Guidelines for the Design of Energy Efficient Retrofitting Strategies using BIM in Multispecialty Hospitals: Case Study Uttar Pradesh India

Dr Indrani Chakraborty[1] Dr Subhrajit Banerjee[2] Syed Mohd Mehndi[1]

1. *Faculty of Architecture and Planning, Integral University, Lucknow, Uttarpradesh, India*
2. *Faculty of Architecture and Planning, AKTU, Lucknow, Uttarpradesh, India*

Absract

Implementation of BIM into practice can be challenging, especially when one lacks any previous experience and necessary knowledge. It is a strategic decision requiring many changes in all levels of project delivery. Against this backcloth, a definition of BIM is provided and key aspects to be considered are listed. Initial findings indicate that the utilization of BIM enables a holistic view of project delivery and helps to integrate project parties into a collaborative process. The initiative to implement BIM must come from the top down to enable early involvement of all key stakeholders. It seems that it is rather resistance from people to adapt to the new way of working and thinking than immaturity of technology that hinders the utilization of BIM. In this paper, we explore how BIM functionalities together with novel management concepts and methods have been utilized in fifteen hospital projects across the world.

Keywords

Building Information Modelling (BIM), Integrated Project Delivery (IPD), building model, information, design and construction

1. Introduction

Delivery of healthcare projects is complex and dynamic process, which requires balancing political, policy, design, and human choice and preferences. Hospitals represent one of the most complex building types combining several functions operating 24/7—emergency rooms, operating rooms, divisions, long and short-stay rooms, laboratories, etc., and, of course, different bedroom typologies. The interaction between the functions as well as a wide network of technological systems strongly contribute to increase this complexity which influences the ageing of the building at different levels: On the one hand, services and equipment's are strictly necessary to keep adequate service level and indoor comfort conditions, but the adopted technologies often update very quickly and require constant maintenance and replacement; on the other hand, the progresses in the medical field impact on the space use and arrangement requiring some transformation and adaptations without which the hosted activities can be totally interrupted.

Retrofitting is mainly aimed at reducing energy consumption and optimising economic benefits by replacing of outdated equipment with efficient ones as one of the most effective solutions. Energy retrofitting is consequently aimed at both reducing energy demand and increasing available resources for health services while maintaining or improving the quality of indoor conditions referred to thermal comfort, pollution level, usability, healthiness. The existing hospital buildings will be demolished, restored, and upgraded to boost energy efficiency, sustainability, and savings.

Despite recent technological advances in new hospital buildings to reduce CO2 pollution and boost building energy quality, the retrofitting of existing building inventory requires proper observation.

Therefore, BIM energy analysis of hospital buildings is essential to estimate the level of energy demand and energy savings potential for economic retrofit steps.

BIM offers a digital picture of the physical and operational properties of the building. BIM is a standard information tool for an organisation that provides a reliable foundation to make decisions during the life cycle. BIM is known as occurring between the original design and the demolition.

Extensive research has been conducted on BIM's future growth and progress. But little work on the effect of BIM on renovations has so far been done. This work was intended to assess the potential for BIM's retrofitting.

Among the several research fields with which hospitals can be associated, there are three specifics issues of great interest that relate to the construction sector making it sustainable or Green:

1. Energy: The huge amount of energy demand (heating, cooling, operating, etc.) and the related Management requires effective monitoring and audit strategies to define use profiles and to drive Adequate retrofitting measures.

2. Environmental, pollution and thermal comfort: It is assumed that the environmental quality and comfort of operating and other key rooms must meet optimal service level.

3. Management: The scheduling and organization of retrofitting actions must ensure the continuity of services with relation to use while considering the building site conditions.

Estimated level energy consumption data in hospital and nursing homes as shown in India (Source Energy Effiency in Hospitals Practise Guide, Published -March 2009, by USAID ECO-III) as shown in Table 1.

Table 1: Estimated Electricity Consumption in Hospitals (including Community Health Centers) and Nursing Homes in India, 2008

Hospital	No. of Beds	Estimated kWh/Bed/ year	Assumed Electricity Cost per kWh	Estimated Electricity Consumption (Million kWh)	Estimated Electricity Cost (Rs. Millions)
Government Hospitals - Urban	328,491*	750 – 1500	Rs. 5	246 - 492	1232 - 2464
Government Hospital - Rural	154,031*	150 - 300	Rs. 4	23 - 46	92 - 184
Private/NGO Hospitals & Nursing Homes	500,000**	1000 – 2000	Rs. 6	500 – 1000	3000 – 6000
Total	**982,522**	**----**	**-----**	**769 - 1538**	**4324 - 8748**

Source: USAID ECO- III Project, 2009

*Central Bureau of Health Intelligence, National Health Profile, 2007

**Estimated for 2008: Based on number of beds as 262,256 in 2002 (11th Plan estimate) and an approx. 12% annual growth rate.

Commercial building sector, which includes offices, hotels, hospitals, retail shops etc. has been growing at a fast pace. As per Central Electricity Authority, the growth of energy consumption in the sector has been highest at over 14% (see Table 2) (Source: USAID ECO- III Project, 2009).

DSCL has estimated that if the growth continues at the present level, additional demand growth for power in the hospital sector would be over 8,500 MW per year. This would mean capacity addition of over 40, 000 MW in the 11th plan just to meet the additional demand of the Present power system is already inadequate to meet the existing demand. There are both peak demand and electricity shortages. Government of India has made a socially desirable plan for making power available to all by 2012. Thus, one of the keyways for managing current shortage and the future need of power is efficiency enhancement and conservation of energy resources. Due to the current situation of the commercial sector, it becomes even more important for this sector to put together greater effort in energy conservation.

Table 2: Energy consumption in various end-use sectors *(Source: USAID ECO- III Project, 2009)*

Category	Electricity Consumption	
	% of total	Increase over last year
Domestic	21.10%	4.63%
Commercial	7.58%	14.61%
Industry	45.13%	7.36%
Public Lighting	1.09%	4.22%
Transport	2.10%	4.72%
Agriculture	19.03%	1.96%
Public Water Works	2.16%	6.65%

1.2 Background

In the current times, the pressure on the healthcare system is increasing due to less availability of hospital/beds per patient. As per the last survey by World Bank there are total 0.7 bed available per 1000 people in India [1].

With the pandemic like COVID-19 the number of patients has increased a lot and hospital need to expand their infrastructure for meeting the current requirements. But the expansion of the hospital is a very complex process and detailed guideline are required for the retrofitting of the hospital infrastructure for reducing the cost and improving the efficiency.

2. Literature Review at a glance

This analysis of fifteen different healthcare projects is based on the information obtained from case study reports, magazines and journal articles. This approach has its advantages and disadvantages, where one of the greatest disadvantages was regarding information availability in each of these sources that differed in matter of quality and quantity. Most of the case studies and articles covered design and construction stages of project delivery, but also included information about other project stages like facilities management.

Table 3 Comparative analysis of fifteen Projects

S.NO	Author	Name of Work	Basic Statement	Relevancy
1.	Hirst, E. (1982). Analysis of hospital energy audits. *Energy Policy*, *10*(3), 225-232.	Analysis of hospital energy audits	Oak Ridge Associated Universities (ORAU) staff conducted energy audits at **48 hospitals** in four states between **1978 and 1980**. **The energy audits show an average potential energy saving of almost 100 kBtu/ ft2 (1.1 GJ/m2), a 20% reduction.** The variation among hospitals is large; the range is from **6% to 49%** of **baseline energy use**. The cost to implement all these conservation practices and measures is quite low, only 25 ¢/ft2 ($2.65/m2), which implies an average payback period of only one year. **Analysis of the audit results shows that the potential energy saving increases with baseline energy use and decreases with fuel price. This suggests that large energy savings will be found at hospitals that are particularly energy-intensive and that have low fuel prices.**	1. It is evidencing that "hospitals are the most energy-intensive building in the commercial sector in which cost to implement all these conservation practices and measures is quite low with short payback period.
2.	Čongradac, V., Prebiračević, B., Jorgovanović, N., & Stanišić, D. (2012). Assessing the energy consumption for heating and cooling in hospitals. Energy and Buildings, 48, 146-154.	Assessing the energy consumption for heating and cooling in hospitals	This work is a part of a larger project initiated under the patronage of Europe's Information Society, within ICT PSP – ICT Policy Support Programme1 to increase energy efficiency in hospitals, using a variety of currently available technologies. A prerequisite for the determination of savings is the accurate calculation of energy consumption and then the application of different methods of intelligent control for the energy savings, which should be combined with a system of expert advices in order to gain the highest efficiency. **This study concentrates on the first part of the problem – the creation of a mathematical tool for the exact calculation of room/building energy demands.**	1. Assuming most of energy demand depends on heating, cooling, and lighting in Hospital.
3.	Fifield, L.-J., Lomas, K. J., Giridharan, R., & Allinson, D. (2018). Hospital wards and modular construction: Summertime overheating and energy efficiency. *Building and environment*, *141*, 28-44.	Hospital wards and modular construction: Summertime overheating and energy efficiency	The UK National Health Service (NHS) is continually under pressure to provide more bed spaces and to do this within a tight budget. Therefore, NHS Trusts may turn to modular buildings, which promise faster construction and low energy demands helping the NHS meet its stringent energy targets. **However, there is growing evidence that thermally lightweight, well insulated and naturally ventilated dwellings are at risk of overheating during warm UK summers.** This paper examines the energy demands and internal temperatures in two 16-bed hospital wards built in 2008 at Bradford Royal Infirmary in northern England using modular fast track methods. The two-storey building used ceiling-mounted radiant panels and a mix of natural and mechanical ventilation with heat recovery to condition patients' rooms. **Monitoring showed that the annual energy demand was**	1. High energy costs mean a reduction of the budget availability for medical and health purposes. 2. Thermally lightweight, well insulated, naturally ventilated hospital wards can be low-energy but are at risk of overheating even in relatively cool UK summer conditions and that this needs to be addressed before such

			289 kWh/m2 ±16%, which is below the NHS guidelines for new hospital buildings. **It was observed that the criterion given in Department of Health Technical Memorandum HTM03-01 can lead to the incorrect diagnosis of overheating risk in existing buildings.** Assessment using other static and adaptive overheating criteria showed that patient rooms and the nurses' station overheated in summer. To maintain patient safety, temporary air conditioning units had to be installed during the warmest weather. **It is concluded that thermally lightweight, well insulated, naturally ventilated hospital wards can be low-energy but are at risk of overheating even in relatively cool UK summer conditions and that this needs to be addressed before such buildings can be recommended for wider adoption.**	buildings can be recommended for wider adoption.
4.	Ascione, F., Bianco, N., De Masi, R. F., & Vanoli, G. P. (2013). Rehabilitation of the building envelope of hospitals: Achievable energy savings and microclimatic control on varying the HVAC systems in Mediterranean climates. Energy and Buildings, 60, 125-138.	Rehabilitation of the building envelope of hospitals: Achievable energy savings and microclimatic control on varying the HVAC systems in Mediterranean climates:	**The study investigates a critical application in the field of energy demand for air-conditioning: the health care facilities.** These buildings are quite energy-intensive, because of necessity of high microclimatic control, need of numerous air changes and, contemporarily, strict set points required for temperature and relative humidity. **The achievable energy savings by improving the thermal–physical characteristics of the building envelope are examined, with reference to a medium-size hospital, located in Mediterranean climate**. The indoor comfort conditions have been analyzed as well as the reduction of energy demands, depending on the HVAC system. **Indeed, the active plants are characterized by quite different energy demands, due to different achievable quality of microclimatic control and indoor air.** The refurbishment of the building envelope, as demonstrated, is always convenient, by considering all possible point of views, and thus energy savings, better indoor microclimate, reduction of polluting emissions, technical and economic feasibility. Finally, even if ventilation loads induce the highest heating and cooling demands, however the envelope refurbishment is an effective retrofit action.	1. Retrofitting actions may be addressed to better insulate the building envelope or to improve/replace HVAC system according to a cost-optimization strategy.
5.	Ascione, F., Bianco, N., De Stasio, C., Mauro, G. M., & Vanoli, G. P. (2016). Multi-stage and multi-objective optimization for energy retrofitting a developed Hospital	Multi-stage and multi-objective optimization for energy retrofitting a developed hospital reference building: A new approach to assess cost-optimality:	The 'Energy Performance of Buildings Directive' Recast (i.e., 2010/31/EU) establishes that **building energy retrofit should pursue "cost-optimal levels". However, a reliable and rigorous cost-optimal analysis is an arduous and computationally expensive issue, especially for complex buildings such as hospitals. The paper tackles this issue by providing a novel methodology to identify robust cost-optimal energy retrofit solutions.** Multi-stage and multi-objective (Pareto) optimization is performed with the aim of minimizing the computational burden required to achieve reliable outcomes. **The methodology combines Energy Plus and**	1. To identify robust cost-optimal energy retrofit solutions combines Energy Plus and MATLAB .

	reference building: A new approach to assess cost-optimality. Applied energy, 174, 37-68.		**MATLAB® and includes two optimization stages,** preceded by a preliminary energy investigation that performs Latin hypercube sampling and sensitivity analysis. The preliminary investigation and the first optimization stage, which **runs a genetic algorithm, aim at detecting efficient energy retrofit measures (ERMs) to reduce thermal energy demand for space heating and cooling. In the second optimization stage, these ERMs are combined with further ERMs, addressed to improve the efficiency of energy systems and to exploit renewable energy sources. Investment cost, primary energy consumption and global cost related to the resulting retrofit packages are investigated by means of smart exhaustive sampling**. **Finally, the cost-optimal solution is identified both in presence of a limitless economic availability and of limited budgets.** The methodology is applied to a hospital reference building (RB), which represents hospitals built in South Italy between 1991 and 2005. The RB is defined by using an original approach, as required by the complexity of the examined building category. **The achieved cost-optimal retrofit packages imply a reduction of primary energy consumption up to 67.9 kW h/m2 a (12.2%) and of global cost up to 2932 k€ (24.5%) with a maximum investment of 1236 k€.**	
6.	Balaras, C. A., Dascalaki, E., & Gaglia, A. (2007). HVAC and indoor thermal conditions in hospital operating rooms. Energy and Buildings, 39(4), 454-470.	HVAC and indoor thermal conditions in hospital operating rooms :	Hospital operating rooms (ORs) require efficient HVAC installations to secure the highly demanding indoor environmental conditions for patients and medical personnel. This paper reviews published standards and guidelines on design, installation, commissioning, operation, and maintenance of HVAC installations in hospital ORs, indoor thermal conditions, and summarizes measured data from short monitoring of indoor thermal conditions along with audit results and main characteristics of 20 ORs in 10 major Hellenic hospitals. Measured indoor temperature ranged from 14 to 29 °C, and relative humidity from 13 to 80%. The number of air changes per hour ranged from 3.2 to 58 ACH. The commonly encountered problems include insufficient indoor air exchange, poor control on indoor thermal conditions, bad space ergonomics that influence the ventilation system operation, poor technical installations maintenance and understaffed technical departments. However, there are still opportunities for energy conservation, without sacrificing comfort, and overall quality of patient care or services.	1. Regarding indoor thermal condition in operating rooms and related use of HVAC system.

7.	Dascalaki, E. G., Gaglia, A. G., Balaras, C. A., & Lagoudi, A. (2009). Indoor environmental quality in Hellenic hospital operating rooms. Energy and Buildings, 41(5), 551-560.	Indoor environmental quality in Hellenic hospital operating rooms:	**Indoor environmental quality (IEQ)** in hospital operating rooms (ORs) constitutes a major challenge for the proper design and operation of an energy efficient hospital. **A subjective assessment of the indoor environment along with a short monitoring campaign was performed during the audits of 18 ORs at nine major Hellenic hospitals.** A total of 557 medical personnel participated in an occupational survey, providing data for a subjective assessment of IEQ in the audited ORs. The OR personnel reported work related health symptoms and an **assessment of indoor conditions (thermal, visual, and acoustical comfort, and air quality).** Overall, personnel reported an average of 2.24 work-related symptoms each, and 67.2% of respondents reported at least one. Women suffer more health symptoms than men. **Special dispositions, such as smoking and allergies, increase the number of reported symptoms for male and female personnel. Personnel that perceive satisfactory indoor comfort conditions (temperature, humidity, ventilation, light, and noise) average 1.18 symptoms per person, while for satisfactory indoor air quality the average complaints are 0.99. The perception of satisfactory IEQ (satisfactory comfort conditions and air quality) reduces the average number of health complaints to 0.64 symptoms per person and improves working conditions, even in a demanding OR environment.**	1. The perception of satisfactory indoor environmental quality (IEQ) i.e. (satisfactory comfort conditions and air quality) reduces the average number of health complaints and improves working conditions, even in a challenging operating room (OR).
8.	Hwang, R.-L., Lin, T.-P., Cheng, M.-J., & Chien, J.-H. (2007). Patient thermal comfort requirement for hospital environments in Taiwan. Building and environment, 42(8), 2980-2987.	Patient thermal comfort requirement for hospital environments in Taiwan	This study examines the comfort criteria of ASHRAE Standard 55-2004 for their applicability in hospital environments. Through an extensive field survey conducted in a university hospital in Taiwan, 927 sets of data have been collected. Above half of the measured samples failed to meet the specifications of Standard 55 comfort zone due to improper humidity control. Acceptability votes by patients exceeded the Standard's 80% criterion, regardless of whether the physical conditions were in or out of the comfort zone. Thermal neutrality, preference and comfort range are compared with other studies conducted in office environments and Standard 55 criteria. **Results of chi-square tests revealed that patients' physical strength significantly affected their thermal requirements. The net effect of health yields a marked difference in thermal neutrality and preference, and in the comfortable temperature range.**	1. Results of chi-square tests revealed that patients' physical strength significantly affected their thermal requirements.

9.	Lomas, K. J., & Giridharan, R. (2012). Thermal comfort standards measured internal temperatures and thermal resilience to climate change of free-running buildings: A case-study of hospital wards. Building and environment, 55, 57-72.	Thermal comfort standards, measured internal temperatures and thermal resilience to climate change of free-running buildings: A case-study of hospital wards:	In view of the warming climate, there is increasing concern about the likelihood of overheating inside UK buildings that are not mechanically cooled. Several studies are examining this matter, of which the DeDeRHECC project is one. The recent availability of the UKCP09 future climate data projections has acted as a stimulus to such work. This paper illustrates how field measurement, thermal modelling and the generation of current and future typical and extreme weather years, can be used to provide a picture of the resilience of buildings to climate change. The unified framework for assessing both measurements and current and future predictions that is offered by the BSEN15251 thermal comfort standard is a crucial component. **The paper focuses on internal temperatures during the day and at night in wards within the tower building at Addenbrooke's hospital, which has a hybrid ventilation strategy. The maintenance of thermal comfort in such spaces is critically important and installing air-conditioning in response to climate change is expensive and potentially energy intensive. Fans appear to be a simple retrofit measure that may substantially improve the wards' resilience to climate change even in extreme years.** Whilst healthcare provides the back cloth, the methodology developed has a much wider utility for assessing thermal comfort in buildings in the current and future climate of the UK.	**1. The paper focuses on internal temperatures during the day and at night in wards within the tower building at Addenbrooke's hospital, which has a hybrid ventilation strategy. The maintenance of thermal comfort in such spaces is critically important and installing air-conditioning in response to climate change is expensive and potentially energy intensive. Fans appear to be a simple retrofit measure that may substantially improve the wards' resilience to climate change even in extreme years.**
10.	Lan, L., Tushar, W., Otto, K., Yuen, C., & Wood, K. L. (2017). Thermal comfort improvement of naturally ventilated patient wards in Singapore. Energy and Buildings, 154, 499-512.	Thermal comfort improvement of naturally ventilated patient wards in Singapore:	Located near the equator, Singapore has a tropical rainforest climate with high temperature and high humidity. In hospitals of Singapore, the subsidized patient wards are designed to be naturally ventilated, considering the affordability for patients. However, due to the high occupant density of the patient wards and the hot humid climate, occupants may feel discomfort, especially in the older hospital wards which were not well designed for natural ventilation. **In this paper, the thermal comfort level of occupants at Singapore's Changi General Hospital (CGH) is evaluated based on both in-situ measurements and modeling analysis. Against this backdrop, several low energy solution concepts that potentially improve the thermal comfort level of occupants in patient wards are analyzed and simulated using detailed building thermodynamic and airflow simulation. We found that this approach of combining thermodynamics, computational fluid dynamics, and thermal comfort level models was effective for analyzing and comparing the thermal comfort impact of alternative, low-energy building retrofit concepts.** We also found that passive solutions to ventilation could be used effectively for a patient hospital ward, even in the tropical warm climate of Singapore.	1. Natural Ventilation could be used effectively for a patient hospital ward, even in the tropical warm climate of Singapore. 2. To improve thermal comfort, several passive building solutions were modeled and analyzed including a change of the window type, thermal chimneys, night air purge, and wing walls. The louvered window alone offers a 32% improvement of thermal comfort.

11.	Shaikh, P., Shaikh, F., Sahito, A., Uqaili, M., & Umrani, Z. (2017). An Overview of the Challenges for Cost-Effective and Energy-Efficient Retrofits of the Existing Building Stock. In Cost-Effective Energy Efficient Building Retrofitting (pp. 257-278): Elsevier.	An Overview of the Challenges for Cost-Effective and Energy-Efficient Retrofits of the Existing Building Stock	The building sector consumes approximately one-third of global primary energy. The energy and environmental performance of buildings for all their energy uses must be revisited. **Building energy retrofitting provides substantial opportunities to reduce the level of building energy consumption, saves cost, improves comfort level, and mitigates greenhouse gas emissions**. **Building retrofitting is a form of technical intrusion in the energy system of a building to effectively utilize its energy. The aim of the chapter is to identify the optimal cost-effective energy-retrofitting strategy.** **A holistic retrofitting scenario has been considered that includes reduced energy consumption, cost savings, capital investments, emissions, technology behavioural change, and comfort indexing, along with sustainability concerns involving geometry and envelope construction.** However, this study primarily focused on energy systems within the building envelope. In addition, various uncertainty parameters and risk factors have been considered. Multifaceted optimal retrofitting strategies based on the optimized decisions are prioritized to address these challenges. Additionally, some challenges for simulation toolkits have been discussed for the success of the building energy retrofit project. **This work helps building practitioners and researchers with in-depth understanding challenges for cost-effective optimal retrofitting within buildings to attain energy conservation and sustainability**	1. This work helps building practitioners and researchers with in-depth understanding challenges for cost-effective optimal retrofitting within buildings to attain energy conservation and sustainability.
12	Gaspari, J., Fabbri, K., & Gabrielli, L. (2019). A study on parametric design application to hospital retrofitting for improving energy savings and comfort conditions. Buildings, 9(10), 220.	A Study on Parametric Design Application to Hospital Retrofitting for Improving Energy Savings and Comfort Conditions	The scientific literature offers a wide range of studies evidencing the progress done in the retrofit actions dealing with the current building stock; however, renovations of hospitals are still an open field of research due to their typical complexity that is usually associated with a very challenging updating processes to maintain or increase operational level. **The paper provides a synthesis of a study developed by a team of the Department of Architecture for Saint Orsola Hospital in Bologna with the scope to explore innovative retrofitting strategies.** The brief provided by the management unit of the hospital was connected to the general renovation plan involving the entire site and particularly some existing buildings taking into account some limitations concerning budget availabilities and everyday activities needed to ensure acceptable service level for the end users. **The design approach starts from defining a basic unit (a typical hospital room) that is deeply analyzed to report the starting conditions (indoor environmental parameters) and then used to simulate the potential impacts of retrofitting actions on its performances. The results allowed to parametrically develop a step by step strategy scaled on each building sector and**	1. The paper provides with the scope to explore innovative retrofitting strategies. 2. To evaluate the global impact on energy performances of building while considering time and costs of each retrofitting options.

			on the building to evaluate the global impact on energy performances while considering time and costs of each retrofitting options.	
13.	Mohammadpour, A., Anumba, C., & Messner, J. (2012). Energy Efficiency in Healthcare Facility Retrofits–Key Issues. Paper presented at the 7th International Conference on Innovation in Architecture, Engineering and Construction (AEC), São Paulo, Brazil.	Energy Efficiency in Healthcare Facility Retrofits–Key Issues	**Healthcare facilities consume significant amounts of energy as compared to average commercial buildings. This large rate of energy consumption can be improved by instituting energy conservation measures (ECMs) in healthcare facility retrofit projects.** From a sustainability perspective, and under the current economic conditions, **it is logical to consider energy efficiency-driven retrofit strategies for healthcare facilities instead of replacing aging healthcare facilities.** To retrofit a healthcare facility, a project team needs to develop a clear understanding of energy conservation measures and the cost and benefits of instituting each measure. **This paper explores the critical issues in achieving energy efficiency in healthcare facility retrofits.** It identifies key considerations and reviews the various methods that are currently being adopted for saving energy in existing healthcare facilities. Preliminary results from two hospital case studies are also presented as a means of illustrating the key issues. An approach for developing a taxonomy of requirements for energy efficient healthcare facility retrofits is also outlined and the potential benefits to the healthcare sector discussed.	1. This paper explores the critical issues in achieving energy efficiency in healthcare facility retrofits. 2. To integrated framework for energy efficiency and safe healthcare retrofits.
14.	Mehndi, S. M., & Chakraborty, I. (2020). Simulation for a Cost- Effective and Energy Efficient Retrofits of the Existing Building Stock in India using BIM. Paper presented at the 2020 International Conference on Contemporary Computing and Applications (IC3A).	Simulation for a Cost-Effective and Energy Efficient Retrofits of the Existing Building Stock in India using BIM	Energy-efficient retrofitting of buildings is a crucial aspect of achieving a specific outcome to both reduce global energy requirements and reduce carbon emissions. The Energy Analysis of buildings using BIM (Building Information Modeling) which reduces energy consumption and optimise the economic benefits. This method is vital in assessing energy demand levels and the power-saving potential for cost-effective retrofitting measures. Energy Simulation is a computer-aided analysis that helps construction professionals to evaluate and increase energy efficiency through required modifications at the project planning phase. A detailed system boundary, including energy consumption reduction, cost savings, capital investment, technical change in emission behaviour, and comfort indexing together with sustainability problems, was defined. The article introduces a new BIM-based systematic approach to energy retrofitting, which comprises a whole spectrum of information acquisition, energy modelling, and software interoperability. This framework consists of identifying indicators; building envelops study, validation of research gap, identification, and energy simulation will help rehabilitation in a simple, reliable decision-making process.	1. Energy-efficient retrofitting of buildings using BIM (Building Information Modeling) in India by case study of actual residential building (G+9) plan of Vakola, Santa Cruz, Mumbai, Maharashtra which involves the use of Building Models produced in Revit for analyzing in Revit and exporting to GBS for further study.

15.	Lu, K., Jiang, X., Tam, V. W., Li, M., Wang, H., Xia, B., & Chen, Q. (2019). Development of a carbon emissions analysis framework using building information modeling and life cycle assessment for the construction of hospital projects. Sustainability, 11(22), 6274.	Development of a carbon emissions analysis framework using building information modeling and life cycle assessment for the construction of hospital projects	Buildings produce a large amount of carbon emissions in their life cycle, which intensifies greenhouse-gas effects and has become a great threat to the survival of humans and other species. Although many previous studies shed light on the calculation of carbon emissions, a systematic analysis framework is still missing. **Therefore, this study proposes an analysis framework of carbon emissions based on building information modeling (BIM) and life cycle assessment (LCA), which consists of four steps:** (1) defining the boundary of carbon emissions in a life cycle. (2) establishing a carbon emission coefficients database for Chinese buildings and adopting Revit, GTJ2018, and Green Building Studio for inventory analysis. (3) calculating carbon emissions at each stage of the life cycle; and (4) explaining the calculation results of carbon emissions. The framework developed is validated using a case study of a hospital project, which is located in areas in Anhui, China with a hot summer and a cold winter. **The results show that the reinforced concrete engineering contributes to the largest proportion of carbon emissions (around 49.64%) in the construction stage, and the HVAC (heating, ventilation, and air conditioning) generates the largest proportion (around 53.63%) in the operational stage.** This study provides a practical reference for similar buildings in analogous areas and for additional insights on reducing carbon emissions in the future.	1. This study proposes an analysis framework of carbon emissions based on building information modeling (BIM) and life cycle assessment (LCA). 2. The results show that the reinforced concrete engineering contributes to the largest proportion of carbon emissions in the construction stage, and the HVAC generates the largest proportion in the operational stage.

3. Conclusion

BIM as a collaboration platform has a profound impact on how healthcare projects are managed and delivered as shown by the findings of this paper. BIM enables early contribution of all the key stakeholders to support evidence-based decision making for planning, designing, constructing and managing facilities. In this paper it is explored how BIM functionalities together with novel management concepts and methods have been utilized in fifteen hospital projects all over the world. The research intends to develop a comprehensive framework and guidelines to retrofit the existing multi-speciality hospitals as per IGBC Guidelines for Optimisation of Carbon footprint output of the building.

References

[1] https://data.worldbank.org/indicator/SH.MED.BEDS.ZS

[2] Hirst, E. (1982). Analysis of hospital energy audits. Energy Policy, 10(3), 225-232 .

[3] Čongradac, V., Prebiračević, B., Jorgovanović, N., & Stanišić, D. (2012). Assessing the energy consumption for heating and cooling in hospitals. Energy and Buildings, 48, 146-154.

[4] Fifield, L.-J., Lomas, K. J., Giridharan, R., & Allinson, D. (2018). Hospital wards and modular construction: Summertime overheating and energy efficiency. Building and environment, 141, 28-44.

[5] Ascione, F., Bianco, N., De Masi, R. F., & Vanoli, G. P. (2013). Rehabilitation of the building envelope of hospitals: Achievable energy savings and microclimatic control on varying the HVAC systems in Mediterranean climates. Energy and Buildings, 60, 125-138.

[6] Ascione, F., Bianco, N., De Stasio, C., Mauro, G. M., & Vanoli, G. P. (2016). Multi-stage and multi-objective optimization for energy retrofitting a developed Hospital reference building: A new approach to assess cost-optimality. Applied energy, 174, 37-68.

[7] Balaras, C. A., Dascalaki, E., & Gaglia, A. (2007). HVAC and indoor thermal conditions in hospital operating rooms. Energy and Buildings, 39(4), 454-470.

[8] Dascalaki, E. G., Gaglia, A. G., Balaras, C. A., & Lagoudi, A. (2009). Indoor environmental quality in Hellenic hospital operating rooms. Energy and Buildings, 41(5), 551-560.

[9] Hwang, R.-L., Lin, T.-P., Cheng, M.-J., & Chien, J.-H. (2007). Patient thermal comfort requirement for hospital environments in Taiwan. Building and environment, 42(8), 2980-2987.

[10]Lomas, K. J., & Giridharan, R. (2012). Thermal comfort standards measured internal temperatures and thermal resilience to climate change of free-running buildings: A case-study of hospital wards. Building and environment, 55, 57-72.

[11] Lan, L., Tushar, W., Otto, K., Yuen, C., & Wood, K. L. (2017). Thermal comfort improvement of naturally ventilated patient wards in Singapore. Energy and Buildings, 154, 499-512.

[12] Shaikh, P., Shaikh, F., Sahito, A., Uqaili, M., & Umrani, Z. (2017). An Overview of the Challenges for Cost-Effective and Energy-Efficient Retrofits of the Existing Building Stock. In Cost-Effective Energy Efficient Building Retrofitting (pp. 257-278): Elsevier.

[13] Gaspari, J., Fabbri, K., & Gabrielli, L. (2019). A study on parametric design application to hospital retrofitting for improving energy savings and comfort conditions. Buildings, 9(10), 220.

[14] Mohammadpour, A., Anumba, C., & Messner, J. (2012). Energy Efficiency in Healthcare Facility Retrofits–Key Issues. Paper presented at the 7th International Conference on Innovation in Architecture, Engineering and Construction (AEC), São Paulo, Brazil .

[15]Mehndi, S. M., & Chakraborty, I. (2020). Simulation for a Cost- Effective and Energy Efficient Retrofits of the Existing Building Stock in India using BIM. Paper presented at the 2020 International Conference on Contemporary Computing and Applications (IC3A).

[16]Lu, K., Jiang, X., Tam, V. W., Li, M., Wang, H., Xia, B., & Chen, Q. (2019). Development of a carbon emissions analysis framework using building information modeling and life cycle assessment for the construction of hospital projects. Sustainability, 11(22), 6274.