy in comparison to normal buildings (http-9). Table 4.3 briefly describes benefits of green building.

Table 4.3. *Benefits of green building (Turcotte et al., 2006)*

Green Building Benefits		
Economic	**Social**	**Environmental**
Create, expand, and shape markets for green products and services	Enhance occupant comfort and health	Enhance and protect biodiversity and ecosystems
Improve occupant productivity	Heighten aesthetic qualities	Reduce waste streams
Optimize life-cycle economic performance	Improve overall quality of life	Conserve and restore natural resources

However, construction cost of green buildings are little bit more than traditional buildings, but they are cost effective and investing on them are 10 times more beneficial than normal buildings, Table 4.4 shows cost benefit result of 33 green buildings in USA.

Table 4.4. *Financial benefit result of green buildings in USA (Kats et al., 2003).*

Benefits	**20 year Net present Value (NPV)**
Energy Value	5.79 $/ft^2
Emissions Value	1.18$/ft^2
Water Value	0.51$/ft^2
Waste Value “Construction only” – 1 year	0.03$/ft^2
Commissioning O&M Value	8.47$/ft^2
Productivity and Health Value	36.89$/ft^2 to 55.33$/ft^2
Less Green Cost Premium	4.00$/ft^2
Total 20 year NPV	**48.87$/ft^2 to 67.31$/ft^2**

Figure 4.10 describes characteristics of environmentally efficient buildings where three of them have positive impact on value.

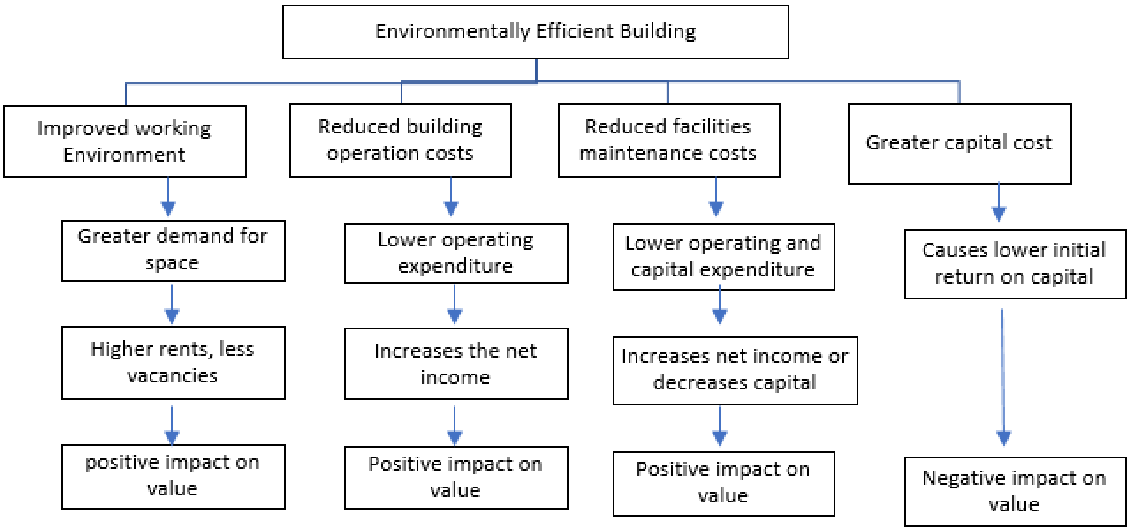


Figure 4.10. *Characteristics of environmentally efficient buildings (Boyd and Kimmet, 2005).*

Beside benefits and advantages, green buildings have minor disadvantages too which are listed below (Bhardwaj and Neelam, 2015):

- Higher implementation cost
- Insufficient savings in short term
- Unfamiliarity of people with this technology
- Shortage of skilled HR
- Sometimes hard to find required material to build such buildings

4.5. Green Building rating system

There are a lot of building councils around the world. Their aim is building sustainability. Among them well known is USGBC or United States Green Building Council which was first established in 1993 by David Gottfried. The council created rating system for building sustainability in 1998 which is Leadership in Energy and Environmental Design (LEED) system (Kim and Anderson, 2013). Different systems like BREEAM from UK, Green Star Australia, CASBEE from Japan in 2001, BEPAC from Canada, BEAM from Hong Kong, DGNB/BNB from Germany are developed as well (Jalaei and Jrade, 2014). These methodologies are established due to needs of sustainable design, increased energy consumption awareness and GHG emissions (Shrivastava and Chini, 2012).

BREEAM was established in 1989 as first and oldest assessment system used to measure sustainability of buildings. It measures building rating levels as pass (30-45)% score, good (45-55)% score, very good (55-70)% score, excellent (70-85)% score and outstanding (>85)% score. Number of BREEAM certified buildings are 20 times more than LEED, and more than one million buildings are registered to get certification (Kibert, 2013). Green star rating system from Australia was first evaluating offices in 2002 but later it included different types of buildings. It is point based rating system with maximum score of 132 points which evaluates buildings rating level from one to six stars (JEONG, 2011).

LEED rating system as measurement tool of environmental performance was evaluated by 7500 companies around the world (Jalaei and Jrade, 2014). As per reports published by USGBC in US 675.9 million ft^2 of real state space got LEED certification in 2014 and 13.8 billion ft^2 of building space is LEED certified by Aug 2015. This way LEED system has grown and been used in more than 150 countries including of US (Kubba, 2017). LEED certified projects have cleaner and healthier quality of indoor environment. BIM model application and LEED certification procedure were performed separately by two groups previously, but recently it is proposed to gather both (Lu et al., 2017). LEED mainly focuses on commercial buildings, but in recent additions it focuses on residential buildings as well (Feltes, 2007).

Buildings desire to receive LEED certification should meet the specific specifications specified by LEED system. Six categories are evaluated to ensure quality of buildings meet minimum requirements of LEED. Above mentioned six categories are sustainable sites, water efficiency, materials and resources, atmosphere and energy, indoor environmental quality and design and innovation process. LEED rating system is point based which means each category is evaluated and given points. Points are being added and then rating level is being issued and building can be rated as Certified, Silver, Gold or Platinum rating (Kubba, 2017). Possible points for each LEED category is shown in Table 4.5.

Table 4.5. *LEED checklist (Feltes, 2007)*

LEED checklist	
Category – possible points	**Summary**
Sustainable sites **14**	Requires the design of a sediment and erosion plan. Site must not be on prime farmland, on land lower that five foot, above 100 year flood plain, on a protected habitat, within 100 foot of wetlands, on public parklands. Offers points for channeling development to urban areas, locating between rail or bus lines, providing bicycle storage and showers for 5% of occupants.
Water efficiency **5**	Reduce water consumption for irrigation by 50%, use only captured rain or gray water for irrigation, or do not install landscape irrigation systems. Reduce use of city water for sewage by 50% or treat 100% of waste water on site to tertiary standards
Atmosphere and energy **17**	Must use best practice commissioning procedures. Must design to comply ASHRAE/IESNA 90.1-1999 or more stringent local code. Zero use of CFC-based refrigerants in HVAC systems. Points for reducing design energy costs, supplying 5%, 10% or 20% of total energy use via on-site renewable systems, installing HVAC and fire suppression systems that contain no FCFC's or halons, providing 50% of electricity from renewable sources over a two-year contract.
Materials and resources **13**	Points for providing an area for recycling waste material, diverting (50 – 70)% of construction demolition and land clearing waste from landfill, using 5% or 10% of salvaged or reused material, using 5% or 10% of total values of materials from post-consumer recycled content, using 20% or 50% of building materials that are manufactured within 500 miles, using 50% of wood based material from Forest Stewardship Council certified forests.
Indoor environmental quality **15**	Must meet minimum requirements of ASHRAE 62-1999. Must prohibit smoking in the building or provide ventilated smoking rooms. Points for installing a permanent CO2 monitoring system, designing ventilation systems that result in air change effectiveness, using wood and agrifiber products containing no added urea formaldehyde resins, designing to minimize pollutant cross contamination of occupied areas.
Innovation and Design process **5**	Points for exceptional performance above the requirements set by LEED or for innovative performance in green building categories not addressed by LEED, having a LEED accredited professional as a principal participant.

LEED v4.0 is the recent version released by USGBC. In previous versions, rating system was as Certified (26-32) points, Silver (33-38) points, Gold (39-51) points and

Platinum (52-60) points while in recent released version, rating system is as Certified (40-49) points, Silver (50 – 59) points, Gold (60 – 79) points and Platinum (>80) points. This way all LEED system have 100 base + 10 bonus points. LEED v2009 was being used until Oct 2016, later using of LEED v4.0 for new projects became mandatory (Kubba, 2017). Figure 4.11 describes point distribution of LEED v2009 for new construction and commercial interiors.

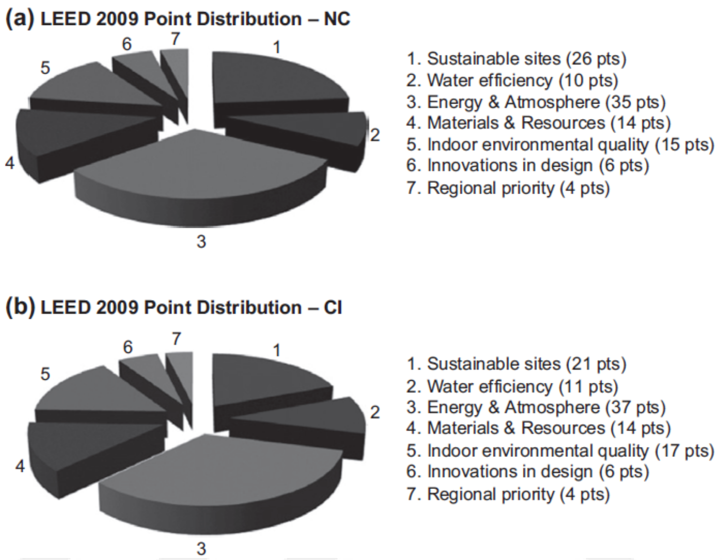


Figure 4.11. *LEED v2009 for NC (new construction) and CI (Commercial Interiors) (Kubba, 2017)*

While LEED rating system is used to evaluate sustainability of projects, still there are some companies and individuals not preferring to use this system with BIM due to reasons mentioned in Figure 4.12 as per McGraw-Hill construction report.

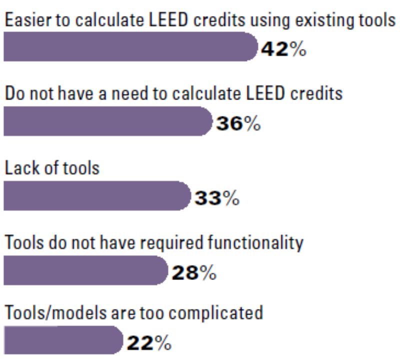


Figure 4.12. *Reasons for not using BIM to calculate LEED points (Smart Market Report, 2010).*

5. CASE STUDY

5.1. Aim of research

In previous chapters complete discussion about BIM and green technology has been done. As the aim of this study is to implement sustainability analysis and green technology in construction using BIM, in this chapter a 3D model of an already built residential building is created using Revit 2018 and for sustainability analysis purpose it is imported to Green Building Studio using gbXML file format. The project is a four story residential building including of an underground floor located in Kabul, Afghanistan. 3D model of the building is created with Revit 2018 as shown in Figure 5.1. It includes an underground basement and four residential floors consisted of 12 residential apartments. Basement plan, ground floor plan, typical floors plan, roof plan and cross section of building are shown in Figures 5.2, 5.3, 5.4, 5.5 and 5.6.

Figure 5.1. *3D model of 4 story building*

5.2. Methodology

Proposed methodology of current research is consisted of four main steps. Step one includes introduction and complete literature review of both BIM and green technology. Step two covers complete discussion about BIM. Step three covers main topics and brief discussion about green technology. Step four consists a case study and sustainability analysis using Green Building Studio application, conclusion, discussions and future recommendations.

Main purpose of current case study is sustainability analysis and comparing of different variants to select most ecofriendly and economical variant which also helps in less CO_2 emission. There are lots of softwares which are used for sustainability analysis as shown in Table 3.5, but the aim of selecting Green Building Studio is that it is compatible with Revit and also it is able to do several analysis as energy, carbon emission, natural ventilation, solar and day lighting and water usage.

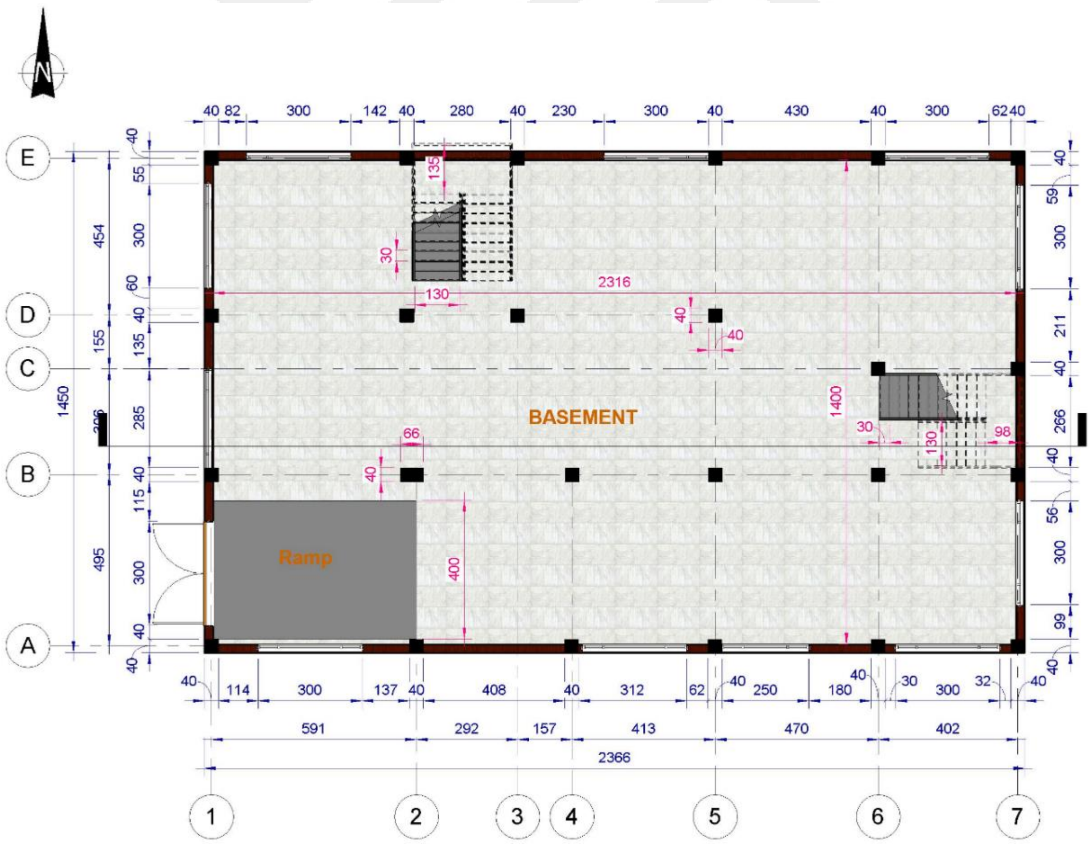


Figure 5.2. *Basement plan of 4 story building*

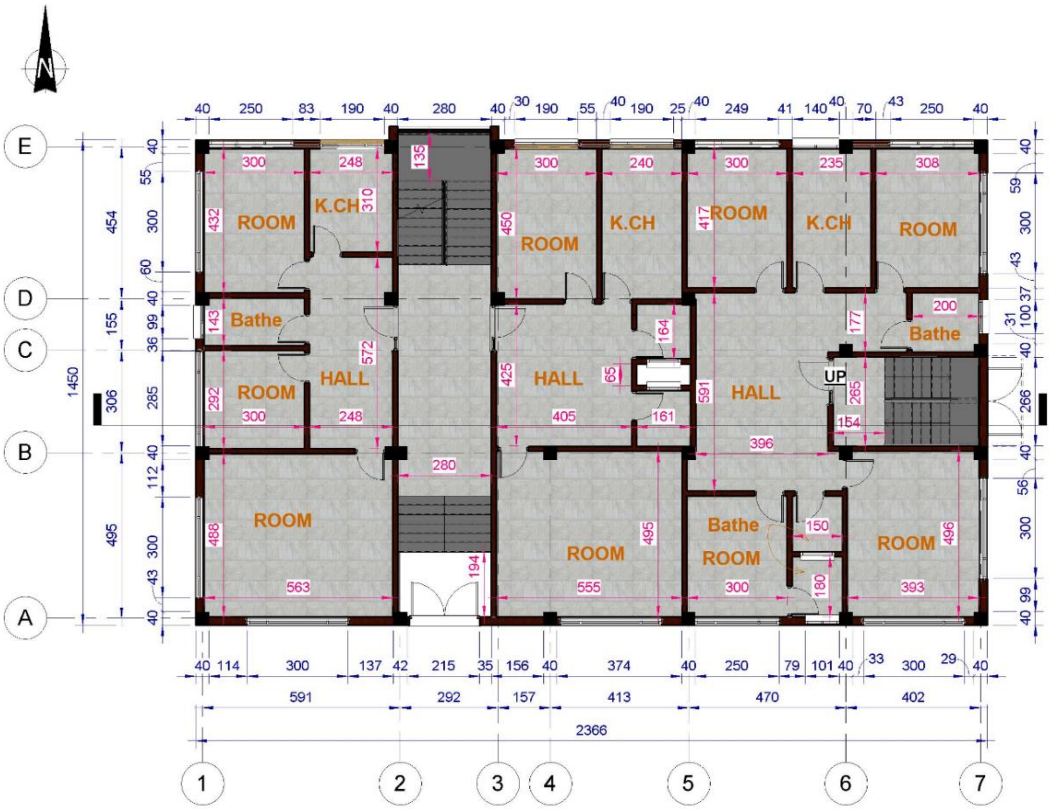


Figure 5.3. *Ground floor plan of 4 story building*

Figure 5.4. *Typical floors plan of 4 story building*

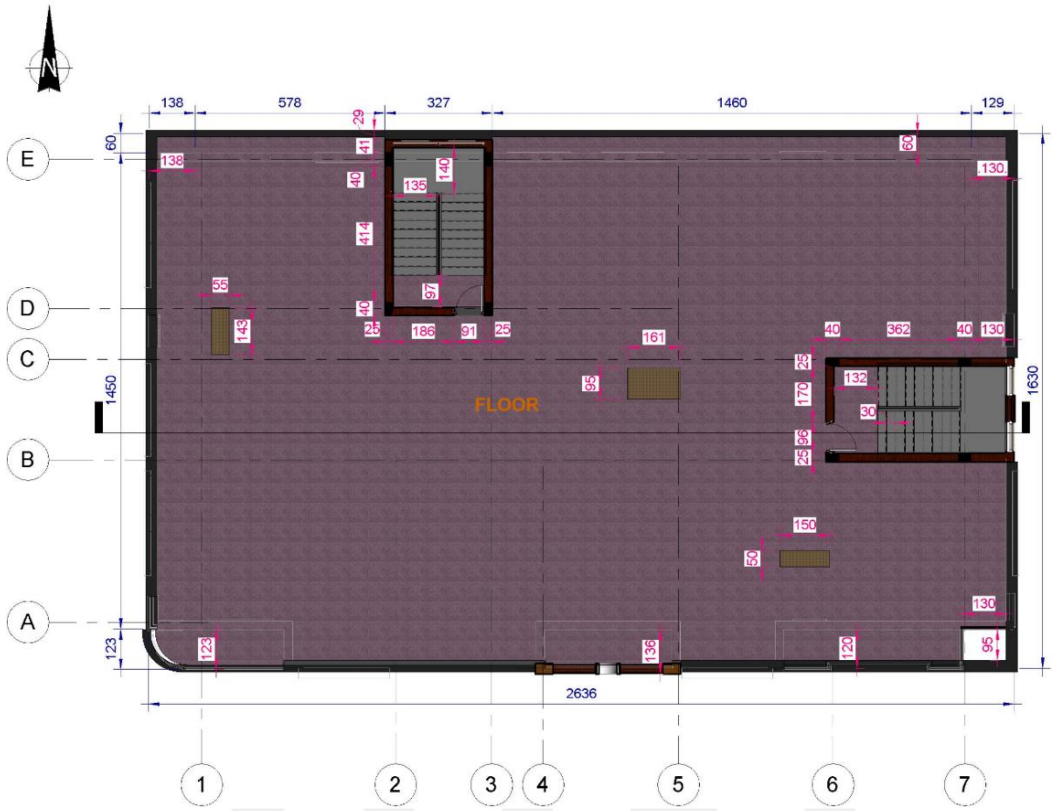


Figure 5.5. *Roof plan of 4 story building*

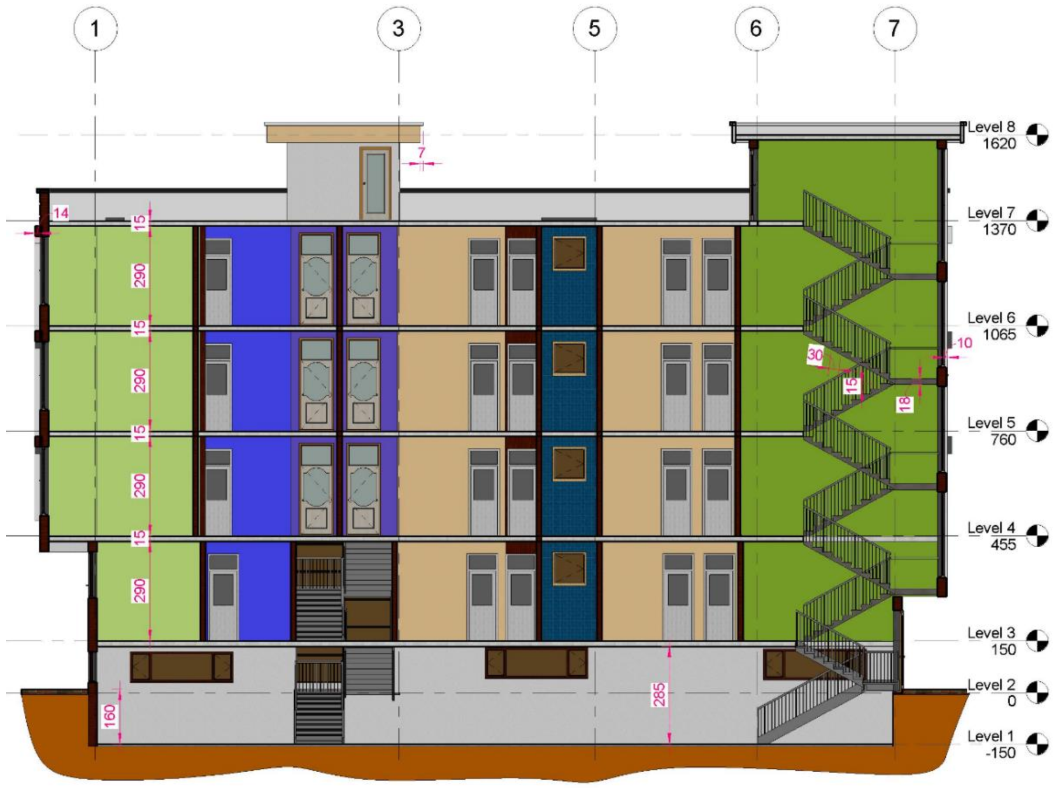


Figure 5.6. *Cross section of 4 story building*

In order to implement the analysis there are some steps to be taken. Firstly project information should be inputed to Revit which includes identity data and energy analysis data which can be accessed from “Manage” tab as shown in Figure 5.7. After identifying project information, building material should be specified using “Manage” tab.

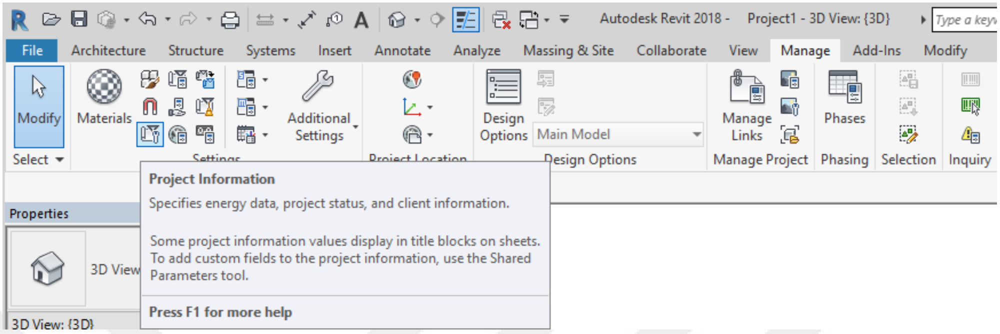


Figure 5.7. *Project Information tab*

After entering the project information and preparing the 3D model, 3D model should be converted to analytical model which means all spaces should be converted into rooms using Room option in “Architecture” tab of Revit. After completion of all above mentioned steps, the model should be exported to Green Building Studio using gbXML file format. Figure 5.8 shows analytical model of building which is ready to export to Green Building Studio application.

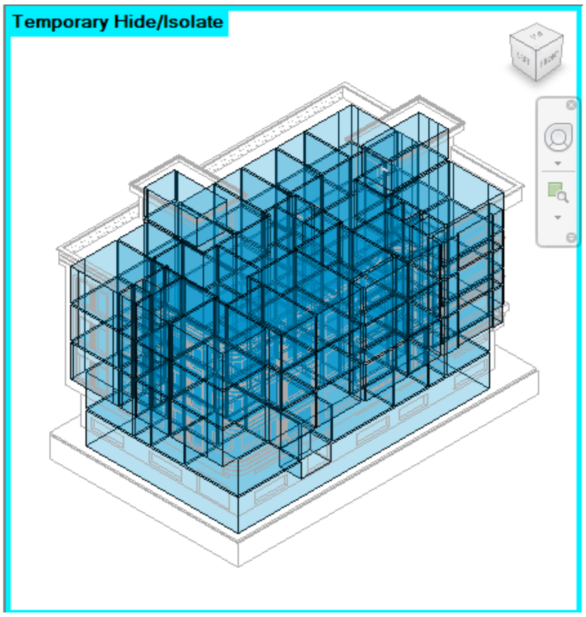


Figure 5.8. *Exporting gbXML file format*

6. CASE STUDY ANALYSIS AND DISCUSSION

6.1. Analysis

As Green Building Studio is cloud based energy analysis service and the analysis via this software is done online, so first we have to log in to the software online via http://gbs.autodesk.com and create a project there. Creating project has three preliminary steps in GBS. First step includes adding initial data regarding project which is shown in Figure 6.1.

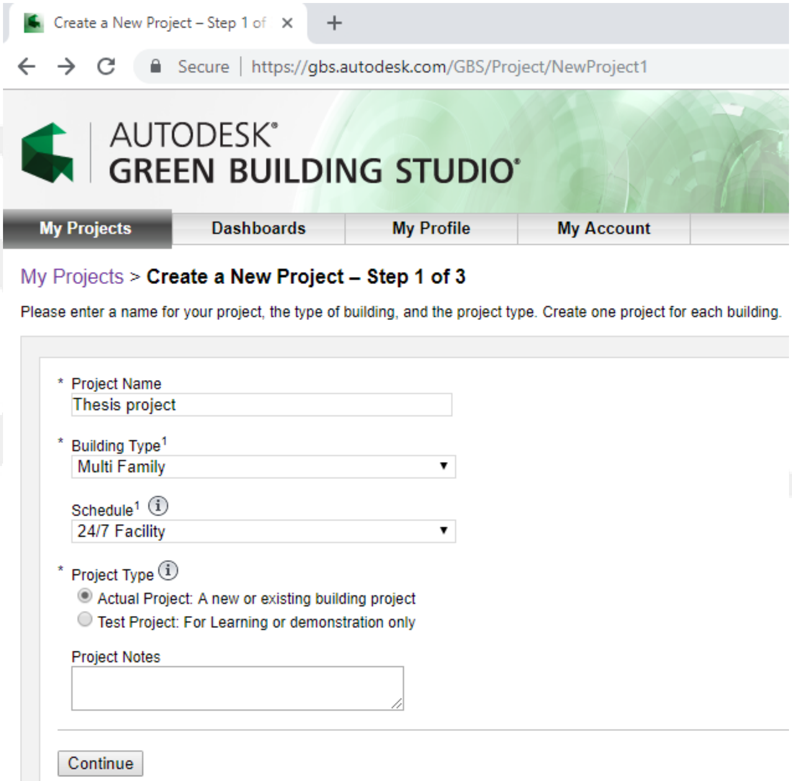


Figure 6.1. *Initial data for GBS*

Step two includes specification of project location and step three includes autorization data regarding the project. Prior to importing gbXML file, it is advised to provide utility information according to selected region and project default data via “Project Defaults” tab. After setting up all the information, gbXML file should be uploaded to analyse the project.

While selecting the project location, Green Building Studio automatically detects weather station and data of the region. As our project is located in Kabul, Afghanistan so region data including of monthly design data, annual wind roses, wind speed frequency distribution, relative humidity frequency distribution, direct normal radiation frequency distribution, dew point frequency distribution, diffuse horizontal radiation frequency distribution and global horizontal radiation frequency distribution which are used in analysis via Green Building Studio are shown in Figures 6.2 – 6.9.

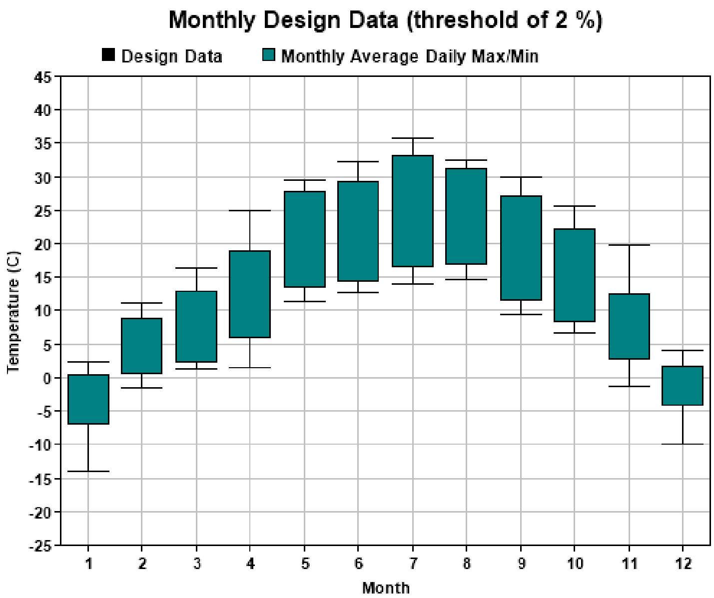


Figure 6.2. *Monthly design data*

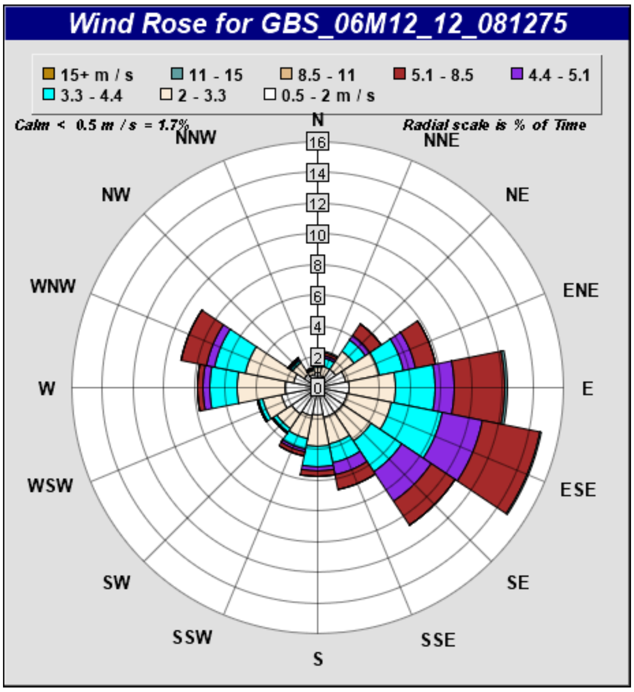


Figure 6.3. *Annual wind roses*

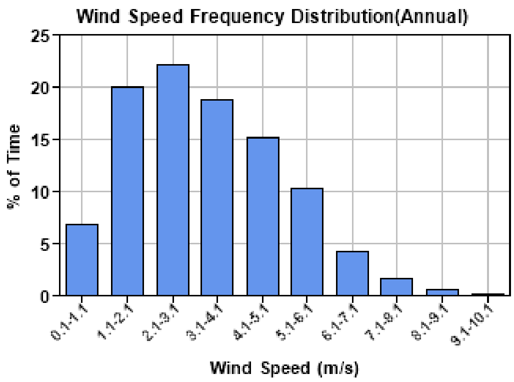


Figure 6.4. *Wind speed frequency distribution*

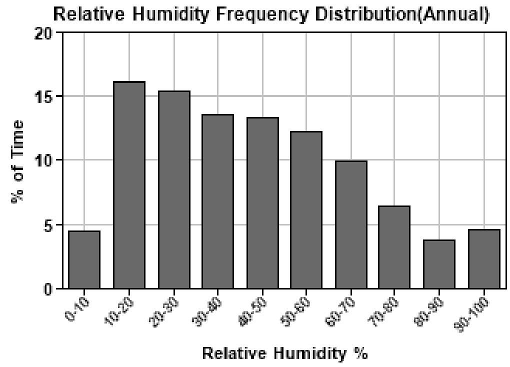


Figure 6.5. *Relative humidity frequency distribution*

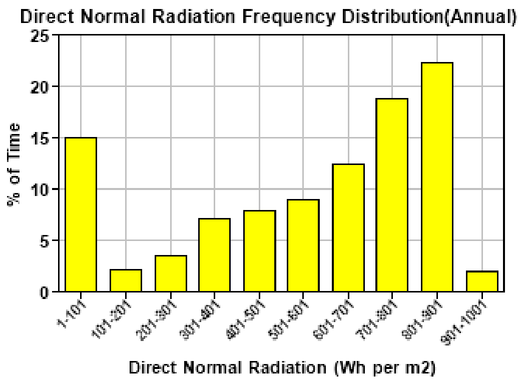


Figure 6.6. *Direct normal radiation frequency distribution*

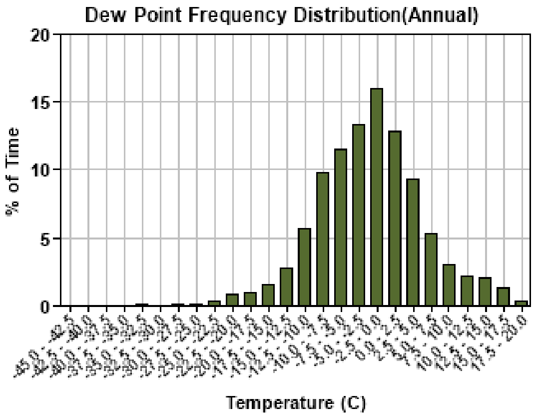


Figure 6.7. *Dew point frequency distribution*

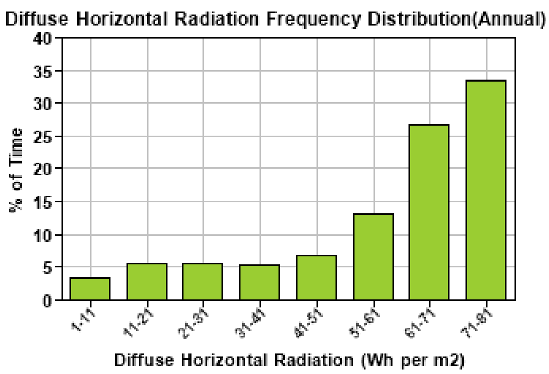


Figure 6.8. *Diffuse horizontal radiation frequency distribution*

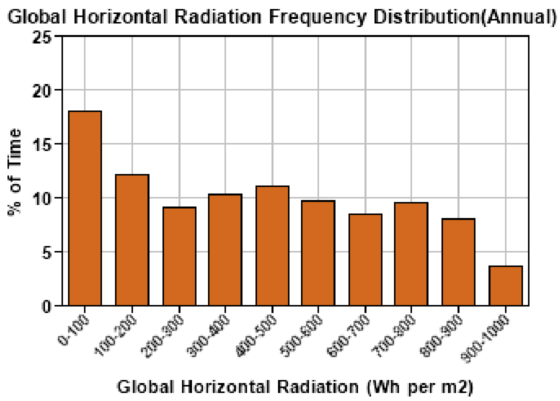


Figure 6.9. *Global horizontal radiation frequency distribution*

Project specifications are taken from gbXML file imported from Revit. Besides that, other specifications can be specified via GBS "Project Defaults" tab. In our case, the type of building is selected as “Multi Family” and condition type is selected as “Heated and Cooled”. Rest of the settings are unchanged which means GBS will select and analyse them as per selected region and standards.

Tentative price of $\frac{4.00\ AF}{kWh}$ is considered for electric cost and $\frac{40.00\ AF}{Therm}$ is considered for fuel cost. After initial analysis by GBS, annual and lifecycle cost, and usage of energy and fuel is provided in Table 6.1. Lifecycle duration of project is being considered 30 years by GBS. Building details and assumptions are shown in Table 6.2.

Table 6.1. *Energy and cost summary*

Energy and Cost Summary			
Annual Enery Cost	1,059,390.00 AFN		
Lifecycle Cost	14,428,889.00 AFN		
Annual Energy		**Lifycycle Energy**	
Energy Use Intensity (EUI)	873 MJ / m² / year	Electric	5,549,682 kW
Electric	184,989 kWh	Fuel	25,271,535 MJ
Fuel	842,385 MJ		
Annual Peak Demand	44.8 kW		

Annual electric end use and fuel end use charts are shown in Figures 6.10 and 6.11.

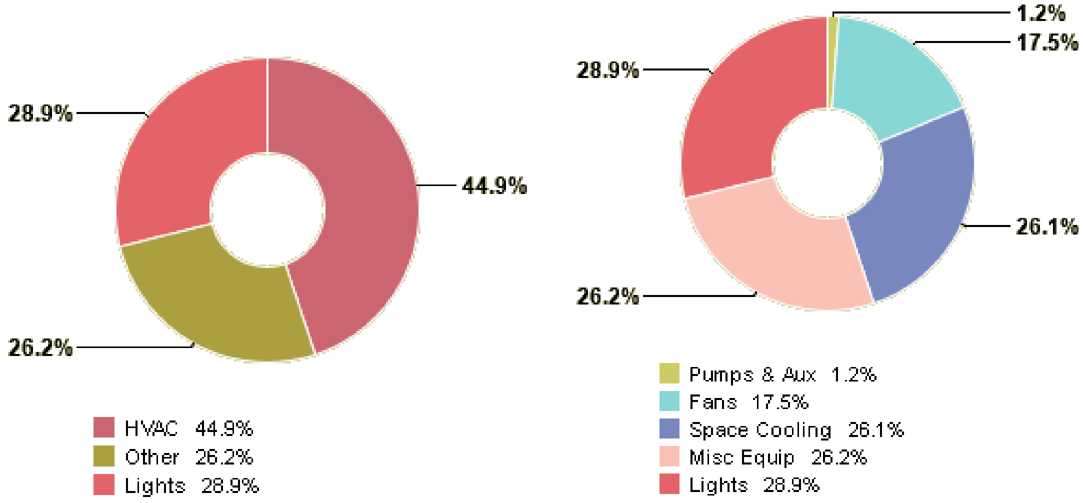


Figure 6.10. *Basic and detailed view of annual electric end use*

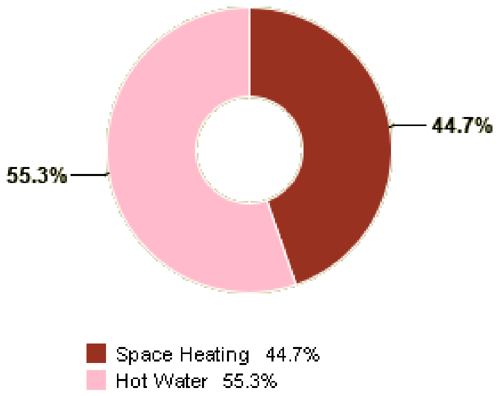


Figure 6.11. *Detailed view of annual fuel end use*

Table 6.2. *Building details and assumptions*

Building Summary - Quick Stats		
Number of People:	51 people	
Average Lighting Power Density:	6.46 W / m²	
Average Equipment Power Density:	5.87 W / m²	
Specific Fan Flow:	5.4 LPerSec / m²	
Specific Fan Power:	-1,189,486.564 W/LperSec	
Specific Cooling:	0 m² / kW	
Specific Heating:	0 m² / kW	
Total Fan Flow:	9,248 LPerSec	
Total Cooling Capacity:	-3,223,749 kW	
Total Heating Capacity:	3,223,749 kW	
Base Run Hydronic Equipment		
Hot Water	Boiler Capacity	847,371
	Pump flow	3 LPerSec
Domestic Hot Water	Average Demand	83,753
Base Run Air Equipment		
Packaged Terminal Air Conditioner	Supply Fan Flow	3,979 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-1,142,966
	Heating Capacity	1,142,966
Packaged Terminal Air Conditioner	Supply Fan Flow	1,763 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-556,829
	Heating Capacity	556,829

Table 6.2. (Continued) *Building details and assumptions*

Packaged Terminal Air Conditioner	Supply Fan Flow	1,482 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-761,977
	Heating Capacity	761,977
Packaged Terminal Air Conditioner	Supply Fan Flow	356 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-117,227
	Heating Capacity	117,227
Packaged Terminal Air Conditioner	Supply Fan Flow	1,534 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-586,136
	Heating Capacity	586,136
Packaged Terminal Air Conditioner	Supply Fan Flow	12 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-29,307
	Heating Capacity	29,307
Packaged Terminal Air Conditioner	Supply Fan Flow	121 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-29,307
	Heating Capacity	29,307

Total amount of monthly energy use including of electricity and fuel (Natural Gas) is provided in Figures 6.12, 6.13 and 6.14.

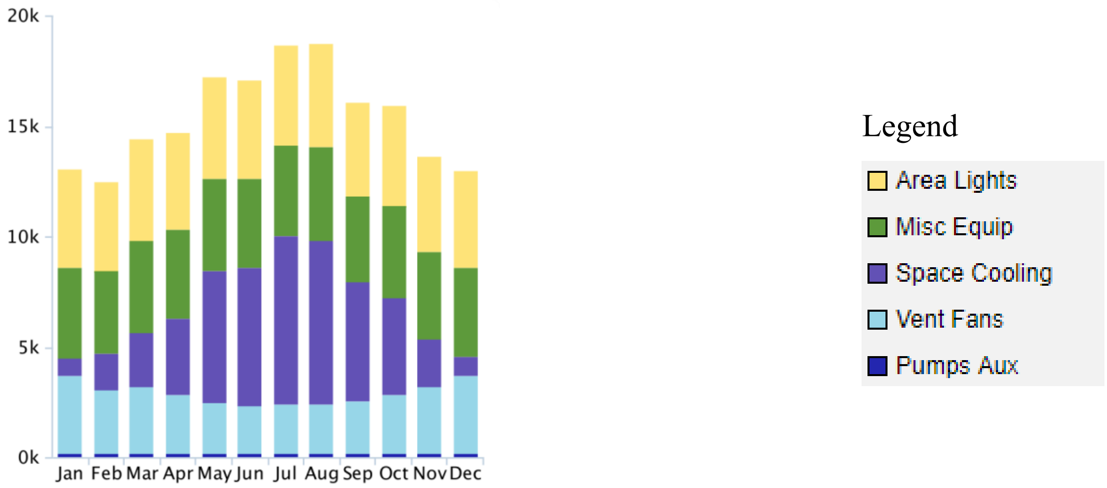


Figure 6.12. *Monthly electricity use (kWh)*

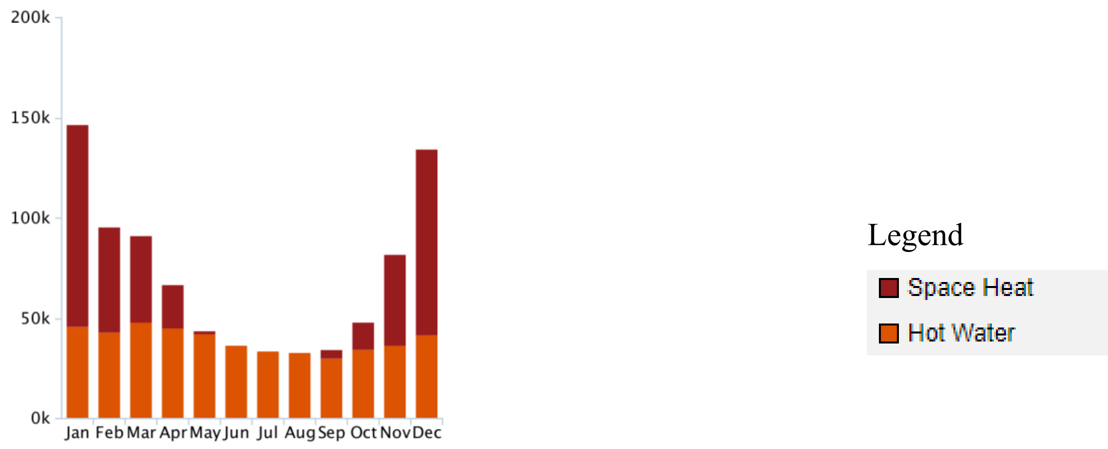


Figure 6.13. *Monthly fuel (Natural gas) use (MJ)*

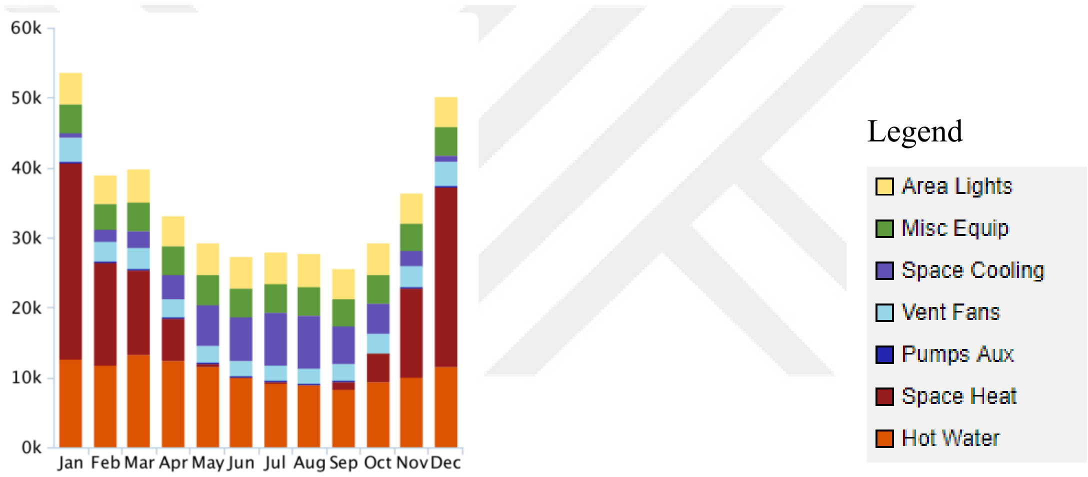


Figure 6.14. *Monthly data of electric and fuel (kWh)*

Due to GBS suggestion, this building is convinent for 51 people in all 12 apartments and a total of 4,136,720 L / year water usage is estimated as per Table 6.3 with standard efficiency. No rainwater harvesting or greywater reclamation are considered in this analysis.

Table 6.3. *Building summary for water usage*

	Total pieces	**Efficiency**
Toilets	27	Standard
Sinks	39	Standard
Showers	19	Standard
Clothes washers	12	Standard
Dishwashers	12	Standard

For comparing and selecting convenient option, an alternative design has been analysed and the results are compared. Building material for both alternatives are the same. Exterior walls and top most floor ceiling includes isolated material to help in prevention of interior energy lost. Different insulation materials can be used. As per a research done in Afghanistan, price comparison of different insulation materials for 1m^2 wall has been done in Table 6.4 (Ayobi, 2016).

Table 6.4. *Price comparison of different insulation material (Ayobi, 2016)*

Dimension	Material	Price in AF
1 x 1 x 0.25	Without insulation	985
1 x 1 x 0.15	With Polystyrene	1542
1 x 1 x 0.25	With Hollow Concrete Blocks	995
1 x 1 x 0.15	With plasterboard and sawdust	1042
1 x 1 x 0.15	With Plasterboard and ash	962

Occupancy sensors and daylight sensors and controls are suggested for lighting control to decrease electricity usage of the building. Translucent Wall Panel, (U-0.29, SHGC 0.19, Tvis 0.20) glazing type is suggested for exterior walls due to the weather condition of the region. Table 6.5 compares the result of both analysis.

Table 6.5. *Energy and cost summary of alternative analyses*

Base Design		**Alternative Design**	
Annual Energy cost	1,059,390 AF	Annual Energy cost	986,396 AF
Lifecycle Cost	14,428,889 AF	Lifecycle Cost	13,434,719 AF
Annual Energy		**Annual Energy**	
Energy Use Intensity	873 MJ / m² / year	Energy Use Intensity	873 MJ / m² / year
Electric	184,989 kWh	Electric	164,664 kWh
Fuel	842,385 MJ	Fuel	864,299 MJ
Annual Peak Demand	44.8 kW	Annual Peak Demand	30.4 kW
Lifecycle Energy		**Lifecycle Energy**	
Electric	5,549,682 kW	Electric	4,939,908 kW
Fuel	25,271,535 MJ	Fuel	25,928,955 MJ

Annual electric end use and fuel end use charts for alternative design are shown in Figures 6.15 and 6.16. Building details and assumptions for alternative design are shown in Table 6.6.

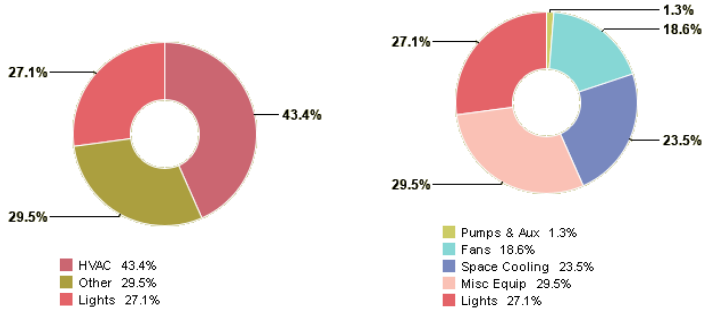


Figure 6.15. *Basic and detailed view of annual electric end use for alternative design*

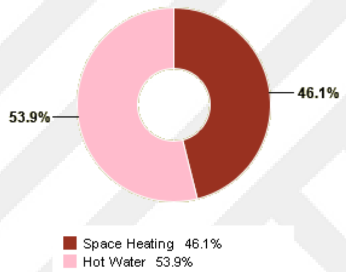


Figure 6.16. *Detailed view of annual fuel end use for alternative design*

Table 6.6. *Building details and assumptions for alternative design*

Building Summary - Quick Stats		
Number of People:	51 people	
Average Lighting Power Density:	5.41 W / m²	
Average Equipment Power Density:	5.87 W / m²	
Specific Fan Flow:	5.0 LPerSec / m²	
Specific Fan Power:	-1,278,860.538 W/LperSec	
Specific Cooling:	0 m² / kW	
Specific Heating:	0 m² / kW	
Total Fan Flow:	8,601 LPerSec	
Total Cooling Capacity:	-3,223,749 kW	
Total Heating Capacity:	3,223,749 kW	
Base Run Hydronic Equipment		
Hot Water	Boiler Capacity	794,301
	Pump flow	3 LPerSec
Domestic Hot Water	Average Demand	83,753

Table 6.6. (Continued) *Building details and assumptions for alternative design*

Base Run Air Equipment		
Packaged Terminal Air Conditioner	Supply Fan Flow	3,897 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-1,142,966
	Heating Capacity	1,142,966
Packaged Terminal Air Conditioner	Supply Fan Flow	1,463 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-556,829
	Heating Capacity	556,829
Packaged Terminal Air Conditioner	Supply Fan Flow	1,381 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-761,977
	Heating Capacity	761,977
Packaged Terminal Air Conditioner	Supply Fan Flow	356 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-117,227
	Heating Capacity	117,227
Packaged Terminal Air Conditioner	Supply Fan Flow	1,372 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-586,136
	Heating Capacity	586,136
Packaged Terminal Air Conditioner	Supply Fan Flow	12 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-29,307
	Heating Capacity	29,307
Packaged Terminal Air Conditioner	Supply Fan Flow	121 LPerSec
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-29,307
	Heating Capacity	29,307

Total amount of monthly energy use including of electricity and fuel (Natural Gas) for alternative design is provided in Figures 6.17, 6.18 and 6.19.

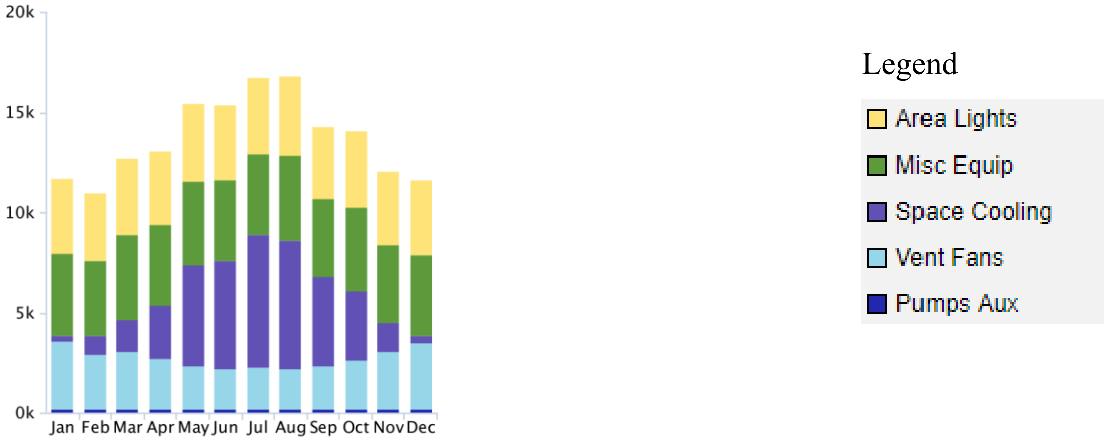


Figure 6.17. *Monthly electricity use for alternative design (kWh)*

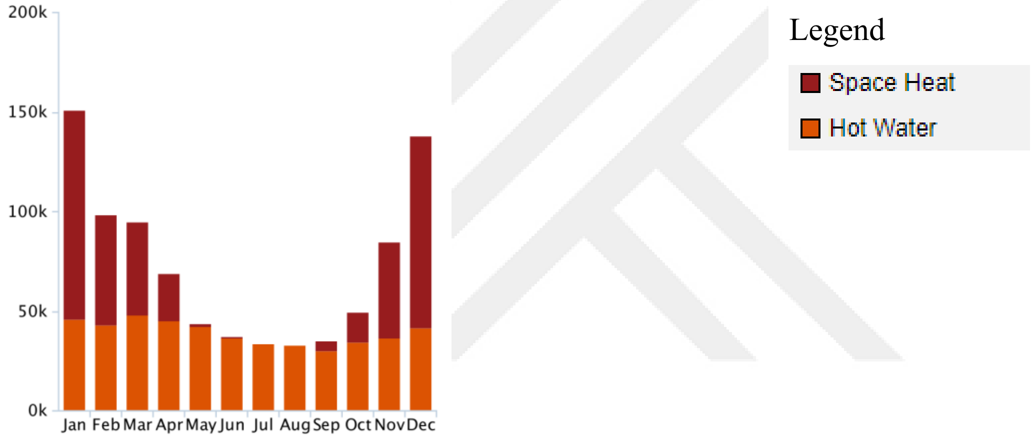


Figure 6.18. *Monthly fuel (Natural gas) use for alternative design (MJ)*

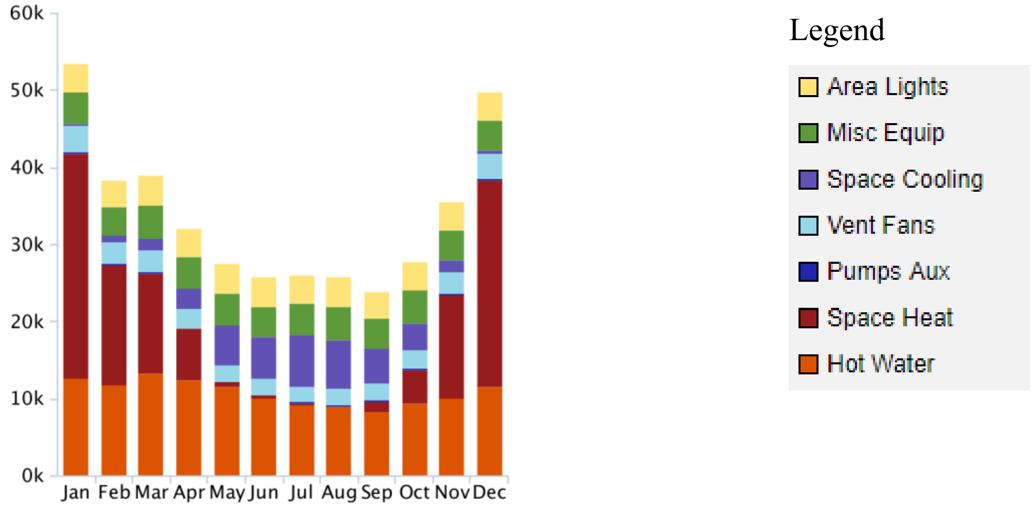


Figure 6.19. *Monthly data of electric and fuel for alternative design (kWh)*

Electricity, fuel and energy comparison of both options are graphically shown in Figures 6.20, 6.21 and 6.22 below.

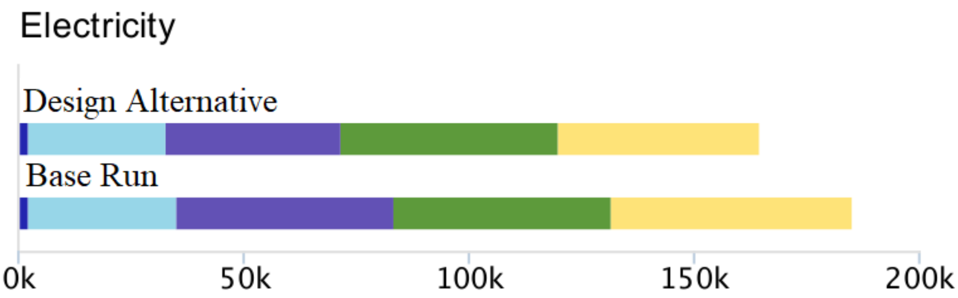


Figure 6.20. *Annual data of electricity (kWh)*

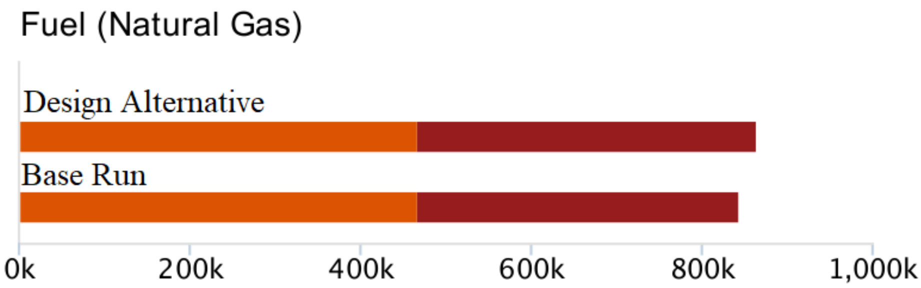


Figure 6.21. *Annual data of fuel (MJ)*

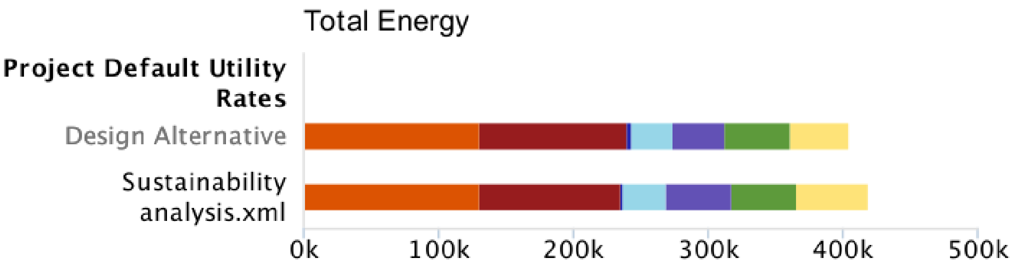


Figure 6.22. *Annual data of total energy (kWh)*

Remarkable energy saving is reported in alternative design. However implementing green technology and sustainability is expensive but it is suitable for environment and is economically best option in long term.

As mentioned previously, this building is convenient for 51 people in all 12 apartments and a total of 4,136,720 L / year water usage is estimated according to the data in Table 5.3 with standard efficiency. In alternative design rainwater harvesting, greywater reclamation and efficiency in water usage are considered and results are shown in Table 6.7. As per project location, annual rainfall is reported 410mm and catchment for rainwater collection is 430 square meter.

Table 6.7. *Building summary for water usage – design alternative*

			Efficiency Savings	
Building Summary	**Total pieces**	**Efficiency**	**Percentage of Indoor Usage**	**Gallons per year**
Toilets	27	Low Flow	17.4	717,760
Sinks	39	Hands free	1.9	80,204
Showers	19	Low Flow	7.2	296,267
Clothes washers	12	Horizontal-Axis	9.6	395,927
Dishwashers	12	Efficient	0.1	4,638
Total efficiency savings:			36.1 %	1,494,796
Rainwater harvesting			141,040 L	
Total annual water usage			2,500,884 L / yr	

As per estimated reduction in annual water usage and LEED water efficiency credit requirements, alternative design is rated as Gold scale by GBS.

6.2. Discussion

BIM and green technology are two important and required aspects for implementation of projects in Afghanistan. Due to more than two decades of war, all construction facilities have been ruined and opportunity for construction of standard buildings was provided, but due to lack of government supervision over construction industry, construction of non-standard buildings are still continuing in most parts of the country.

Due to non-standard construction and using of wooden and coal heaters for heating buildings during cold weather, CO_2 emission has been increased and air has been polluted significantly. Recently government has started to supervise the construction industry and standardize it according to the norms. According to a report by Pajhwok news agency on 24th April 2018, 26% of death in country is due to air pollution (http-10).

Thinking green and using of green technology is the only way to decrease air pollution caused by construction industry. However there is not any exact background of green technology in implementation of construction in Afghanistan and all constructions are built using traditional methods, but recently companies and individuals are referring to green technology.

As the aim of this study is to implement building sustainabiliy analysis using BIM, a four story residential building in Kabul city is considered for analysis. The building is already built, alternative design is analysed using GBS and both variants have been compared. For saving energy in buildings, it is required to insulate building with ecofriendly material, and as most of the energy lost in buildings occur from exterior walls and top most floor roof, so material of exterior wall and top most floor roof layers of current project is considered according to design norms of ministry of urban development which includes insulation layers.

For saving electricity, occupancy sensors and daylight sensors and controls are suggested. For saving water, low flow toilets and showers, hands free sinks, efficient dishwashers and washing machines are suggested. Greywater reclamation and rainwater harvesting are other suggestions for saving water usage.

With consideration of water, electricity and fuel savage and using of ecofriendly material for building construction, construction industry can go toward standardization and qualify for LEED registration.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

The main focus on this research paper was on BIM and green technology and the connection of these two phenomenon. Application of green technology using BIM and sustainability analysis of a construction project located in Kabul city has been taken under the study.

As discussed in the literature review, origin of BIM goes back to 1970s. It developed significantly by time. One of the most important characteristics of BIM is level of details or level of developments which is required detail amount in a BIM system. Via BIM, accurate model can be created which can be used during the life of the project. It can be widely used by building industry, architects, engineers, contractors, owners and Green BIM professionals. BIM is more than a software. It can be used for project models, connecting schedule of work to model, estimating project cost, energy and sustainability analysis, facility management and focusing on health and safety of projects. Application areas of BIM can be studied in detail via its multidimensions. 3D BIM is an intelligent model, 4D BIM is the time element and defines construction scheduling, 5D BIM is cost element, 6D BIM defines sustainability, 7D BIM defines facility management and 8D BIM is about health and safety. Till now 8D BIM has been introduced and further dimensions would be raised in the future.

Green technology is used to reduce global warming and CO_2 emission. Main goals of this technology are sustainability, eco-friendly design, reduction of built environment impact on environment and human health. In this research we focused on sustainability analysis. Green technology in construction industry is used to reduce building impact on environment and human health and for measuring sustainability of buildings, rating systems are used. Different building rating systems are created including of LEED from USA, BREEAM from UK, Green Star from Australia, CASBEE from Japan, BEPAC from Canada, BEAM from Hong Kong, DGNB from Germany, GRIHA from India, NZGBC from New Zealand, GBC from South Africa. LEED from USGBC is the most famous and usable among them.

Green BIM significantly helps in reduction of global warming and CO2 emission. Construction cost of green building might be little bit higher than traditional buildings, but their operation cost is about 25% lower than traditional buildings. They don’t have any difference from traditional buildings except the design. Due to ecofriendly materials used in green buildings, their level of comfort and healthiness is higher than common buildings. According to previous researches about 11% less water and 25% less energy is used by LEED certified buildings.

In the current study, sustainability analysis of an existence residential building and an alternative design has been done with Autodesk Green Building Studio. Results show that green technology suggestions significantly save energy which is economically efficient and also helps in reduction of pollution and CO_2 emission. Also saving water via suggested methods can help in qualifying for LEED rating system. Heating system for both designs are considered same fuel type. According to the analysis, fuel required for space heating of alternative design is little bit higher due to change in building material, but in overall comparing of both design, alternative design saves more in the long run.

Autodesk Green Building Studio has 233 HVAC equipments type to select. In case of not selecting any HVAC equipment for analysis, GBS will suggest a HVAC type as per project location and project specification. For more detailed energy analysis, analysis should be done by eQUEST or EnergyPlus (Green Building Studio Help). As electric power plant sources of Afghanistan is not registered with GBS, so the application could not calculate CO_2 emission for the current project.

7.2. Recommendations

- With comparison of different insulation material for building, insulating with plasterboard and ash has been suggested which is economically better suggestion among other insulation types.
- Further research is required to find solution for analysis of central heating operated by coal or gas.
- Solar panels are suggested to prepare significant amount of building energy.
- Due to daily emission of CO_2 and pollution of air, its required to implement green technology in large scale and include both indoor and outdoor environment of buildings. For getting rid of pollution, not just buildings but other sectors like transportation, aviation, water resources and so on should be equipped with green technology.

REFERENCES

Aithal, S. and Aithal, S. (2016). Opportunities & Challenges for Green Technology in 21st Century. *International Journal of Current Research and Modern Education (IJCRME)*, Vol. 1, No. 1 (9 September 2016): pp. 818-828.

Amaratunga, D., Baldry, D., Sarshar, M. (2000). Assisment of facilities management performance – what next?. *Facilities*, 18(1/2), 66 – 75.

Ampratwum, E.A. (2017). *GREEN BIM: Adaptation of green building design concept with BIM into a new construction market – GHANA in the AEC/FM industry*, MSc thesis, Place of publication: Denmark Aalborg University

AMS admin. (2014). http://www.amscad.com/2014/03/understanding-bim-levels-of-development-lod/, Understanding BIM Levels Of Development (LOD), Accessed: 15-12-2017

ASHRAE (2009). *An Introduction to Building Information Modeling A Guide for ASHRAE Members*. Georgia

Autodesk Inc. (2011). *Realizing the benefits of BIM*

Autodesk® Ecotect™ Analysis. (2011). *Getting Started with Autodesk Green Building Studio*, www.greenbuildingstudio.com/default.aspx.

Ayobi, W. (2016). *Building heat insulation in Afghanistan*, MSc thesis, Place of publication: Afghanistan Kabul Polytechnic University

Azhar, S., Khalfan, M., Maqsood, T. (2012). Building Information Modelling (BIM): now and beyond. *Australasian Journal of Construction Economics and Building*, 12(4), 15 – 28.

Azhar, S., Sketo, B., Hein, M. (2011). Building Information Modelling: Benefits, Risks and Challenges. *Leadership and Management in Engineering*, 11, 241 – 252.

Bai, V. and Ravindra, R. (2014). Energy Efficient and green technology concepts. *International Journal of Research in Engineering and Technology* – 3 (6): 253 – 258.

BIMFORUM. (2015). *Level of Development Specification,* Version: 2015.

Boyd, T. and Kimmet, P. (2005). *The triple bottom line approach to property performance evaluation.* Australia: School of Construction Management and Property, QUT.

Criminale, A,. and Langar, S. (2017). Challenges with BIM Implementation: A Review of Literature. *53rd ASC Annual International Conference Proceedings Associated Schools of Construction*: 329 – 335 http://www.ascpro.ascweb.org

CommScope, (2017). *Building information modeling and intelligent green buildings,* CommScope

Das, G. (2015). Advantages of green technology. *International Journal of Research – GRANTHAALAYAH* 3(9): 1 – 5.

Denis, F. (2015). *Building Information Modeling Belgian Guide for the construction industry,* First Edition. Brussel: ADEB-VBA

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction* 36 (2013) 145–151.

Eastman, C., Teicholz , P., Sacks, R., Liston, K. (2011). *BIM Handbook A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors,* Second Edition. USA: John Wiley & Sons, Inc.

Ehmida, M. (2011). *Investigating the green construction: The contractor's perspective,* MSc thesis, Place of publication: Indonesia Diponegoro University

Fischer, M., Kund, J. (2004). *The Scope and Role of Information Technology in Construction.* California: Stanford University

Feltes, V. (2007). *TOWARD SUSTAINABLE BUILDING – GREEN BUILDING DESIGN AND INTEGRATION IN THE BUILT ENVIRONMENT,* MSc thesis, Place of publication: America Washington State University

GSA. (2009). *GSA BIM guide for 4D Phasing.* Version 1.0. Washington

Gu, N., London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, 19 (8), 988 – 999.

Hardin, B. (2009). *BIM and Construction Management.* First Edition. Indiana: Wiley Publishing, Inc.

http-1 http://www.aproplan.com/blog/quality-management-plan-construction/what-is-bim, *What is BIM*, Accessed: 11-12-2017

http-2 https://www.gsa.gov/real-estate/design-construction/3d4d-building-information-modeling/bim-guides/bim-guide-04-4d-phasing, *BIM Guide 04 - 4D phasing, (2009),* Accessed: 13-12-2017

http-3. https://www.autodesk.com/redshift/building-information-modeling-top-10-benefits-of-bim/, *Top 10 Benefits of BIM*, Accessed: 15-12-2017

http-4 https://green-technology.org/green-technology-what-is-it/, *Green Technology – What is it?*, Accessed: 19-09-2018

http-5 http://www.voicesofyouth.org/en/posts/reduce--reuse--recycle, *Reduce, Reuse, Recycle,* Accessed: 06-10-2018

http-6 https://greentechbox.com/960/the-main-features-and-benefits-of-green-technology.html, *The Main Features and Benefits of Green Technology*, Accessed: 12-10-2018

http-7 https://www.weetas.com/article/green-buildings-advantages-and-disadvantages/, *Green Buildings: Advantages and Disadvantages,* Accessed: 12-10-2018

http-8 https://www.conserve-energy-future.com/green-building.php, *What is a Green Building?,* Accessed: 12-10-2018 http-9 http://www.worldgbc.org/benefits-green-buildings, *About Green Building,* Accessed: 12-10-2018

http-10 https://www.pajhwok.com/en/2018/04/24/air-pollution-reaches-unhealthy-level-kabul, *Air pollution reaches unhealthy level in Kabul,* Accessed:04-12-2018

http-11 https://www.theatlantic.com/technology/archive/2011/03/the-electric-taxi-company-you-could-have-called-in-1900/72481/, *The Electric Taxi Company You Could Have Called in 1900,* Accessed:07-02-2019

Iravani, A. Akbari, H. and Zohoori, M. (2017). Advantages and Disadvantages of Green Technology; Goals, Challenges and Strengths. *International Journal of Science and Engineering Applications* – Volume 6 Issue 09: 272 – 284.

Jalaei, F. and Jrade, M. (2014). Integrating building information modeling (BIM) and energy analysis tools with green building certification system to conceptually design sustainable buildings. *Journal of Information Technology in Constrution (ITcon)* – vol.19: 494 – 519, http://www.itcon.org/2014/29

JEONG, H. (2011). *SUSTAINABILITY POLICY AND GREEN GROWTH OF THE SOUTH KOREAN CONSTRUCTION INDUSTRY,* MSc thesis, Place of publication: United States Texax A&M University

Jiang, X. (2011). *Developments in cost estimating and scheduling in BIM technology,* MSc thesis, Place of Publication: USA Northeastern University

Jung, Y., Joo, M. (2010). Building information modelling (BIM) framework for practical implementation. *Automatoin in Construction*, 20 (2011), 126 – 133.

Kamardeen, I. (2010). 8D BIM modelling tool for accident prevention through design. In: Egbu, C. (Ed) Procs 26th Annual ARCOM Conference, *Leeds, UK, Association of Researchers in Construction Management*, 281-289.

Kats, G., Alevantis, L., Perlman, J. and Mills, E. (2003). *The Costs and Financial Benefits of Green Buildings A Report to California's Sustainable Building Task Force,* USA: Capital E, Washington DC

Kibert, C. (2013). *Sustainable Construction Green Building Design and Delivery Third Edition*, USA: John Wiley & Sons, Inc., Hoboken, New Jersey

Kim, H,. and Anderson, K. (2013). Energy Modeling System Using Building Information Modeling Open Standards. *Journal of Computing in Civil Engineering,* 27 (3): 203 – 211.

Kim, J. (1998). *Sustainable Architecture Module:Introduction to Sustainable Design.* USA: National Pollution Prevention Center for Higher Education, 430 E. University Ave., Ann Arbor

Kreider, R.G., Messner, J.I. (2013). The Uses of BIM Classifying and Selecting BIM Uses. Version 0.9. Penn State

Kubba, S. (2017). *HANDBOOK OF GREEN BUILDING DESIGN AND CONSTRUCTION*. USA: Butterworth-Heinemann an imprint of Elsevier

Kuehmeier, J.C. (2008). *Building Information modeling and its impact on design and constrcution firms*, MSc thesis, place of publication: USA University of Florida

Lester, A. (2014). Project Management, Planning and Control. Chapter 11 – Project Life Cycles. Sixth Edition. 2014, 47 – 50 Published by: Elesevier Ltd.

Lindblad, H. (2013). *Study of the implementation process of BIM in construction projects Analysis of the barriers limiting BIM adoption in the AEC-industry*, MSc thesis, Place of publication: Stockholm KTH royal institute of technology

Liu, Z,. Osmani, M,. Demin, P,. Baldwin, A. (2011). The potential use of BIM to aid construction waste minimization. *IN: Proceedings of the CIB W78-W102 2011: International Conference.* 26th – 28th Oct 2011, Sophia Antipolis, France, paper 53

Lu, Y., Wu, Z., Chang, R., Li, Y. (2017). Building Information Modeling (BIM) for green buildings: A critical review and future directions. *Automation in Construction* 83 ( ) 134–148.

Meher, P., Behera, S., Rath, B., Dash, S., Choudhary, P. (2016). A comparison between Normal buildings and Green buildings- A case study approach. *International*

Research Journal of Engineering and Technology (IRJET) Vol 3, Issue 5, pp. 51-54

Monokova, A., Vilcekova, S. and Burdova, E. (2017). *Possibilities of Green Technologies Application in Buildiing Design from Sustainability Dimensions.* Lithuania: Vilnius Gediminas Technical University

Mueller, S. (2017). *Green technology and its effect on the modern world,* Bachelor's Thesis, Place of publication: Finland Oulu University of Applied Sciences

Noori, A. (2015). *Artificial recharge of ground water in Kabul City by rain water of roofs,* MSc thesis, Place of publication: Afghanistan Kabul Polytechnic University

Ritchie, H. and Roser, M. (2018). CO_2 and other Greenhouse Gas Emissions. Published online at OurWorldInData.org, https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions, Accessed: 04-10-2018

Salah, F. (2014). *Investigation of strengths and weaknesses of 4D BIM software applications in managing construction projects*, MSc thesis, Place of publication: Turkey University of Gaziantep

Shrivastava, S,. and Chini, A. (2012). Using Building Information Modeling to Assess the Initial Embodied Energy of a Building. *International Journal of Construction Management*, 12(1): 51 – 63.

Smart Market Report, (2010). GREEN BIM How Building Information Modeling is Contributing to Green Building and Construction, McGraw-Hill Construction www.construction.com

Succar, B. (2008). Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automatoin in Construction*, 18 (2009) 357 – 375.

Su, Y., Lee, Y.C., Lin, Y.C. (2011). Enhancing maintenance management using building information modelling in facilities management, Proceedings of the 28th ISARC, Seoul Korea.

Swarnkar, D. and Singh, S. (2015). ANALYSIS OF GREEN TECHNOLOGY APPLICATION IN CONSTRUCTION, *International Journal of Engineering Research & Management Technology* – Volume 2 Issue 06: 147 – 150.

Turcotte, D. Villareal, J. and Bermingham, C. (2006). *The Benefits of Building Green: Recommendations for green programs and incentives for the City of Lowell*, USA: University of Massachusetts Lowell

Uparwat, A. Gawatre, D. and Shahezad, M. (2013). Advantages of Green Building. *International Journal of Scientific Research* – Volume 2 Issue 04: 68 – 70.

Volk, R., Stengel, J., Schultmann, F. (2013). Building Information Modeling (BIM) for existing buildings – Literature review and future needs. *Automatoin in Construction* , 38 (2014), 109 – 127.

Wan, O. Zulkifli, M. and Dani, S. (2012). Green Technologies and Their Application in Malaysian Construction Industry. *The 3rd International Conference on Technology and Operations Management,* Indonesia: Bandung, July 4-6 2012. Pp. 75-79. ISBN:978-979-15458-4-6

Wong, J. and Zhou, J. (2015). Enhancing environmental sustainability over building life cycles through green BIM: A review. *Automation in Construction*, 19 ( ) 156 – 165.

Wong, K., Fan, Q. (2013). Building information modelling (BIM) for sustainable building design. *Facilities,* 18(3/4), 138 – 157.

World Green Building Council. (2013). THE BUSINESS CASE FOR GREEN BUILDING A Review of the Costs and Benefits for Developers, Investors and Occupants www.worldgbc.org

Wu, W. (2010). *INTEGRATE BUILDING INFORMATION MODELING AND GREEN BUILDING CERTIFICATION: THE BIM – LEED APPLICATION MODEL DEVELOPMENT,* PhD thesis, Place of publication: America University of Florida

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