"GREEN BIM –It's Various Aspects and Future Potential for Construction of Green Building Projects."

Ar. Swati Srivastava, Ar. Nikhat Parvez

Abstract-Green BIM can be defined as a relationship between Green Attributes, Project phases and BIM Attributes. This relationship triangle is known as Green BIM. Green Attributes are related to the green aspects of green building project, Project phases are the design aspects of a building project and BIM attribute is application of Building Information Modelling (BIM) in supporting design aspects and green aspects of a green building project. This research focuses on understanding the various aspects of Green BIM, its integration at various design stages, its integration in calculating the green aspects as well as credit score for green building certification systems, its advantages and limitations and the potential of Green BIM for construction of future green building projects.

Key Words- Green BIM, Rating Systems, Certification Systems, Sustainability, LCA (Life Cycle Assessment), BIM (Building Information Modelling), Energy Efficiency.

INTRODUCTION

In today's scenario concern for the deteriorating environment is growing at a very fast pace. This concern has led to development of new techniques and technologies in each and every field for protecting the environment. Environmental agencies have shown their concern about the amount of negative impact construction industry is having on the environment by the amount of co2 emission and waste production.[1] The Architecture, Engineering and Construction (AEC) Industry contributes to huge amount of carbon emission and waste production, also the amount of energy consumption is huge in AEC industry. For example, in USA the energy consumption in building industry is 45%, in U.K its 42% and in other economically developing countries on an average the energy consumption is 31% in construction industry.[2] A lot of research on developing various methods to reduce this energy consumption, carbon emission and waste production has been done for the past many years both at industrial level as well as government policy level to promote Green Building Projects.[3] Green stands for the various aspects which needs to be implemented in a building to reduce its environmental effect. Another important term which we come across in the past research done is BIM. BIM stands for "Building Information Modelling".[4] It acts as a tool which is used for incorporating all the environmental aspects in a sustainable building project. When BIM is used for green building projects then it is known as Green BIM.[5]

The aim of this review paper is to understand the concept, usage, advantages, disadvantages, and potential application of "Green BIM" in the development of Green Building Projects and to study the integration of BIM as effective tool for various Green Building Certifications. Green BIM can be understood as a relationship triangle between Project Phases, Green Attributes and BIM Attributes. Project Phases consists of various phases in building construction.[5] It includes the design phase, construction phase, operation, and maintenance phase. Green attributes consist of seven aspects of green building which are 1) Energy Consumption 2) Carbon Emission 3) Natural Ventilation 4) Solar and Lighting Analysis 5) Acoustics 6) Water Usage and 7) Thermal Comfort Analysis. [5,6] BIM attributes includes application of BIM in supporting Green Building aspects along with BIM integration for various phases of construction of a project. [5,6]

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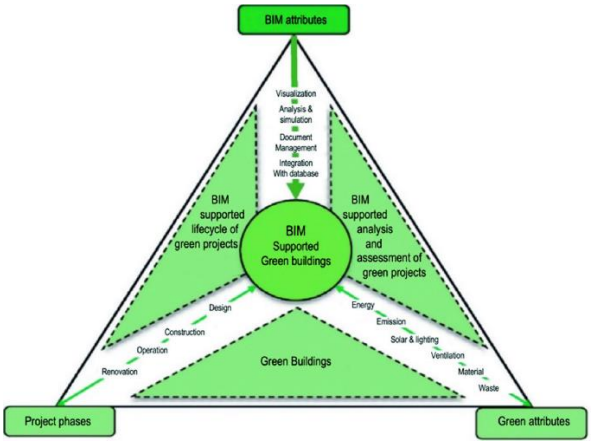

Fig 1 Green BIM Triangle [5]

RESEARCH METHODOLOGY

The methodology used for this review paper is collection of research papers and study material related to the subject. The selection criteria for academic research papers have been kept that the reviewed papers must be a part of a Journal having a high reputation in the field. This review paper analyses the various aspects of Green BIM, its integration with various phases of building construction, its integration with various green building aspects, its usage and ease for calculating various credits in Green Building Certification Systems. The paper also tries to analyze the various advantages of Green BIM and its limitations and is an attempt to understand at a greater depth Green BIM's potential for the construction of future Green Building projects.

1.INTEGRATION OF GREEN BIM IN THE PROJECT PHASES OF GREEN BUILDINGS

1.1 GREEN BIM APPLICATION IN DESIGN AND CONSTRUCTION OF GREEN BUILDING PROJECT.

Building Information Modelling (BIM) acts as an enabling platform for the various stakeholders of a Green Building project.[7] Traditional methods which are used for green building projects involve a lot of data which needs to be collected and analyzed, this process of collecting data becomes very tedious and time consuming.[8] The information to be collected from various sources is stored on different platforms and bringing it together becomes a task in itself requiring a lot of time energy and manpower. The information needs to be shared with various stakeholders of the project like the professionals, experts, and end users.[9] But in absence of a common platform all this information is shared either manually or through emails where size of the data and its privacy becomes a major issue. Usage of Green BIM provides a solution to the above-mentioned issues.[6]

An online integrated BIM tool has been developed which is known as Green 2.0[10]. The main objective of Green 2.0 is Managing interactions around BIM and linking BIM to sustainability analysis.[10] It has been observed that a lot of information of the project is either shared through mails or through hard copies. Green 2.0 aims at making this information readily available to all by using web services and portals like IFC (Industry Foundation Classes Model) which is an ISO registered standard platform for sharing all the file formats.[11] Green 2.0 makes the data available to the architects, experts as well as to the end users through BIM Social Network Analytics Module making it a socially interactive platform.[10]

In Green BIM Green stands for the various aspects which needs to be implemented in a building to reduce its environmental effects and BIM stands for the tools which are used to apply these aspects in green buildings.[5,6] To promote the social sustainability in Green Buildings it has been suggested that BIM is integrated using a Social Network Analysis (SNA) where all the stake holders are involved in the project from the initial phases and with the help of BIM it is easier to collect and analyses the huge amount of data from stake holders. The BIM integration also helps in the development of integrated Project Delivery model (IPD) which involves and informs all the stake holders at various stages of the project development.[12]

To maximize the Green BIM in a social context it is necessary to incorporate a Corporate Social Responsibility (CSR) model for BIM application as a benchmark for evaluating this integration and promoting its benefits.[12] Considering that industrial practice scarcely includes reference to social components of sustainability, the past research suggests bridging the gap using a CSR-based BIM index: The Green BIM Index.

The efficiency of Green BIM Index has been researched by applying CSR for Sustainable Benefits of Green BIM Using SNA, doing case studies by applying theses indexes in existing building projects and analyzing its efficiency, setting up questionnaire for SNA and participants and finally evaluating all the indexes and studying their fittings in various scenarios.[12]

The usage of Green BIM in construction industry can be carried out in two phases: Phase -1 in which BIM inherent software's like AutoCAD Revit, AcriCAD and Bentley can be used for designing the building orientation and massing.[13] Phase -2 in which software like Autodesk Green Building Studio, Autodesk ECOTECH, Virtual Environment etc. can be used for sustainability analysis of a building in terms of energy consumption, water conservation, environmental effects etc. [13]

Green BIM uses digital models to support virtual design and construction. It converts a 2D project to be visualized in a 3D model set in the existing environment.[14] BIM acts as

a powerful tool in the whole life cycle of a project, starting from collecting all the data, creating libraries, and then analyzing and converting it from a two-dimensional data to a 3-D model set.[15] It also plays a key role as a participant and experiential aided management in construction and operation. It helps in reducing the cost of the project, saving resources reducing pollution etc. It can ensure the involvement of all the stake holders at the initial phase of the project rather than after the completion resulting in better performance of the building in a sustainable environment.[15] With the help of computer graphics and certain software it is possible to have photo-realistic images, animations walk through's etc. which improves the understanding between the architects and the end users.[9] With the help of BIM, it is possible to decide what type of materials are to be used to enhance the sustainability of the building during the design stage itself which has a great impact on the life cycle of the Green Building.[7]

1.2 Green BIM application in Project Location Analyses.

The construction of Green Building project involves land, water resource, energy, and materials. BIM has a great application in the judicious utilization of all the above-mentioned aspects.[16] For reducing land use BIM needs to be integrated with GIS to plan ideal site conditions. Land use situation keeps on changing during the ongoing construction process and BIM helps analyze these changing situations and accordingly identifying the new demands and requirements.[14]

Project Location and transportation is an important factor in green building design. A building if located in a developed area with certain density of population, can utilize the already existing resources judiciously thus effectively reducing energy consumption.[16] Moreover, if the site is located near areas having essential services like banks, schools, restaurants, offices etc. it can reduce vehicular movement, save parking spaces, and motivate people to walk thus helping in their physical fitness and directly impacting the CO2 emission also if the location of building is near around bus stations and railway stations it will again increase use of public transportation and result in lesser usage of fuels for vehicles and lesser pollution.[14,16]

Till now the architects have been manually extracting information about site area, building area and project location, surrounding buildings, road networks, services, traffic etc. from AutoCAD REVIT and Google Maps but doing this manually takes a lot of time and is less accurate.[16]

The C++ programming language together with Google Maps API and Autodesk Revit API are used for the integration of BIM, WMS, and green building (GB) standards. The integration Module uses three modules: BIM module, WMS Module and Green Building Module.[16]

2.Integration of Green BIM in Analyzing Green Attributes and Sustainability of a Project

2.1 Green Attributes:

The various attributes which need to be implemented in the development of a Green Building Project to reduce its environmental effects are known as Green Attributes.[5] There can be many such aspects of a building which can be implemented to lessen the environmental effects but the attributes which are considered worldwide on a standard basis are seven in number.[5]

Energy Consumption

CO2 Emission

Natural Ventilation

Solar and Lighting Analysis

Acoustics

Water Usage

Thermal Comfort Analysis.

Energy Consumption calculates the amount of energy produced and consumed during the construction of the Green Building analyzing its effect on the environment. CO2 emission analyses the carbon footprint, Natural ventilation analyses the use of natural air circulation and load calculation of HVAC.[17] Solar and Lighting analysis is about the use of solar energy to reduce electricity consumption. Acoustics analyzes what type of construction materials to be used in a green building project to reduce the effects sound from the outside and enhance the acoustical environment inside.[9] Water usage is concerned with the techniques applied to reduce the water consumption and increase the amount of water conservation. Thermal Comfort analysis is about the type of construction materials used, number and location of openings provided to increase the amount of natural ventilation and reduce the use of artificial ventilation with a priority given to the thermal comfort of the end users.[17]

2.2 Green BIM usage for calculating sustainability of a project.

BIM and sustainable structures are the future of the construction industry. A lot of research and studies are being conducted to understand the integration of BIM for facilitating assessment of the LCA (Life Cycle Assessment) of a green or sustainable building.[18] BIM also plays an important role in reducing and conserving the energy

resources by doing thorough analysis of solar radiation, luminous flux, natural ventilation, acoustics etc. It integrates information at construction stage to calculate and analyze the thermal environment and energy flux in buildings. Then it could adjust model parameters and verify that if the construction meets the Green Building requirements or not.[18]

BIM acts as an enabling platform for the various stakeholders of a green building project. It handles all the data analysis and provides a platform for the interaction of the stake holders and end users. It can ensure the involvement of all the stake holders at the initial phase of the project rather than after the completion resulting in better performance of the building in a sustainable environment.[9] With the help of BIM, it is possible to decide what type of materials are to be used to enhance the sustainability of the building during the design stage itself which has a great impact on the life cycle of the Green Building.[19]

BIM can be divided into Processes, technologies, and policies. Processes facilitate the collaboration and integrating roles among stakeholders. Technologies assist the stakeholders to visualize the virtual environment in which the project is to be developed and detect any clashes or issues that may occur during the design, construction, or operation of the project. Moreover, BIM also has policies in the form of laws, standards, and rules.[20] Usage of BIM must be assessable which will not be possible without having any benchmarks.

The maturity of BIM can be evaluated in the form that BIM is not just a tool for 3D modelling or visualization but is extremely helpful in generating the workflow and delivery procedures of the project through IPD which in Integrated Project Delivery. IPD promotes the interoperability during the entire life cycle of the project.[20] This collaboration within BIM helps to integrate all the data related to stakeholders, materials, machines and planning and enhances better communication by developing a harmonious model. The main functions of BIM for green building analysis covers all the nine aspects of green building certification system which are: Energy Consumption, Carbon emission, Natural ventilation, Solar and daylighting, Acoustics, water usage, user performance, Materials, and waste management. Building Energy Modelling deals with the energy performance and it identifies the various options which can be incorporated for optimizing the amount of energy consumption in a building project.[6] This aspect of Building Energy Modelling is included in Green BIM and is applied throughout the lifecycle of a project. BIM allows storage of the data and its usage by the professionals, experts, and end users at each stage of the project lifecycle, thus avoiding any discrepancy, duplicacy or delay in the information. This helps in saving a lot of money and time.[5]

Green BIM helps in understanding the concepts of sustainable design and making a digitized model visualization in the built environment. The 'Green BIM' helps to cultivate better construction practices in developing sustainable building projects.[6] 'Green BIM' not only helps in collecting a huge and complex amount of data but also helps in making it available to all the professionals, experts and end-users involve in the project. It calculates the energy efficiency of a building project not for just one phase but for the whole life cycle of the project.[19] Such a Life cycle assessment helps in increasing the energy efficiency of a building project during its entire life cycle. Its implementation helps in reducing time, saves money, resources, reduces manpower, increases accuracy, reduces any clashes and many more such advantages and benefits can be achieved by incorporating 'Green BIM'.[19]

2.3.1 Green Building Certifications and BIM integration for credit calculations.

BIM and LCA (Life Cycle Assessment) can be two tools which can be highly beneficial while designing buildings with lower environmental impacts. A lot of research and studies are being conducted to understand the integration of BIM for facilitating assessment of the LCA (Life Cycle Assessment) of a green or sustainable building.[9] For this purpose, various green building certification systems are used all over the world like LEED (US), BREEAM (UK), BEAM Plus (Hong Kong), Green Star (Australia) and Green Mark (Singapore) are a few internationally used systems.[13]

LEED used for rating green buildings in USA, has defined 6 categories with a total point weightage of 69, a building requires to score at-least 34 points to a get a rating. Out of these 69 points 38 points can be calculated using BIM. [21] Similarly, BEAM Plus used as a green building rating system in Hong Kong has defined five aspects with a total point weightage of 128 points out of which 56 points can be achieved using BIM calculations.[22] Then Green Star rating system used in Australia has 8 categories making a total point weightage of 146 out which 97 points can be achieved using BIM.[23,24] Along with this the paper describes in detail the various types of certifications given by these three Green building rating systems depending upon the point calculations. Like LEED gives certifications as LEED Certified, LEED Platinum, LEED Gold & LEED Silver. BEAM Plus gives certifications as Platinum, Gold, Silver & Bronze. Green Star gives certification as 4-star, 5 star & 6 stars. Below given tables show the complete analysis of the various categories of three Green Building Certification Systems, LEED, BEAM Plus and Green Star,

and integration of BIM for calculating various credits along with the details of BIM tools used. [21,22,23,24]

Table-1 LEED-BIM Credit Analysis [13,21]

LEED Categories	Maximum Points	Weightage %	BIM Point	BIM weightage %	BIM Tool
Sustainable Sites	14	20.3	6	8.7	Revit
Water Efficiency	5	7.2	5	7.2	Revit, VE
Energy and Atmosphere	17	24.6	10	14.5	VE
Material and Resources	13	18.9	9	13.1	Revit
Indoor Environmental Quality	15	21.8	4	5.8	Revit, VE
Innovation and Design Process	5	7.2	4	5.7	Revit, VE
Total	69	100	38	55	

Table-2 BEAM PLUS-BIM Credit Analysis [13,22]

BEAM Plus Categories	Maximum Points	Weightage %	BIM Point	BIM weightage %	BIM Tool
Site Aspect	22	25	6	7	Revit, IES
Material Aspect	22	8	13	5	Revit
Energy Use	42	35	26	22	Revit, IES
Water Use	9	12	4	6	Revit
Indoor Environmental Quality	32	20	6	4	IES
Innovation & Design Process	1	0	1	0	Revit, IES
Total	128	100	56	44	

Table-3 Green Star-BIM Credit Analysis [13,24]

Green Star Categories	Maximum Points	Weightage %	BIM Point	BIM weightage %	BIM Tool
Management	12	9	0	0	Revit
Indoor Environmental Quality	27	20	19	14	IES
Energy Efficiency	29	25	15	13	Ener-Win, Trace
Transport	11	8	5	7	Revit
Water Efficiency	12	12	11	11	Revit
Material	21	14	20	13	Revit, Navisworks
Land Use	8	6	2	2	Revit
Emissions	16	6	15	6	Revit
Innovations	10	0	10	0	
Total	146	100	97	66	

Usage of BIM by construction industry enhances the long-term productivity of the building and helps to improve its sustainability as well. Moreover, integration of BIM with the Green Building assessment tools not only facilitates the ease of calculation of various sustainability aspects but also plays a big role in achieving the credit score required for Green Building Rating. It can achieve 55% of LEED credit equivalent to silver certification, 44% BEAM Plus credit equivalent to bronze certification and 66% Green Star Credit equivalent to 5-star certification. [13,24]

For understanding integration of BIM as an effective tool for various Green Building Certifications let us consider three Green Building certifications, 1) LEED (Leadership in Energy and Environmental Design, used in United States of America), 2) BREEAM (used in United Kingdom) and 3) DGNB (used in Germany).[24] All these three certifications have a similar structure which considers different levels of information. To organize these levels and define a common criterion to analyze the three GBCs mentioned a Work Breakdown Structure (WBS) was chosen.[8] The whole process is divided into 13 phases out which phases 2, 5,6 and 11 are repeated in at least 4 of the 6 documents analyzed. After doing the BIM case study of EUREF HAUS 12 –13 it was found that BIM can assist 100% DGNB energy related criteria, 60% for BREEAM and 55% for LEED. Then a methodology consisting of SQL language was worked upon, through which the 45% data of LEED and 40% data of BREEAM which was not directly integrated through BIM was converted into these SQL languages and then the phases 2,5,6 and 11 were again rerun and it was analyzed that all the energy related criteria of both LEED and BREEAM could now be integrated with BIM.[8]

It was also found that when compared to the traditional method which took 25 hours per project with 4 emails and repetition of the process for every new project the workload was reduced drastically to 15 hours only one time, 4 emails and automized process for the upcoming projects by integration of BIM. This time reduction gives a huge advantage to the usage of BIM integrated projects.[8]

To effectively enforce BIM processes, it is essential to have communication between different participants of the project and this communication needs to be upgraded from the traditional processes.[10] Therefore, it is crucial to have interoperability between information systems and tools. This can be incorporated by using IFC to extract information from BIM as IFC specifies how information is to be exchanges in a standard neutral data format. It is an object- oriented data model of buildings specifying physical items or abstract ideas or their relationships.

While managing the rating systems criteria within the BIM model has double complexities first there is a problem of defining all the right attributes to fulfill the criteria calculation procedures and second is that all the attributes must comply with the IFC (Industry Foundation Classes is

standardized data exchange format) format.[10] Many of the attributes are not listed in the IFC format so a new list needs to be created for them. We can clearly state that having a tool able to calculate and manage criteria since early design stages allows for a better and more sustainable design based on the three pillars of environment, economic and social key issues.[18] Using IFC standard to exchange data from a BIM model assures that these are correctly transferred from one software to another and further from professionals to end users.[11]

In the current scenario the per capita energy consumption of China is just less than half of the world per capita energy consumption. China ranks second as far as energy consumption is concerned. It is because of this reason that sustainable development of building energy has become the national strategic goal of China.[25]

Facility Management is an integration of people, facilities, process, and technology which covers a lot of management work like property management, space management, facilities and equipment management and energy management. Its application in green building is firstly about a strategic approach where different guidance is given to different building types like energy saving management for a building undergoing renovation, or a newly constructed building or a residential or public building etc. [25] Its clear priority is to develop management reforms which lead to energy conservation and improve energy efficiency of a building. Secondly its application is about the strategic measures which are to be taken based on the public demand thus effecting the national policies.[25]

As far as usage of BIM is concerned in green buildings it helps in processing energy management data by collecting it through various systems of BMS and energy management teams. [24] The BIM can be used as a tool to collaborate all the data collected from various sources and help analyze enormous data as well as eliminating data in a layer control system saving a lot of energy time resources and money. BIM technology also helps in Building Performance Evaluation based on the building's architectural geometry, structure, usage pattern, HVAC and Lightning by analyzing and sharing the enormous data within itself as well as with other systems.[26]

The introduction of BIM technology, according to its visual function, information integration, simulation technology and other characteristics, starting from the design stage of building energy management, focusing on the control of design errors, inadequate research, data mismatch and other congenital problems. Secondly, FM concept will be brought into the later construction energy management to optimize from the aspects of strategic principles and measures.[25]

The use of BIM as a tool to develop an architectural geometry model in energy simulation. The BIM tool creates a space boundary geometry model. As the walls floors roofs etc. form a major architectural element the space which is enclosed within these elements becomes a major issue because the major object in energy simulation is the space which utilizes these objects.[4]

Once the architectural geometry model is developed using a BIM tool it needs to be checked for error. This is first done within the software using Revit Checking then the model is exported to a gbXML (Green Building XML) file from where they are exported to the energy simulation software's like Ecotec, IES VE and GBS. But before exporting them they are rechecked in the gbXML viewer for any error, if any error found it is modified.[2]

LEED certification system like most of the certification systems gives maximum weightage to energy conservation or energy efficiency of a building throughout its life cycle. It gives around 30% weightage to energy efficiency. So, energy simulation through BIM becomes extremely important.

In this process the architectural geometry model after getting checked through Revit and rechecked through gbXML Viewer is done it is finally verified through FZK viewer, then exported to energy simulation software's like Eco tech, IES etc. where the rest of the analysis in terms of air gaps and thermal simulation is done.[2] For this purpose, first the location and weather data is inserted then a template is created for purpose specific occupancy density, lighting load density and instrumental load density. The next step is equipment stage setting. After doing all this a base line case is developed which is analyzed for its energy efficiency during the entire life cycle of the project.[18]

The major limitations for this whole process are the errors which may occur in the BIM tool developed geometry model. Errors may occur due to difference in geometry expression method of BIM and that of gbXML viewer. Thirdly errors may occur due to inefficient or incorrect information input in the BIM model.[2]

2.3.2 Development of a Model to Integrate BIM with LEED.

A model which integrates BIM with the LEED Green Building Certification System for new construction (LEED) has been developed.[27] It explains how this BIM integration will assist in calculating the number of points required for LEED certification along with giving options of using various materials which would enhance the credit ratings of LEED for a project. Also, it will help to calculate the various registration costs, material costs etc. for green building certification of the project.[27]

The methodology was developed firstly by doing a literature review and collecting data about various certification systems, the various aspects covered by them, number of credits given to each aspect and BIM integration at various levels in these systems was studied thoroughly.

LEED being a worldwide accepted green building rating system, this system was considered for the study.

The model was developed in four phases. Phase 1- In this phase a relational database was designed and developed for the model in which an external database having all the details of green materials was prepared and added as a plugin to the BIM tool with the help of which a conceptual schematic work breakdown structure was developed.[28]

Phase 2 focuses on customizing BIM tool so that it has all the features as per the modularity requirements of the model. This module, design and create a 3D module capable of storing newly created families commonly used in building projects using certified green building materials and their associated key notes in the BIM tool.[28]

Phase 3 In this phase a module for the green building certification was designed and developed and then it was linked to the BIM tool.[28]

Phase 4 The main focus of this phase was on the calculations regarding the registration costs of the project with CaGBC and related certification costs. The LEED process consists of three steps: 1) Project Registration 2) Technical Support 3) Building Registration. There are 4 specific criteria for new building construction: 1) Prerequisites for the LEED category 2) Building Size. 3) Number of LEED components selected 4) CaGBC membership. [28]

The validation of this module was done by applying it on a midrise residential project and analyzing all the data and readings.

The development of this model has helped in eliminating the documentation process which was a huge barrier in the process of developing a green building project. This is the first model dealing with LEED categories, the certifications required at different levels of LEED and helps in saving users time and money by calculating the soft cost estimation as well. This model's main focus lies in the calculation of soft cost. [28]

2.4 Case Study Exploring Adoption of BIM Models

For this experimental study, tent themed hotels (these hotels can adapt to any climatic zone,they mix and become a part of the local cultural environment, can be built conveniently and because of these reasons are an inspiration for a new way of holiday making) were adopted to apply the designed BIM models. The site taken into consideration is situated in Hengshan NaShan Village which is in Hengyang city.[29]

The requirements of tent hotels as mentioned already were considered and for site analysis a Revit AUTOCAD 3D model was used to analyze the location, climate conditions, transportation, and ecological evaluation. In the design process a lot of options were tested and analyzed before reaching any conclusion.[29]

Green BIM model was used for building design and analysis through which features like natural ventilation, use of solar energy, rainwater harvesting, usage of green building materials was done.[25] The BIM software model was used for energy efficient computing and performance analysis. Like all windows and openings were provided on the south face to utilize maximum amount of day lighting. Building Information Model was highly beneficial in defining a reasonable position of the openings along with incorporating an installation guide and helping in direct light diffusion in the internal spaces. The solar panels were used on the roofs to use solar energy efficiently, these solar panels were not battery operated but were directly connected to the supply system.[4] Also, these panels could be deactivated when not in use thus saving more amount of energy. The tent shaped roof of the building was used to collect rainwater, and a building was provided below for collecting all the rainwater which was later used for outdoor irrigation and other resources.[29]

BIM is an efficient tool which can be utilized for proper integration of the building design and the natural environment, thus reducing its negative impact on the environment, and making the building energy efficient and environmentally friendly. This process not only reduces the impact of building on environment but also helps in enhancing the health conditions and quality life of end users by connecting them to their natural environment.[26]

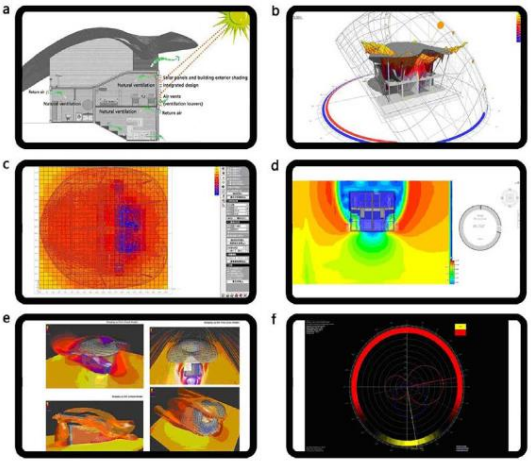

Fig -2 Tent Hotel in Hengshan NaShan Village (a) Natural Ventilation Analysis (b) Natural Lighting (c) Natural Light and Lighting (d) Wind Environment Simulation (e) Wind Analysis (f) Optimum Orientation. [29]

3. BIM AS A SUBJECT IN UNIVERSITY CURRICULUM

As the development of green buildings is happening at such fast pace at the same time the competencies of students at college in green buildings and BIM is also being judged. Keeping this into account the University of California launched a Project Based Learning program which aims at developing an approach which integrates both sustainable design and BIM implementation and this is to be done through a course project. [30]

The course was designed by instructors from two departments namely Architectural Advance Design and Green Building Design and Delivery. The main objectives of this project learning were to (a) to make students understand integration of BIM as a tool for the design and development of green building projects (b) to make students challenge themselves to different types of tasks which are normally not experienced in a course curriculum (c) to assess selected program SLOs through project-based learning.[30]

For this project students were provided with a site within the campus which was 30000 square feet broke ground which was to accommodate in 2014 researchers coming from three colleges. The brief was to design this building as per the 2010 California green building norms. The students were exposed to few software from Autodesk for the usage of BIM.[30]

The students were accessed on their SLO's based on their communication, teamwork and team relations, Problem solving and critical thinking and sustainability. The project plans were shared with the students and they met a BIM consultant to fully understand its application and implementation. At each phase there were specific tasks and deliverables to be given by the students. One team worked on BIM tools and other Team gathered LEED documentation details for working on the project.[30]

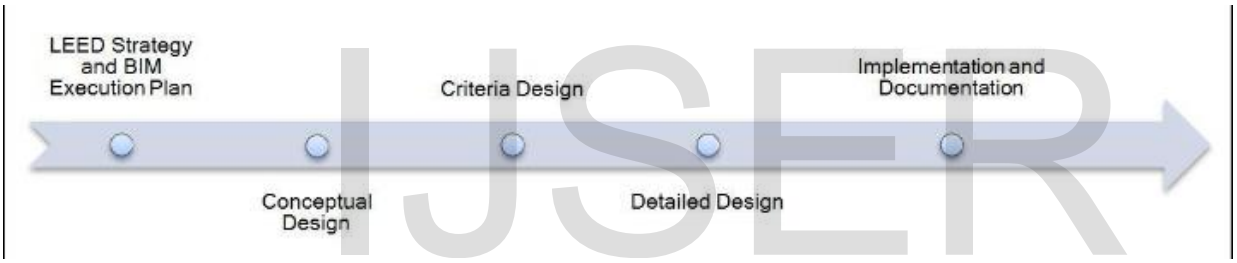

Fig 3 The Joint Course Project Delivery Process [30]

The teams faced challenges on three fronts which were the LEED Challenges, The BIM challenges, and the communication challenges. But even after facing so many challenges the students enjoyed collaborating with the other class and complete the project on time. The took a time of 3.5 months to complete the project and were graded based on their SLO's as low medium or high for their performance.[30]

To access the understanding of students on BIM implementation and Green Building design an entry exit survey was conducted at the end of the semester. To improve the future aspects of this project based learning an exit survey was conducted which incorporated certain open ended questions regarding students work experience of working with different classes on a combined project. A total of 29 students from both the classes completed the entry survey and 24 students were able to complete the exit survey as well.[30]

This type of project-based learning gave the students a great exposure to understand and learn the integrated Green BIM design of a project. After going through the results we can conclude that addition of BIM integrated for designing of sustainable projects into the university curriculum and be beneficial to provide the students a better insight about BIM as a tool for sustainable and green design.

4. ADVANTAGES AND LIMITATIONS OF BIM

4.1 ADVANTAGES OF BIM

The major advantage of BIM is that it provides a digital platform to support virtual design and construction. Through this design the type of material to be used, building orientation, types of construction techniques to be used, various design aspects of the building can be analyzed to meet the parameters of Green Building Project. [4,26]

Since Green BIM focuses on meeting the parameters of Green Building Certifications it reduces the amount of pollution caused in the form of waste production during the building construction. As it analyses all the sustainable aspects of a building thus resulting in reducing energy consumption. [21,22,23,24]

The usage of Green BIM saves resources to a great extent. Designing reasonable arrangement of pipelines using Green BIM reduces wastage of water. Using Green BIM in designing Natural Ventilation and air movement reduces the amount of electricity used and many such resources like solar energy are used to their full potential thus reducing the buildings impact on the environment.[4]

It was also found that when compared to the traditional method which took 25 hours per project with 4 emails and repetition of the process for every new project the workload was reduced drastically to 15 hours only one time, 4 emails and automized process for the upcoming projects by integration of BIM. This time reduction gives a huge advantage to the usage of BIM integrated projects.[8]

Another major advantage of Green BIM is Data Analysis. The huge amount of data required for a green building project can be easily stored, accessed, and operated by the professionals, experts and end user thus reducing the amount of time required, saving in cost of construction, and increasing the efficiency of building construction. [2]

Green BIM can be used for credit calculations of Green Building Certification systems to a great extent and can make certification processes easy, fast, and economical.

4.2 Limitations of BIM

Each organization or company adopts its own unique BIM strategy to be applied for green building projects as there is no specific BIM strategy to be adopted on a standard basis.

Due to its lack of capacity to integrate all the design aspects of a green building simultaneously, its usage in industrial practices is very limited.[20]

Application of BIM is mature in decision and design. But in construction and operation it is at the very beginning. [14]

The integration or interoperability of BIM and Life cycle assessment tools requires further research and investigations. It is because of lack of this integration that even after having so much of potential to support and enhance the sustainability aspects BIM is not commonly and effectively being used in the construction of Green buildings. [18]

In all the previous research studies it has been found that there has been a gap between the research and practice of BIM in construction industry of green building projects. The main reason behind this gap is lack of social integration of Green BIM in the development of green building projects. Steps are being taken on developing a methodology or model for the social integration of Green BIM for development of projects known as the Green BIM Index.[12]

The online survey reveals that the users from AEC industry are hesitant for using BIM due to their lack of understanding for it leading to a low demand of Green BIM in construction of Green Building Projects.[6]

BIM has made a huge impact on the construction industry because of its major advantages of saving cost, reducing energy consumption, reducing pollution, saving resources, making various data analysis, and effectively optimizing management strategy. But the one drawback or research gap which has been observed in the past is BIM has great advantages during the designing and initial phases of the project but its advancement or integration in the construction area is quite low.[14]

Most of the people think that BIM and Green Building certifications are absolutely two different processes.

The documentation process for certification as per Green Building Certification system requires lot of documentation which are to be prepared manually and their integration with BIM requires a lot of expertise in the different software's of BIM like Revit, IES, VE, AcriCAD, etc. which sometimes appears like an extra cost in the project thus making people reluctant for using Green BIM in their projects.[2]

Different environmental databases have different details and structures. So, the type of BIM model to be used, its structure and environmental database required may differ with different conditions. Foe g. the IFC (Industrial Foundation Classes) which is an ISO certified standard format may have certain libraries, but many materials or objects required for that project may require new materials, objects, or libraries to be added, which requires interference of a BIM expert as well as professional understanding IFC format thoroughly.[10]

Lack of social integration of Green BIM in the development of Green Building Projects.

5. Potential Usage of Green BIM for Future Green Building Projects.

To utilize Green BIM to its full potential it is necessary to use BIM for Green Building Certifications for which most of the experts said that there was a need to integrate BIM and Green Building Certification processes secondly training should be provided in both BIM and Green Building Certifications and third that government should intervene and make amendments in their policies to promote construction of Green buildings and integration of BIM with Green Building Certification processes.[5,27]

The major challenge which was incurred in the development of Green 2.0 was materializing an open platform which integrates different technologies for socio technical analysis. After so many research which has been done on green BIM it can be inferred that Green Building Research is a socio technical process. The development of Green 2.0 describes a significant improvement over the current ongoing practices and it tries to advance in green building design towards sustainable development. [10]

It can be asserted that usage of BIM tool for developing a 3D architectural geometry model in energy simulation is a very fast accurate efficient and economical process. But in order to improve the problems concerning the simulation it is extremely important to utilize quality check programs like Solibri Model Checker and Navisworks. Also, it is necessary to develop gbXML editor that can immediately rectify any errors found through an error checking program.[2]

Future research could respond to this gap and try to come out with a solution to increase the applicability and usage of Green BIM to a larger scale.

This study identifies certain recommendations which can be used for developing BIM models that are more suitable for LCA. The main recommendation being to develop a BIM model which is not just successful on an academic context, but which can be readily used for the actual AEC (Architecture, Engineer & Construction) market situation. [18,19]

CONCLUSION

In current scenario BIM software is still insufficient in providing an integrated analytical solution for an individual Green Building as it does not have the capacity to simultaneously analyze all green aspects of the building. Though there are innumerable advantages of incorporating 'Green BIM' there is no denial from the fact that it has its limitations and challenges like, interoperability between different software platforms, additional cost of software, lack of knowledge and among people about 'Green BIM' are few disadvantages due to which people are hesitant or reluctant about using 'Green BIM' in their projects. It can be said that though the integration of BIM for Green Building Certifications has its certain constraints and challenges but the advantages of the automatization after the implementation of all the parameters significantly increase the efficiency of this process and the recollection of the documentation required for each certification. Comparing and considering the advantages and constraints of using BIM integrated GBC, every AEC industry can individually analyze and decide about its feasibility. It can be concluded from the paper that BIM and LCA have a huge potential growth in developing Green or Sustainable buildings but at the same time a thorough and in-depth knowledge of both BIM and LCA shall be required or else the results shall be incorrect.

To fully utilize Green BIM merits, the implementation must be properly planned and designed according to the objectives of the proposed projects, concurrently depreciating the barriers that might disrupt the progress. So much more efforts are needed from the implementers so that 'Green BIM' can be utilized at its full potential towards, improving the sustainability of green building projects.

The main conclusion is the deduced organizational framework to regulate and optimize collaboration and maturity potentials of a BIM model as a strategic basis of firms to produce green buildings. The proposed framework can be developed and modified as a practical strategy depending upon the policy of each organization or company. This will eventually lead to the usage of BIM to its full potential for the development of green building projects.

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