Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 07, July-2021

Comparative Analysis of Initial Cost Between Conventional and Energy Efficient Building using BIM as A Tool: A Case Study Approach

Tushar Jadhav [1,*], Eshwar Pandalaneni[2], Bhargav Kandula[2] and Eesha Thakre[2]
[1] Associate Professor, SOPRIM, National Institute of Construction Management and Research, India.
[2] Former Project Engineering and Management student, SOPRIM, National Institute of Construction Management and Research, India.

***Abstract*:- Energy efficient buildings have gained a lot of significance in recent years due to more emphasis on energy conservation. There is a general perception amongst the stakeholders that energy efficient buildings will always have more initial cost as compared to the traditional conventional buildings. The present research compares the initial cost of major elements such as building envelope, mechanical and electrical systems for conventional and energy efficient building. The effective use of building information modeling (BIM) to understand the cost management aspects is also discussed. The findings of this study indicate that the initial cost of energy efficient building can be significantly lower compared to the conventional building. The study also highlights the effective use of BIM to estimate the major cost drivers associated within the building. The flow chart for comparative initial cost analysis between conventional and energy efficient building can provide significant insights to the different stakeholders in promoting energy efficient buildings.**

Keywords: Buildings; cost management; building services; building information modeling

1. INTRODUCTION

Energy conservation in buildings has received lot of significance in recent years. There is a growing demand to construct energy efficient or energy compliant buildings globally. In India, energy conservation building code (ECBC) has been framed to the address the energy performance standards for new commercial buildings in India. A study on the critical aspects of energy efficiency and management in buildings was conducted by Danish et al. (2019). Adopting different energy efficient strategies can have significant impact in reducing the energy consumption of a building (Sadineni et al., 2011). Pacheco et al. (2012) have reviewed different building designs that can reduce the energy demand of residential buildings. Dhaka et al. (2014) investigated the effect of building envelope on the comfort conditions for a naturally ventilated building. An integrated design approach was recommended by Jones & Bogus (2010) for achieving energy efficient retrofits in a building. Jadhav (2019) investigated the strategies for reducing cooling load for buildings and improve the energy efficiency of building. Killian & Kozek (2016) have discussed the use of model predictive control for energy efficient buildings. Hong et al. (2020) have addressed some of the important questions related to urban building energy modeling. Building information modeling (BIM) can be looked upon as an important tool in project management (Bryde et al., 2013). Smith, P. (2014) examined the global issues related to project cost management and investigated the role of BIM in cost estimation in the construction sector. Gu & London (2010) evaluated the readiness of Architecture, Engineering and Construction (AEC) industry for adoption of BIM technology. Abanda & Byers (2016) investigated the use of BIM to predict the impact of energy consumption due to the orientation of the building. Sadeghifam et al. (2019) studied the effect of building components for a residential building located in tropical climatic zone. Gerges et al. (2019) investigated the role of BIM at the conceptual design phase by analyzing the case of a UK construction project. There are studies on use of BIM for various applications reported by few researchers around the world (Becerik-Gerber et al., 2012; Chen & Tang, 2019; Di Giuda et al., 2015; Jenkins, 2018; Kiziltas & Akinci 2010; Ozturk, 2020; Stumpf et al., 2009; Jadhav, 2019). ICCEB (2015) have documented the experiences and case studies from architects, consultants and building owners on several energy efficiency aspects in a building. The preceding literature has limited information on the initial cost aspects and its variation between a conventional and energy efficient building. This information is important to understand the cost implications for promoting energy compliant building.

2. RESEARCH OBJECTIVES

The purpose of this study is to understand the important cost engineering parameters for analyzing the initial cost of a building. The specific questions that needs to be investigated in the present study includes

(1) What is the variation in the initial cost of a conventional and energy efficient building?
(2) Can BIM be used as an effective tool to estimate the initial cost of a building and perform comparative analysis?

3. RESEARCH METHODOLOGY

This study uses a hypothetical building case study constructed using a BIM interface. A simple commercial layout is evaluated using variations in the building envelope and subsequent variations in the construction cost of civil, mechanical and electrical components. The commercial office building layout is shown in Fig. 1.

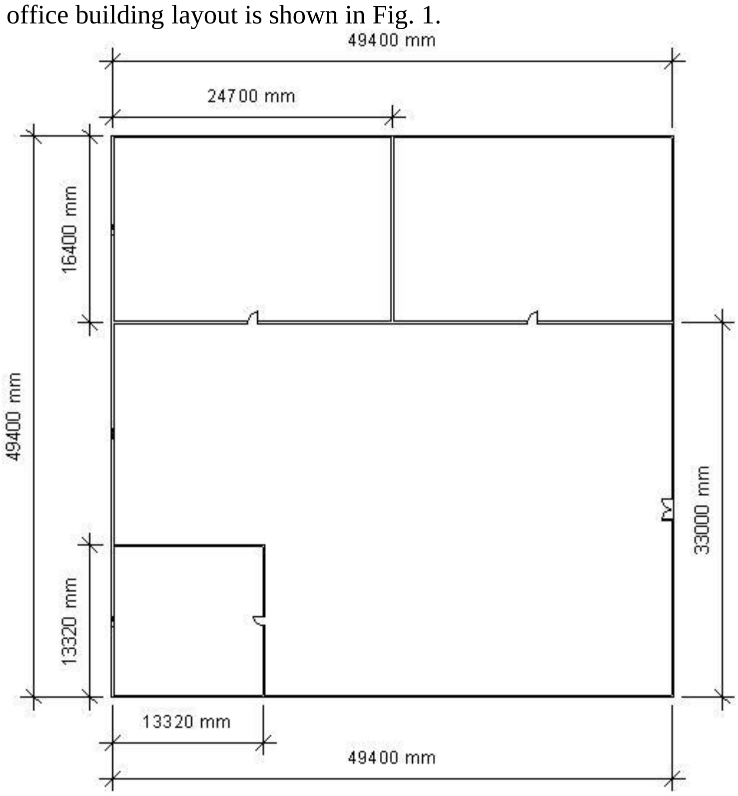

Fig. 1 Layout of office building

The commercial office building in the present study has three floors with total floor area of 7320 sq. m., with each floor of approximately 2440 sq. m. The building location is assumed to be in Mumbai, India which falls under warm and humid climatic zone.

The building envelope is analyzed for both conventional and energy efficient construction type, to understand the variation in the mechanical and electrical requirements of the building in relation to the building envelope. The building model is analyzed using Autodesk Revit (BIM) software.

3.1 Comparison between conventional and energy efficient building

One of the major differences in the conventional and the energy efficient (or compliant) building lies in its building envelope. The ECBC (2017) has prescribed few guidelines in terms of building envelope depending upon the climatic zone. The building model in the present study is analyzed by comparing the building envelope for conventional and energy efficient building (Refer Table 1). The selection of building envelope for conventional building is referred from the general practices adopted in the construction sector whereas the selection of building envelope for energy efficient building is referred using ECBC (2017) guidelines.

Table 1 Building envelope

Category	Conventional building	Energy efficient building
Overall heat transfer coefficient (U) value for roof, W/m^2K	3	0.3
Overall heat transfer coefficient (U) value for wall, W/m^2K	2	0.4
Overall heat transfer coefficient (U) value for glass, W/m^2K	4	3
Solar Heat Gain Coefficient (SHGC) for glass	0.86	0.13

The building construction materials are selected in Revit software based on the options available in the software. One can select a building material from the software default options that matches with U value and SHGC of actual building material to be used in the project. It is also implicit that subsequent iterations are possible by modifying the building construction material and its geometry.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 07, July-2021

3.2 Variation in the cooling load requirements

The building envelope plays a significant role in the cooling demand of a particular building. In conditions where the outside temperatures are high, it is recommended to use building materials with lower 'U' value to provide less heat gain inside the building. This results in drastic reduction in the cooling load requirements. The building model (Refer Fig. 2) is simulated using Autodesk Revit (BIM) software to understand the variation in the cooling load requirements of conventional and energy efficient building.

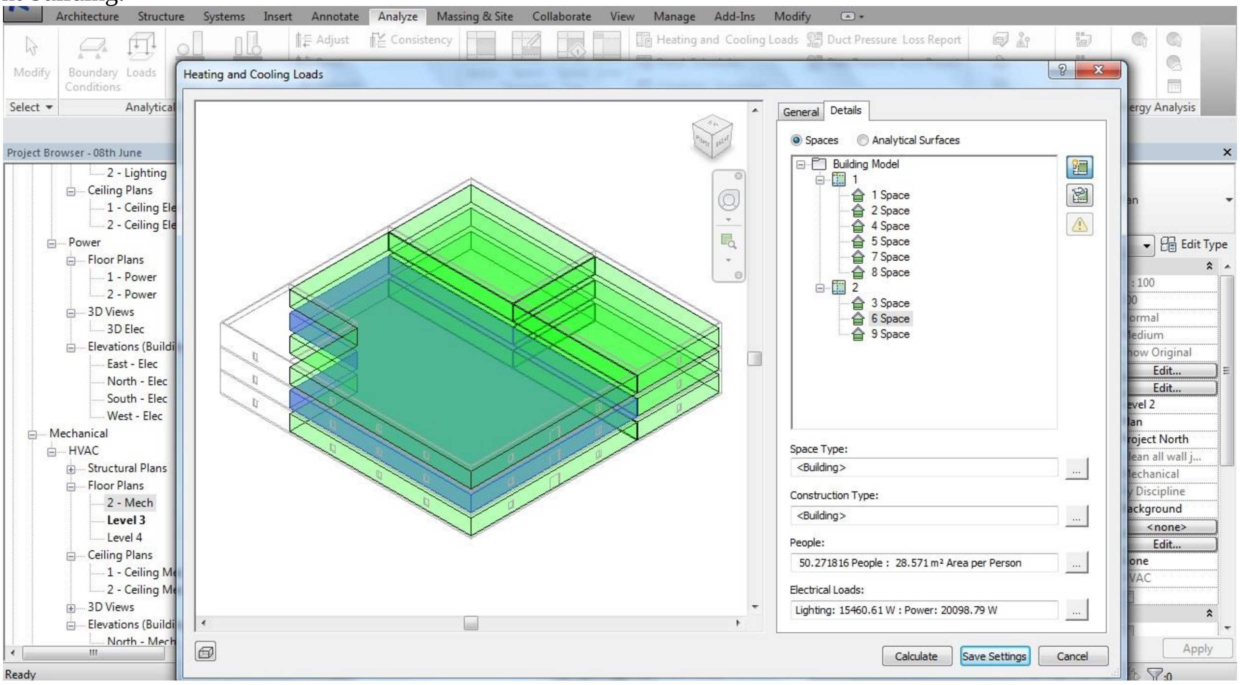

Fig. 2 Simulation using BIM

The assumptions made for performing the air conditioning load calculations are summarized in Table 2.

Table 2 Assumptions for air conditioning load calculation

Occupancy	181
Sensible gain per person (W)	73.27
Latent gain per person (W)	58.61
Equipment load	14 W/m^2
Lighting load	10.76 W/m^2
Outdoor air	2.5 L/s per person and 0.3 L/s per m^2

Table 3 gives an insight into the cooling and heating load requirements for the office building under study.

Table 3 Comparison of load calculations for the present study

Inputs		
Building Type	Office	
Location	Mumbai, India	
Area (m²)	6,690	
Volume (m³)	20,071.24	
Calculated Results		
	Conventional building	**Energy efficient building**
Peak Cooling Total Load (W)	**1,565,287**	**370,482**
Peak Cooling Sensible Load (W)	1,501,907	288,652
Peak Cooling Latent Load (W)	63,380	81,830
Peak Cooling Airflow (L/s)	111,614.1	20,130.7
Peak Heating Load (W)	133,023	22,021
Peak Heating Airflow (L/s)	8,305.7	2,007.1
Checksums		
Cooling Load Density (W/m²)	233.96	55.38
Cooling Flow Density (L/(s·m²))	16.68	3.01
Cooling Flow / Load (L/(s·kW))	71.31	54.34
Cooling Area / Load (m²/kW)	4.27	18.06
Heating Load Density (W/m²)	19.88	3.29
Heating Flow Density (L/(s·m²))	1.24	0.30

The summary of Table 3 is summarized in Fig. 3 which indicates that the building cooling requirements has drastically reduced from 1,565,287 W (445 TR) for conventional building to 361,863 W (103 TR) for energy efficient building (1 Ton of refrigeration (TR) = 3.517 kW).

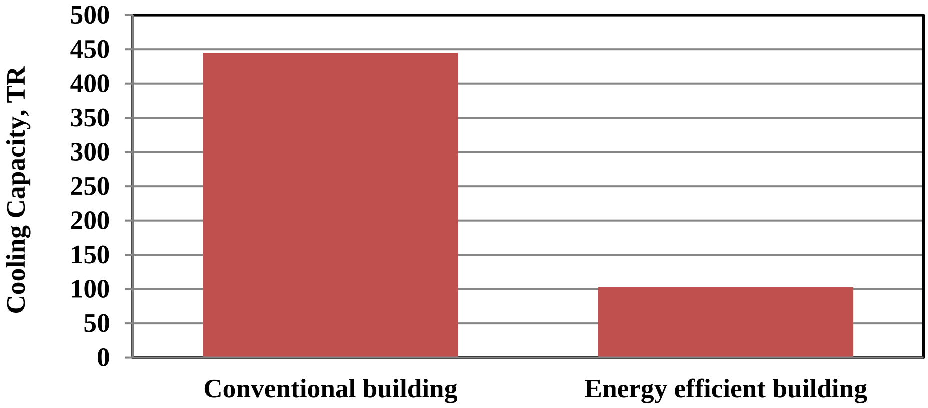

Fig. 3 Variation in the cooling capacity

This reduction of 77 % in the cooling load is possible due to the selection of building envelope with lower U value (for energy efficient building) in comparison with the conventional building.

3.3 Variation in the initial cost for civil, mechanical and electrical components

The purpose of this section is to understand the impact of energy compliance on the major cost drivers of a building. The cost engineering parameters that indicate major difference in the initial cost of conventional and energy efficient building are building insulation (civil component), air conditioning system (mechanical component) and building electrical distribution (electrical component).

Following are the assumptions considered for calculating the initial cost of civil, electrical and mechanical components.

3.3.1 Assumptions:

1. The energy efficient building envelope has insulation of 75 mm polyurethane for roof and 50 mm expanded polystyrene insulation for wall.
2. The air conditioning system considered is unitary air conditioning.
3. Cost of unitary air conditioning = 35000 INR per TR
4. Power consumption for air conditioning = 1 kW/TR
5. No. of computers = 50, Computer load: 65 W per computer.

With the above consideration, the connected electrical load for conventional building works out to be 529 kW and for energy efficient building as 169 kW. Thus there is significant reduction of 68 % in the connected load. The major cost of electrical system includes cost of components such as transformer, cables, distribution panel and load break switch. The rate analysis for civil, electrical and mechanical components is considered based on data available in open literature, standards and equipment catalogues.

Table 4 highlights the variation in the initial cost between conventional and energy efficient building. It must be noted that the only variation considered in the civil component is the building insulation cost.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 07, July-2021

Table 4 Initial cost variation between conventional and energy efficient building

Sr. No.	Description	Initial Cost for conventional building in INR	Initial Cost for energy efficient building in INR	Difference
1.	Civil component (building insulation)	Nil (No insulation for conventional building)	10967,751 (Insulation cost for energy efficient building)	(+) 10967,751
2.	Mechanical component (air conditioning system)	15575,000	3605,000	(-) 11970,000
3.	Electrical component (electrical distribution)	3731,586	1243,862	(-) 2487,724
4.	**Total**	19306,586	15816,613	Variation = 18 % (initial cost is 18 % less for energy efficient building in this case)

4. DISCUSSIONS

The following section discusses the findings to the key questions raised in this study.

4.1 What is the variation in the initial cost of a conventional and energy efficient building?

Several case studies in the past have shown the potential of energy efficient buildings. Various simulation tools can help the designer in arriving at a comprehensive understanding about the impact of various building components on the energy consumption (Abaza, 2008). Sastry (2016) highlighted the deep green retrofits implemented at Infosys. Taleb (2014) analyzed the benefits of different passive cooling strategies on the energy performance of a building. The energy performance index (EPI) was seen to be reduced by 32 % in Aranya Bhawan, Jaipur (Chetia et al., 2015). This was possible due to implementation of efficient building envelope and air conditioning system. Indira Paryavaran Bhawan (Prashad and Chetia, 2015) can be seen as a new paradigm of self-sufficiency. The above literature demonstrates the benefits of energy efficient buildings. Energy efficient (or compliant) building requires an energy efficient building envelope. The need of insulation thus becomes significant as there is necessity to reduce the U value of building envelope (Refer Fig. 4).

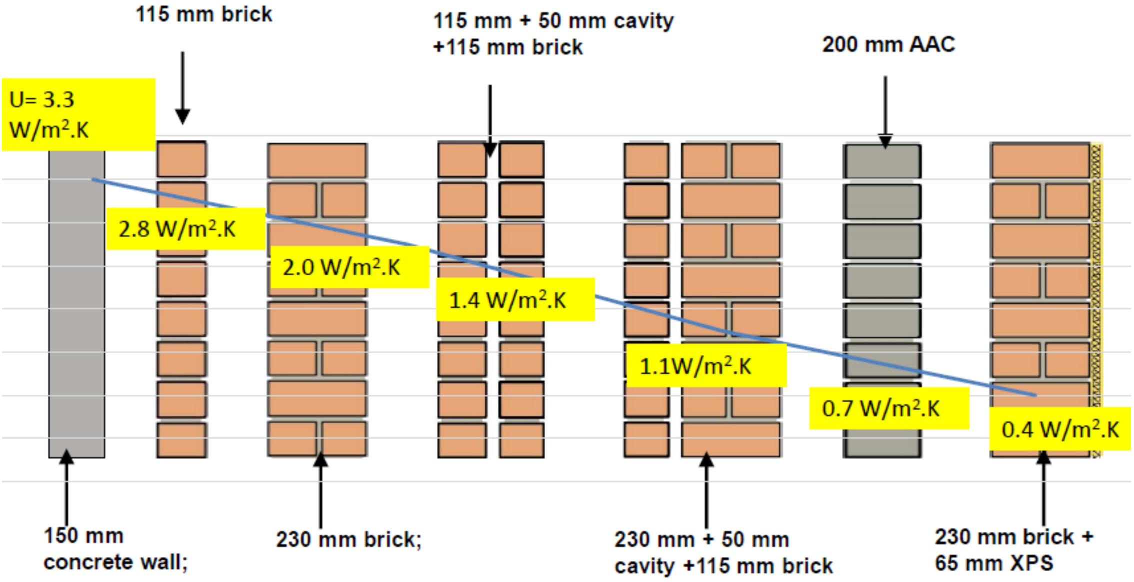

Fig. 4 Variation in the U value of building material (https://beepindia.org)

However, the fundamental question on the variation in the initial cost between conventional and energy efficient building is investigated in the present study.

The cost of civil component in energy efficient building is more than the conventional building due to extra cost of insulation. However, the efficient building envelope reduces the air conditioning demand drastically which further reduces the sizing of electrical components. In the present study, the air conditioning cooling load got reduced from 445 TR to 103 TR. This resulted in saving of approximately 1 crore 19 lakhs INR in the initial cost of mechanical (air conditioning) system (approximately 77 % reduction). Further, the electrical demand got reduced due to lower capacity of air conditioning system. The reduction in the initial cost of electrical system was approximately 24 lakhs 87 thousand INR (approximately 67 % reduction). The results of Table 4 indicate that there is a saving of 18 % in the initial cost of energy efficient building in comparison to the conventional building. It is a general perception that energy efficient building are costlier to construct than the conventional one. However the present study highlights the need of a comprehensive and integrated approach to understand the benefits of increase in building insulation cost and subsequent reduction in the initial cost of mechanical and electrical systems. The practice of integrated approach (Jaboyedoff et al., 2014) can bring considerable change in the sustainable development practices in building projects. The above comparative analysis of variation in the initial cost of major building parameters can increase the confidence of stakeholders and help in promoting the concept of energy efficient buildings.

4.2 Can BIM be used as an effective tool to estimate the initial cost of a building and perform comparative analysis?

Estimating cost of building projects is often a complex and challenging task. Use of software helps to ease out the process especially when the quantum of work is exhaustive and the number of iterations is quite large. Energy and thermal simulations can help in achieving improvements in building design (Aksamija, 2015) and sustainability goals (Biswas, et al., 2013). BIM can be looked in the dimension of both technology as well as process (Azhar et al., 2012). Turk (2016) has addressed some of the important questions related to BIM. BIM and energy simulation has gained increasing attention in the building sector (Lewis et al., 2019). Value engineering and cost estimation must begin at the early stage of design process to ensure cost effective project delivery (Forgues et al., 2012). Volk et al. (2014) have reviewed over 180 recent publications on use of BIM for existing buildings. The results revealed limited use of BIM in existing buildings. Early decisions on cost aspects related to building envelopes can improve the cost certainty of building construction projects (Idowu & Lam 2019). Eastman et al. (2011) have also summarized the lessons learned (in the form of case studies) by different stakeholders using BIM across all phases of the project. Gerges et al. (2019) in their investigation analyzed the benefits and limitations of BIM for a construction project. The authors found visualization and coordination to be the two main advantages of BIM.

The effective use of BIM in studying the initial cost variations for major building components is discussed in the present study.

The present study demonstrates how BIM can be integrated in analyzing the cost of energy efficient building. The iterations in the building envelope can be applied to the model developed in BIM. The air conditioning load calculations can then be simulated to calculate the variation in the equipment sizing. Thereafter the electrical equipment sizing can be determined. Thus the number of iterations in the building envelope (civil component) and subsequent variation in the mechanical and electrical components can be demonstrated with better accuracy and speed compared to conventional design process using BIM. The use of BIM can supplement the cost estimation process effectively. The results obtained through BIM can be integrated with excel software to perform the cost calculations and subsequent comparisons.

The overall methodology of comparing the initial cost between conventional and energy efficient building using BIM is indicated in Fig. 5.

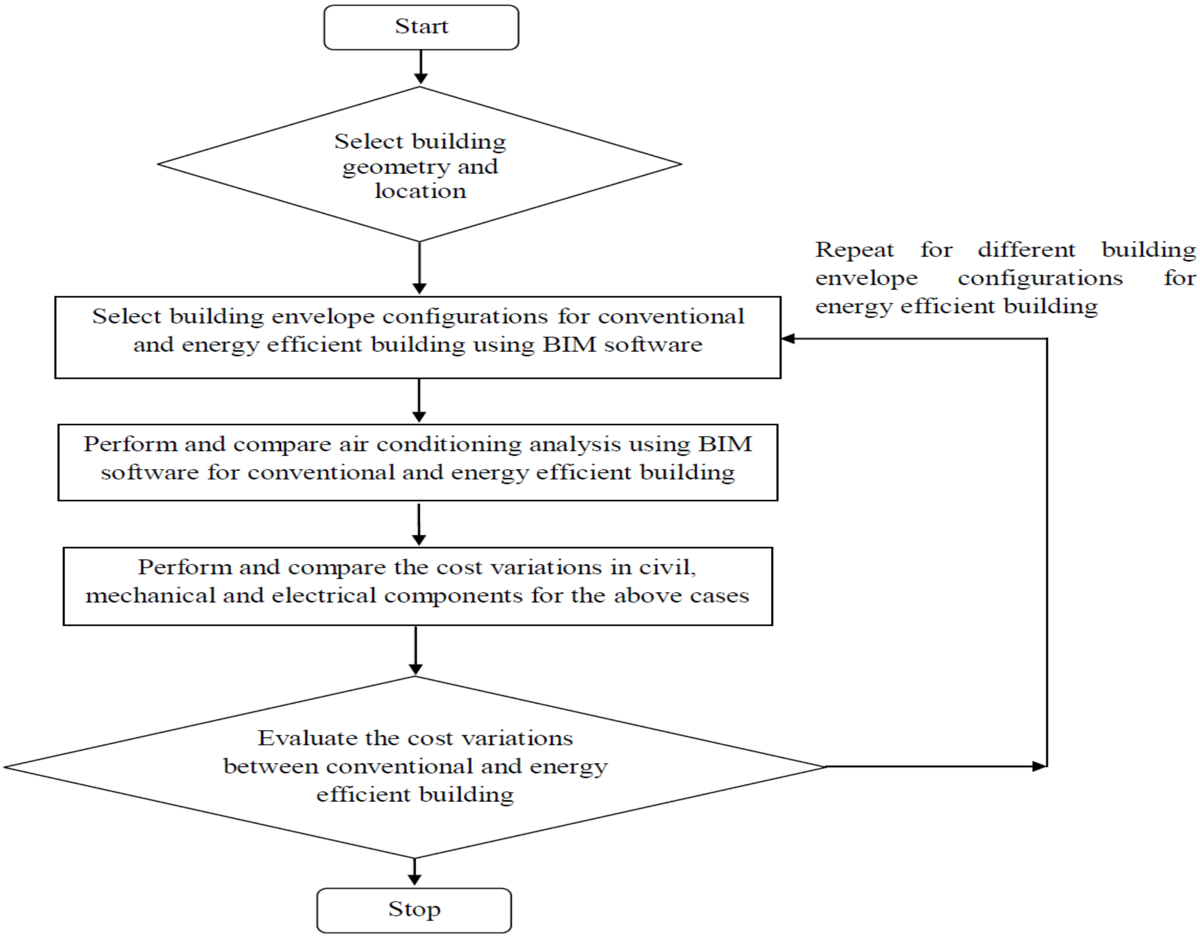

Fig. 5 Flow chart for comparative cost analysis

The application of BIM (Batlle et al., 2017) can be extended from 3D to 10 D comprising of different dimensions such as design, schedule, cost, sustainability, facility management, health and safety, lean construction etc. The cost estimation process (5D) can be reviewed and aligned with scheduling (4D) as well as energy and sustainability (6D) using BIM. The benefit of BIM can be seen in presenting the data to different stakeholders in a simplified form.

5. Conclusions, Limitations and Further Research

It has been observed that lack of good research in terms of case studies is one of the major reasons why energy efficient buildings are not getting promoted. A general perception that energy efficient buildings are costly to construct has been challenged in the present research. In fact, the present study reveals that energy efficient building are less costly compared to conventional building, if an integrated approach is taken into consideration. The comparative analysis of initial cost engineering parameters for conventional and energy efficient building are investigated using BIM as a tool. The use of BIM as a tool is nowadays becoming increasingly popular amongst architects and engineers as it allows the team to work on a centralized model and each one gets the access to the latest file version while working on a particular project. The present study provides insights into the initial cost dimension of a building by considering major parameters such as building insulation cost, air conditioning cost and cost of electrical distribution.

This study has few limitations which can be considered in further research. This study has considered only one building layout and only one climatic condition. The variations in factors such building layouts, building envelope optimization, alternative air conditioning systems and their impact on the initial cost is not addressed in this study. Though the trend of the result remains the same as seen in Table 4, yet it will be an interesting research to see the percentage variations in the initial cost.

The authors have made an attempt to enable the readers understand the role of integrated approach while working on the cost management of building and building services. A further research in this connection will be to integrate initial cost of additional features such as renewable energy, waste water treatment, efficient lighting, advanced sensors, etc. in an energy efficient building and studying its operational benefits. The present study highlights only the variation in the initial cost between conventional and energy efficient building. It will also be interesting to see the cost variations in the overall life cycle cost between energy efficient and conventional building through some real life case studies.

REFERENCES

[1] Abanda, F. H., & Byers, L. (2016). An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling). *Energy*, 97, 517-527.
[2] Abaza, H. (2008). An interactive design advisor for energy efficient buildings. *Journal* of Green Building, 3(1), 112-125.
[3] Aksamija, A. (2015). A strategy for energy performance analysis at the early design stage: predicted vs. Actual building energy performance. *Journal of Green Buildin*g, 10(3), 161-176.
[4] Azhar, S., Khalfan, M., & Maqsood, T. (2012). Building information modelling (BIM): now and beyond. *Construction Economics and Building*, 12(4), 15-28.
[5] Batlle, J., Gallego, S., and Toa, R. (2017). Building for success: Why it's time to adopt building information modeling. Accenture report. https://www.accenture.com.
[6] Becerik-Gerber, B., Jazizadeh, F., Li, N., & Calis, G. (2012). Application areas and data requirements for BIM-enabled facilities management. *Journal of construction engineering and management*, 138(3), 431-442.
[7] Biswas, T., Wang, T. H., & Krishnamurti, R. (2013). From design to pre-certification using building information modeling. *Journal of Green Building*, *8*(1), 151-176.
[8] Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). *International journal of project management*, 31(7), 971-980.
[9] Chen, C., & Tang, L. (2019). BIM-based integrated management workflow design for schedule and cost planning of building fabric maintenance. *Automation in Construction*, 107, 102944.
[10] Chetia, S., Bhanware, P., Cusack, K., Jaboyedoff, P., & Maithel, S. (2015). Energy-Efficient Building Design: A Case-Study of Aranya Bhawan, Jaipur. Implementing Energy Efficiency in Buildings, A compendium of experiences from across the world, International Conference on Energy Efficiency in Buildings (ICEEB), pp. 113 – 122.
[11] Danish, M. S. S., Senjyu, T., Ibrahimi, A. M., Ahmadi, M., & Howlader, A. M. (2019). A managed framework for energy-efficient building. *Journal of Building Engineering*, 21, 120-128.
[12] Dhaka, S., Mathur, J., & Garg, V. (2014). Effect of building envelope on thermal environmental conditions of a naturally ventilated building block in tropical climate. *Building Services Engineering Research and Technology*, *35*(3), 280-295.
[13] Di Giuda, G. M., Villa, V., & Piantanida, P. (2015). BIM and energy efficient retrofitting in school buildings. *Energy Procedia*, 78, 1045-1050.
[14] Eastman, C., Teicholz, P., Sacks, R., and Liston, K. (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors. John Wiley & Sons.
[15] Forgues, D., Iordanova, I., Valdivesio, F., & Staub-French, S. (2012). Rethinking the cost estimating process through 5D BIM: A case study. *In Construction Research Congress 2012: Construction Challenges in a Flat World* (pp. 778-786).
[16] Gerges, M., Mayouf, M., Watson, P. D. J., John, G. A., Ahmed, E. K., & Wenman, B. (2019). BIM Role within the Conceptual Design Phase: A Case Study of a UK Construction Project. *International Journal of Architecture, Engineering and Construction*, 8(1), 54-62.
[17] Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in construction*, 19(8), 988-999.
[18] Guruprakash Sastry (2016). Infosys: Front-runner in energy efficiency- A Case Study. *Energetica India*, Jan – Feb 2016, 4-6.
[19] Hong, T., Chen, Y., Luo, X., Luo, N., & Lee, S. H. (2020). Ten questions on urban building energy modeling. *Building and Environment*, *168*, 106508.
[20] Idowu, O. S., & Lam, K. C. (2019). Web-based application for predesign cost planning of vertical building envelopes. *Automation in Construction*, 106, 102909.
[21] Jaboyedoff P., Cusack K., Maithel S., Ganeshan K., Chetia S., Bhanware P. (2014) Integrated Design Charrettes for Sustainable Development in India's Soaring Building Sector. In: Bolay JC., Hostettler S., Hazboun E. (eds) Technologies for Sustainable Development. Springer, Cham
[22] Jadhav, T.S. (2019). Strategies for reducing cooling load of buildings. *Journal of Construction Management, NICMAR*, 34 (3), 32-36.
[23] Jadhav, T (2019). Building Information Modeling for Heating, Ventilation and Air Conditioning Application. *International Journal of Architecture, Engineering and Construction*, 8(4), 29-35.

[24] Jenkins, D. (2018). Integrating building modelling with future energy systems. *Building Services Engineering Research and Technology*, *39*(2), 135-146.
[25] Jones, B., & Bogus, S. M. (2010). Decision process for energy efficient building retrofits: the owner's perspective. *Journal of Green Building*, 5(3), 131-146.
[26] Killian, M., & Kozek, M. (2016). Ten questions concerning model predictive control for energy efficient buildings. *Building and Environment*, *105*, 403-412.
[27] Kiziltas, S., & Akinci, B. (2010). Lessons learned from utilizing building information modeling for construction management tasks. *In Construction Research Congress 2010: Innovation for Reshaping Construction Practice* (pp. 318-327).
[28] Lewis, A. M., Valdes-Vasquez, R., & Clevenger, C. (2019). Understanding the perceived value of using bim for energy simulation. *Journal of Green Building*, *14*(1), 79-92.
[29] Ozturk, G. B. (2020). Interoperability in building information modeling for AECO/FM industry. *Automation in Construction*, 113, 103122.
[30] Pacheco, R., Ordóñez, J., & Martínez, G. (2012). Energy efficient design of building: A review. *Renewable and Sustainable Energy Reviews*, 16(6), 3559-3573.
[31] Prashad, D., & Chetia, S. (2015). A Paradigm of Self-sufficiency— Indira Paryavaran Bhawan. Implementing Energy Efficiency in Buildings, A compendium of experiences from across the world, International Conference on Energy Efficiency in Buildings (ICEEB), pp. 150 – 157.
[32] Sadeghifam, A. N., Meynagh, M. M., Tabatabaee, S., Mahdiyar, A., Memari, A., & Ismail, S. (2019). Assessment of the building components in the energy efficient design of tropical residential buildings: An application of BIM and statistical Taguchi method. *Energ*y, 188, 116080.
[33] Sadineni, S. B., Madala, S., & Boehm, R. F. (2011). Passive building energy savings: A review of building envelope components. *Renewable and sustainable energy reviews*, 15(8), 3617-3631.
[34] Smith, P. (2014). BIM & the 5D project cost manager. *Selected papers from the 27th IPMA* (International Project Management Association).
[35] Stumpf, A., Kim, H., & Jenicek, E. (2009). Early design energy analysis using bims (building information models). *In Construction Research Congress 2009: Building a Sustainable Future* (pp. 426-436).
[36] Taleb, H. M. (2014). Using passive cooling strategies to improve thermal performance and reduce energy consumption of residential buildings in UAE buildings. *Frontiers of Architectural Research*, 3(2), 154-165.
[37] Turk, Ž. (2016). Ten questions concerning building information modelling. *Building and Environment*, *107*, 274-284.
[38] Volk, R., Stengel, J., & Schultmann, F. (2014). Building Information Modeling (BIM) for existing buildings—Literature review and future needs. *Automation in construction*, 38, 109-127.