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# SUSTAINABLE DESIGN OF BUILDINGS THROUGH BIM: A COMPREHENSIVE REVIEW

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***Abstract-*** Building Information Modeling (BIM) is an effective and emerging approach for managing the complex construction projects. BIM has been successfully applied in construction industry. However, several compatibility issues were recorded. This article provides an overview of the literature on sustainable digital building models. Moreover, it covers cost estimation, energy savings, energy analysis, carbon calculation and waste management in the buildings. Furthermore, this study suggests that these parameters should be considered at an early stage of project. In practice, this type of management is usually done at later stage in the design process, which leads to the re-design of complete project. In addition to this, it also provides information on the various software tools that can lead to the selection of efficient structure. Autodesk Review, Dynamo Factory and HBERT Recovery are the different softwares selected. Future aspirations are also offered for implementation.

***Keywords***- BIM, cost estimation, energy efficiency, sustainable buildings.

**List of Abbreviations:** Building Information Modeling (BIM); Computer Aided Design (CAD); Mechanical electrical plumbing (MEP); Architecture, Engineering, and Construction (AEC); Cost model (CM); Carbon dioxide $CO_2$; Leadership in Energy and Environmental Design (LEED); Green Building Index (GBI); Energy Efficiency (EE); Indoor Environment Quality (EQ); Materials and Resources (MR); Water Efficiency (WE); Revit Green Project Template (RGPT); International Energy Agency (IEA); Building Energy Modeling (BEM); Agent-Based Modeling (ABM); visual programming language (VPL); industrial information classes (IFC); IDA Indoor Climate and Energy (IDA ICE); Plumbing Engineer (ME); Building Management System (BMS); Facilities Management (FM); Construction and destruction (C&D); Life Cycle Assessment (LCA); Life Cycle Costing (LCC); Incorporated Material Profile and Costing Tool (IMPACT).

## 1 INTRODUCTION

**Normally the building components were drafted by architects, engineers through symbolic language using setsquares, T-squares and pencils. In 1980's, the Architects and engineers shifted towards Computer Aided Design (CAD) but the fundamental manual method of symbolic expression remains the same. The BIM innovation is another emerging method of managing complex development projects. It predominantly concentrates on the flowing of tasks information which are fed into the advanced model. Thus, it is the technique through which the digital model of the structure is developed which is rich in information including MEP (mechanical electrical plumbing), architectural and structural models. The digital model starts initially from 2D drawings which is converted into 3D [1] model and then, there is 4D model related to project scheduling, 5D related to cost estimation, 6D sustainability, 7D related to safety and 8D related to Assets management. As the BIM covering broad areas of technology practicing in Architecture, Engineering, and Construction (AEC) industry. But the primary need is to develop strong coordination between the academia (who continuously develops new research techniques) and the AEC industry to adopt this emerging technology in real engineering practice. Hence, In this research we will cover the cost estimation, embodied carbon calculation, waste management, and energy analysis though BIM approach and will be shared with AEC industry for awareness purposes.**

## 2 RESEARCH SIGNIFICANCE

This research will cover the cost estimation, energy analysis, carbon calculations, and waste management through BIM technology. The related areas will then debate the implementation issued in the industrial zones and try to highlight the reasons which hinders the BIM technology in the construction zones. By stating and clearing the issues in real implementations, will minimize the cost of overall projects in terms of management and coordination. Also, providing best decision making tools in real scenarios and good approach to environment friendly constructions.

## 3 COST ESTIMATION

**Cost estimation is a strenuous and tiring process, which mainly include changes and reworks calculations [1]. It happens in a huge number of projects due to unforeseen and unexpected scenarios occurring in the construction field. BIM can assist effectively in reducing the reworks to establish more reliable estimate as compared to manual estimates. Through BIM enabled model, it is possible to simulate different scenarios for the clients keeping financial constraint in mind. Table 1 shows the current utilization of BIM in construction industries for various activities. About 75% is using BIM for visualization and 55% for estimating purposes. The cost manager should be well-aware to utilize the BIM model for the project financial management. The traditional way of estimating involves meetings, work plan, schedule, estimate preparation, documentation, reviews and adjustments and then feedback upon completion. However, BIM estimation follows the same footsteps, but the advancement brought the errors and uncertainties to minimum level by extracting information from 3D rather than 2D model.**

Table 1 : Application of BIM in construction industry based on activities [2]

| Activities | Percentage |
|---|---|
| Scheduling | 42% |
| Marketing | 45% |
| Visualization | 75% |
| Estimating | 55% |

### *3.1 BIM Adaptation for cost estimation*

**BIM adoption has been tremendously increased in many countries like Australia, USA, Europe and Middle East. Different organizations like International Alliance for interoperability, CRC-IC, ANZRS, PBS also played a vital role in promoting this technology. In USA BIM implementation grown up from 17% to 71% from 2007-2012 [3]. Similarly, the Building Smart Australia conducted a survey, which reveals the highest adoption rate [4]. The overview provided by National Building predicts that 13% of private organizations utilize BIM in their projects. As BIM is inclined towards development industry, and numerous nations settled on choices to require BIM in broad daylight contracts. One of its usage is the utilization of BIM for projects cost estimation. Various researchers conducted a survey from construction sector specialists and firms to decide the degree to which assessing forms were automated with the help of BIM model. Questionnaire was designed to extract information about how BIM was utilized inside their association and how it was utilized in the different projects engaged with cost estimation. Information presented in Table 1 was obtained from the survey and highlights the applications and utilization of BIM in various stages of the project within construction industry [6]**

### *3.2 Implementation issues*

**Table 2 shows the results obtained from the survey conducted by Farooq., et al. [2]. There are likewise some usage issues in BIM for the cost estimation but when once implemented, will decrease the estimation time from weeks to certain minutes. The issues in the BIM software is that of interoperability and reliability of data [4]. Because of the absence of consistency, the data during transferring among various software get missing. It is intended to create technique and devices to meet the necessity of small scope industry procedures for cost estimation through BIM. For example, cost evaluating and booking must be reengineered thinking about the new innovation. BIM has just been received by a few contractual workers in the US and is rapidly picking up familiarity inside the construction sector. The future goal for Building Information Modeling is for general laborers to have the alternative to opt out a quantity takeoff in a matter of seconds. BIM isn't improving nature of estimations or decreasing the time required for cost estimation for contractors [6]. This could be the eventual outcome for large general contractor having separate divisions for surveying and BIM, having negotiable contracts, gives favorable results for contractors most of the time. This prevents the feasibility of detailed BIM model. There need to be an upgrade in BIM modeling before going into legal binding with contractors. Organizers and design engineers need to make BIM models with enough information so statements may be made without the contractors, redrawing entire models without any preparation. [6] Detailed and exact drafts of competition are required to effective BIM execution. The investigation has been led for the transportation cost estimation in Czech Republic. This shows that it must be guaranteed by determinations in contract, the extent that data model and Cost model (CM) are concerned. The determinations required are information arrangement and Execution plan of building data demonstrating it to be remembered for contract. [5]. The paper here is for various cases when all is said to be done, so the outcomes are applicable for most of the individual framework of cost estimation throughout the world. The presented solutions are then compared to show their advantages and disadvantages. The various issues it face are**

a. Sometimes drawings and specification are in conflict with each other.
b. Misunderstanding of drawing by designer or surveyor.
c. It is time consuming process.
d. When drawings are in large amount it becomes very difficult.
e. Chances of human error.

Table 2: Different implementation barriers [2]

| Barriers | Rating |
|---|---|
| Absence of government guideline about BIM | 78% |
| Absence of classes on new advances like BIM by firms | 77% |
| BIM adjustment requires authoritative rebuild | 72% |
| Absence of BIM experts | 70% |
| Absence of competency to organize projects though BIM | 64% |
| Poor communication in organization | 60% |

## 4 GREEN BUILDING THROUGH BIM

**Currently the world has a lot of challenges due to environmental changes and global warming. From recent research we came to know that some industries have an immense role in creating green buildings, particularly the construction industry. The Green BIM projects have improved the sustainability by developing sustainable design by using natural resources and prevail environmental quality by reducing toxic waste[6]. From recent studies it was observed that applications of BIM not only reduce $CO_2$ emissions but also makes environment pleasant by**

**reducing use of fossil fuels[7]. The construction industry realizes to produce the green building we should use strategies to reduce the $CO_2$ emission. The green building has less effects on environment as compared to the conventional building throughout the building life cycle. Due to this the green building is used as innovative operation for Energy Efficient Environment.**

### *4.1 Challenges in adoption of BIM for Green building*

**From recent studies we know that the unsuitable materials used in building damaged the environment as well as the health of human. So, the question arises is that how to resolve these issues. Some engineers have proposed that we can easily resolve these issues by preferring green and sustainable buildings. We know that the main goal of the green building is to move from harmful to harmless materials used in buildings. This results in decrease of energy usage, $CO_2$ emission, water resources etc. We know that the green buildings can reduce the harmful effects on the environment.[8] Government of Malaysia pronounces various sorts of incentives for construction improvement in Malaysia. The incentive is grouped into three; financial incentive, fiscal incentive and structural incentive. Due to the case financial incentive building developers are attracted to adopt a green building and they submit their documents for new projects. Structural incentives are much more important because we can use such a material that can be recycled and reused.[8] The sustainable green building enhance the natural light, rain water system and much more. The green building have a lot of benefits to the constructors and as well as the purchasers but we should prefer the standards like LEED which can enhance the environment.[6] The capacity, supportability and combination of green structure evaluation with BIM is the principle expectation to be finished. "Green BIM Triangle" is scientific categorization which gives a systematic way to deal with the current range of information on green BIM.[7] The GBI introduced environmental friendly features like EE, MR, WE, EQ, etc. RGPT is produced to help the user of BIM in documentation & assessment of Green buildings. These tools help in saving time.[7] In India the number of population is expected to increase massively, focused by population development. Due to increase in population, increase in construction is also expected. So in the recent year advancements in the building construction is important in survey analysis headed by the professionals who have great contribution in green construction. The green building helps to incorporate expenses, reduce the energy consumption and beneficial well-being. In addition it is now necessary to achieve more green building construction through the green and sustainable building polices [9]**

## 5 ENERGY ANALYSIS THROUGH BIM

**In last decade energy consumption is increasing rapidly by the rise of population. The proper energy consumption can be achieved by proper design and operation. One of the effective ways to achieve this is by BEM. Through BIM model which is rich in data and digital representation of facilities for the energy efficient building using BIM based BEM model. In the structure planning process Energy reproduction devices are ordinarily utilized daily. They permit originators to anticipate the energy required to give interior natural relief, while conveying an ideal degree of vital productivity. In most of the daily life structures, which are maintainable structures, it is important for engineers and experts to work even more carefully in a multi-disciplinary group with a common objective of the energy and natural environmental impacts of new structures. The International Energy Agency (IEA) has recognized a coordinated structure process (IDP), conveyed through a multi-disciplinary plan group is essential for effectively managing structures. In the construction industry the necessary degree of multi-disciplinary joint effort in building configuration isn't ordinary. The construction is directly related to an unnatural weather change, the construction industry is starting to concentrate more on energy utilization of the structure and to address energy efficient structure.[10].**

### *5.1 Application of BIM for energy analysis*

**Recently numerous devices are produced to demonstrate building energy (BEM) or building energy utilization by the merging through Agent-Based Modeling (ABM). Ordered trade of information from BIM to BEM. The BIM information sent out as contribution to Energy Plus. Two three-dimensional processing models, BIM and BEM are leading in divided style. Making a BIM model, the parametric and social information trade among BIM and BEM is created in operator-based model. A portion of the model examine in paper are effort at reproducing the effect that inhabitant on building energy utilization. At long last set of models archived after energy examination result**

**that up to 11% energy consumed by utilizing BIM for BEM. During surveying of large scale systems conducted on the active and differing energy by utilizing BIM, BEM and ABM. Results of surveys introduced were not reliable, made in BIM model utilized the visual programming language (VPL) to systematize the parametric information trade with BEM and ABM. Construct an ABM which interact with environment and made decisions based on visual comfort level. Documentation of the behavioral decision and export of BIM model and energy consumption generated. Validated the proposed BIM, BEM and ABM framework by comparing with results.[11] methodology workflow is summarized in following four points:**

1. Create architectural model or 3D model in Revit.
2. In second step import the industrial information classes (IFC) data into IDA Indoor Climate and Energy (IDA ICE) energy simulation tool.
3. Energy simulation setup described in detail.
4. Merge IDA-ICE results within IFC file.

The construction industry consumes energy and natural resources and is commonly known as "the industry of the 40%", since buildings produce nearly 40% of overall $CO_2$ emissions, 40% of overall waste generation and consumes 40% of overall natural resources over their entire life spans. The world witness increases in awareness with regards to enhanced energy efficiency in construction. Figure 1 shows the impact of construction industry on the economic activities and resources utilization. BIM has been proposed as an innovative approach with multidisciplinary tools that can effectively evaluate energy performance in buildings by harmonizing information of building material and facilitating the calculation of their environmental impacts. In the last decade, the energy consumption of buildings has been intensely increasing, driven by the rising population, growing economy and higher demand on life quality. Nevertheless, significant energy savings can be achieved, if buildings are properly designed, constructed and operated.[12]

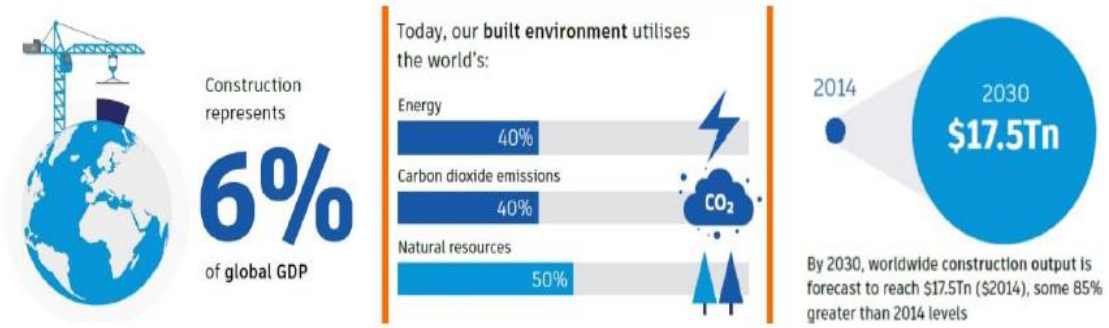


Figure 1:Impacts of the construction industry on economic activities and resource utilization [12]

## *5.2 Implementation issues*

**Despite the various possible advantages of using BIM, there are some issues which are related to real life scenarios to implement. BIM adoption is a progressive task, and is a difficult assignment. The utilization of BIM also brought some hazards and risks including expert hazard, the administrator's chance, natural hazard, money related hazard and legitimate hazard. One of the fundamental difficulties associated with BIM movement is the licensed innovation and digital security of BIM apparatuses results. As data sharing makes sensitive information open to all staff, digital security is a worry because of the chance of online unapproved access and copyright violation. Also, the improvement of far reaching and clear re-use and response approaches for BIM models either by a similar group for various purposes or by others is a difficult undertaking. Lawful concerns likewise exist, issue is with responsibility to ensure the privacy of data as the model is rich with data of all disciplines. Moreover, joint initiation of various BIM model, engineers confuses joint and separate obligation for any mistakes made during the undertaking lifecycle. The exactness of information of the BIM model involves significant risks and the duty regarding this accuracy must be defended by responsible authorities just as constrained guarantees from the planners[13]. The absence of categorized responsibility is who claims and regularize the execution information, was told by every interviewee. Conduct difficulties stay a critical obstruction to innovation and procedure comment by**

**the interviewees as hesitance to take on extra duties. A past encounter of the ME incorporated an account where after being asked where the BMS was, the FM reacted, "what's that?" as it had been covered up in a cabinet while the structure was being controlled physically.[14] Absence of instruction and Lack of training is one of the most testing hindrances for BIM selection in construction industry. The absence of instruction on BIM reminders is lacking of abilities, and demonstrable skill in the genuine work environment. There is a deficiency of tertiary training that helps in conveying BIM information through talk or lab mix, familiarizing the aptitudes with model for assessing and getting drawings. Restricted training programs were familiar with tertiary instruction understudies on BIM innovation. The number of educational organizations bringing BIM into their educational plan. Difficulties exist when there are challenges in preparing staff in region of information taking care of. The representatives of associations may require finishing certain confirmation to have the option to take part in the new authoritative procedure. Troubles emerge in preparing individuals in BIM and conquering protection from change and the weaknesses identifying with learning new programming and rethinking work process forms.[15]**

## 6 APPLICATION OF BIM FOR WASTE MANAGEMENT

**The waste generated on construction site is mainly due to rework, insufficient coordination and collaboration. Figure 2 presents the salvage performance of building over the period of 60 years. 4D BIM develops construction planning, scheduling and on-site management of waste as well as enhance communication and information flow. BIM helps undertaking members improve the measures of plan development and destruction stages. Furthermore, limiting Construction and destruction (C&D) waste is commonly a mix of surplus materials emerging from development and devastation exercises including land diggings, street fixes, remodel and pulverization [16] . Renovating present buildings and recycling remaining construction materials provide the true solution to lessen waste and minimize impacts on the environment. To control C&D waste management practices, a specific set of frameworks is required that should include the better practice for managing waste and achieve minimum waste strategy [17]. There is a collective need to lessen construction waste as well as encourage further sustainable construction. Incorporated Material Profile and Costing Tool (IMPACT) is a database with comprehensive point of coordinating Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and BIM [17]. It is anticipated that 4D planning, diversion and origination can propel the aggregate improvement of development natural administration plans and they're on location observing.**

**This research is based on the facts and results from the prior construction projects and areas that generates the maximum amount of waste in a construction project. BIM being the latest addition to manage waste in the industry, the idea is to integrate the proposed framework into BIM as described in the introduction. The information gathered from numerous urban areas demonstrates that enough development and destruction waste is delivered throughout Construction phases in various segments of the world which vary from 18 kg for each capita/year to 842 kg for every capita/year [18]. Moreover, the Environmental effects of materials changed into waste is evaluated in an incorporated situation by developing an enhancement inside BIM device (LCA), which registers waste shaped in each progression of structures lifetime**

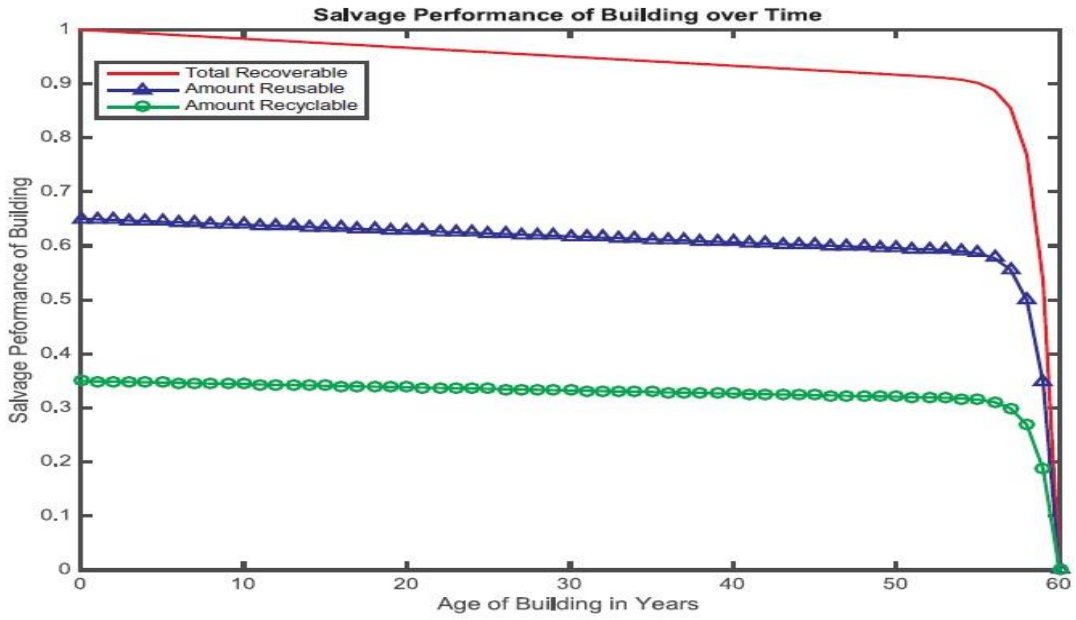


Figure 2: Salvage performance of building [15]

### *6.1 Tools usage and selection survey for the different analysis of digital model.*

**Various software tools are used to prepare digital models. This section provides a brief overview of previous articles. The general findings of the literature review are shown in Table 3. It contains data on the use of tools for various activities carried out in BIM.**

Table 3: Digital tools normally used in BIM enabled projects

| S No | ACTIVITY | TOOL NAME | REMARKS |
|---|---|---|---|
| **1** | Quantity takeoff | Autodesk Revit | Basic detailed schedules are prepared |
| **2** | Cost management and optimization | Autodesk Revit with dynamo refinery | Extension of Autodesk Revit 2018 |
| **3** | Surface area to volume ratio optimization | Generative design tool with dynamo refinery in Revit | Extension of Autodesk Revit 2018 |
| **4** | Equipment arrangement and natural light optimization inside building | Dynamo Refinery Autodesk Revit 2018 | Extension of Autodesk Revit 2018 |
| **5** | Carbon calculation for green building | Hubert in Autodesk Revit 2018 and green building studio | Extension of Autodesk Revit 2018 and cloud storage. |

| | | | |
|---|---|---|---|
| **6** | Energy Analysis | Autodesk Revit | Extension of Autodesk Revit 2017 |
| **7** | Heating and Cooling load Analysis | Autodesk Revit with zoning | Extension of Autodesk Revit 2017 |

## 7 PRACTICAL IMPLEMENTATION IN INDUSTRY

The current research highlighted the problems in industry and reviewed the four aspects of BIM technology. With the practical implementation of this technology, the construction industry can easily overcome all the problems related to cost and time overruns, minimizes reworks and managing a project effectively and efficiently.

Similarly we know that environment care is one of the challenging task in the modern world and the concept of green building is one of the modern option available which is possible through BIM enabled model in the terms of operation and embodied carbon calculations.

# 8 CONCLUSION

**BIM technology is tremendously increasing in the AEC industry. Based on above observations following findings are drawn:**

- Government should focus and support the BIM technology in their projects to achieve sustainability.
- Due to the lack of professionals, its developments are hindering so the universities should offer courses regarding BIM.
- The industries need to focus on this new technology. As it is difficult to implement in start but once implemented, it will reduce the fatigue from month to weeks and days.
- As some features are designed especially for the collaboration so, BIM can be proved very effective in project management.

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