frontiers | Frontiers in Built Environment

TYPE Original Research
PUBLISHED 01 September 2023
DOI 10.3389/fbuil.2023.1194636

OPEN ACCESS

EDITED BY
Cristina Piselli,
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Federal University of Rio de Janeiro, Brazil

*CORRESPONDENCE
Ashik Iqbal,
md.ashikiqbal11023@gmail.com

RECEIVED 28 March 2023
ACCEPTED 03 August 2023
PUBLISHED 01 September 2023

CITATION
Iqbal A, Jahan I, Wasiew QA, Emu IA and Chowdhury D (2023), From existing conventional building towards LEED certified green building: case study in Bangladesh.
Front. Built Environ. 9:1194636.
doi: 10.3389/fbuil.2023.1194636

From existing conventional building towards LEED certified green building: case study in Bangladesh

Ashik Iqbal [1]*, Ismat Jahan [2], Qudrati Al Wasiew [2], Imtiaz Ahmed Emu [3] and Dipta Chowdhury [2]

[1]Institute of Water and Flood Management, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh, [2]Department of Building Engineering and Construction Management, Khulna University of Engineering and Technology, Khulna, Bangladesh, [3]Local Government Engineering Department, Dhaka, Bangladesh

Green Building refers to the planning, design, construction, and operation of buildings considering indoor environment quality, occupant health, using energy, water, and other resources more efficiently; and reducing waste, pollution, and the overall environmental impact. Among the Green Building guidelines, Leadership in Energy and Environmental Design (LEED) offers a certification and rating system by which buildings are certified in different categories. The LEED rating system is used to rate an existing building how much it is fulfilling the criteria of Green Building (GB) or not. This research explored how an existing conventional building can be retrofitted to satisfy green building standards. An academic building of KUET has been selected for the study. A field survey and Participatory Rural Appraisal (PRA) tools (i.e., Focus Group Discussion (FGD), Key Informant Interview (KII)) were used for the data collection and then the data was analyzed by comparative analysis concerning the LEED 2009 rating system for assessing the building. The New Academic building receives 31 points out of 110 and so cannot earn any certification level. The lacking for which the points were not gained is identified and the installation of water and energy efficiency features, rooftop gardening is suggested as retrofitting options to earn the green building certification level.

KEYWORDS

green building, existing building, green rating, leadership in energy and environmental design (LEED), KUET

1 Introduction

Due to population growth and rapid urban development, an enormous number of buildings are being constructed worldwide for residential, official, and industrial purposes. Industrialization and urbanization have directly been impacting water, soil, air, materials, and natural resources, thus polluting our environment and changing the climate (Hochella et al., 2019; Rafi et al., 2021). The construction of buildings and their utilization and users are playing a massive role in universal energy consumption and impacting the environmental balance. Buildings are what mostly consume the world's natural resources (Abidin and Powmya, 2014). Urban buildings are liable for 40% of total CO_2 emissions and 30% of solid waste output and raw material consumption, consuming virtually 70% of the electricity used and 12% of potable water (Bernstein and Andrew, 2008; Bond and Perrete, 2012).

Additionally, material exploitation and transportation produce 18% of harmful emissions (Bernstein and Andrew, 2008). The construction of buildings is responsible for 40% of the raw stone, gravel, and sand consumed worldwide annually, as well as 25% of the raw timber (YU, 2008). Furthermore, non-standard indoor environments may cause severe disease to the occupants of these buildings, hence scaling down the level of comfort (Park and Yoon, 2011; Aktas and Ozorhon, 2015). The planning and design of conventional buildings in Bangladesh do not consider these impacts on resources and the environment.

The perception of sustainable development spread widely during the 1960s and 1970s energy and environmental pollution crisis (Mao et al., 2009). Green building is a particular type of building in which the planning, designing, construction, operation, and maintenance are performed in such a way that they offer an opportunity to consume renewable or fewer resources and have accountability for limiting the deplorable impacts on the environment (Boeing et al., 2014a; Kriss, 2014; Allab et al., 2017; Legrand, 2019). Green building creates the path of a sustainable environment even with homebuilding, which requires a confined operation with the architects, the engineers, and the clients at every stage of the project (Edwards, 2006; Ji and Plainiotis, 2006; Manoliadis et al., 2006; Iqbal and Swapnil, 2017). Because of the remarkable effect on the resource and environmental sector, green buildings are gaining popularity nowadays.

The rating system provides a systematic way for the assessment of the green building, and its focus is to provide a valuation of the sustainable characteristics of a building (Ali and Al Nsairat, 2009; Fernandez-Solis et al., 2011). There are several green building assessments and rating systems for identifying a building's service level (Rastogi et al., 2017). These guidelines are followed to assess whether a building is a green building or not by comparing each specification and guideline. Points are given to any intervention based on the criteria mentioned in those green building rating guidelines.

Bangladesh is one of the most climate-vulnerable developing countries, and because of urbanization and industrilization, a vast amount of building construction projects has been undertaken in the last two decades (Ahmed et al., 2018; Iqbal et al., 2023). In recent years, the degradation of the outdoor environment and increase in the Air Quality Index (AQI) in the cities of Bangladesh have also indicated the awful impact on the environment because of the massive development (Islam et al., 2020; Hossain et al., 2021; Iqbal et al., 2022). Also because of the country's climate vulnerability, its environment is facing huge negative impacts that will bear eventual consequences on the people of the area. An inclusive environmental consideration of the design, construction, and operation of buildings, the consumption of resources, and the impact on the environment and users' health must be considered for a sustainable environment and society. However, in a developing country such as Bangladesh, it is impossible to demolish the previous interventions to construct sustainable structures. In this prospect, the existing structures can be retrofitted to become sustainable ones (Sun et al., 2018). If the building can be analyzed with the green rating criteria and the gaps are identified, the authority can identify the possibilities to adopt the retrofitting to make them sustainable.

Among the selected academic journals from 2004 to 2016, no study was found on green buildings among conventional buildings in Bangladesh (Li et al., 2013). Jamal et al. (2018) assessed the green rating of an industrial building in Dhamrai, Dhaka, but there is no critical insight into the criteria. No study has been conducted on an existing academic building in Bangladesh. An academic building has been selected for this study as this type of builidng is more conducive to the implementation of the research objectives than random buildings and because of the availability of information and the number and frequency of the diverse users (Hopkins, 2016; Schwartz and Krarti, 2022). Aktas and Ozorhon (2015) assessed the green building certification process in academic buildings for developing countries but did not provide any recommendations or guidelines to make the way forward for the improvement of their the green building certification levels.

This research explored how conventional buildings can be retrofitted to satisfy green building standards. The specific objective was to assess the green rating point of the New Academic Building of the Khulna University of Engineering and Technology (KUET) based on the LEED 2009 for the existing building's operations and maintenance rating criteria. Moreover, as the criteria for which the building can earn green building points cannot be identified, the obstacles and prospects of retrofitting this existing building to meet green building standards have been identified, and the ways to attain a green building certification level have been suggested (Umar, 2020). The study has identified potential options for improving building performance in terms of energy efficiency, resource conservation, and occupant health and comfort, as well as challenges and opportunities for retrofitting conventional buildings to meet green building standards. This research has the potential to guide future sustainable building design and construction policies in developing nations for adopting such practices toward sustainable cities.

2 Materials and methods

The methodology consisted of an extensive literature review, field survey, data collection, questioner survey, focus group discussion (FGD), and key informant interview (KII), and then the data were was analyzed for a green building rating, and finallythe suggestions were made for improvement. A socio-technical approach was followed for the green rating. The social consultation was conducted with the relevant stakeholders to attain information, after which they were analyzed following the framework of Fernandez-Solis et al. (2011) based on the LEED 2009 guideline to find out the rating. The methodological framework is shown in Figure 1.

2.1 Green building rating system selection

Green building has benefits in terms of economic, environmental, and social health as it is energy and water efficient, long lasting, and non-toxic, and it uses durable materials, enhances user satisfaction and sustainability, and reduces operation and maintenance costs (Flower and Rauch, 2006; Ali and Al Nsairat, 2009; Gou et al., 2013). Green building is one of the steps being taken to mitigate the negative impacts of buildings on the environment, economy, and society and to minimize the threatening risks to human health, hygiene, and the

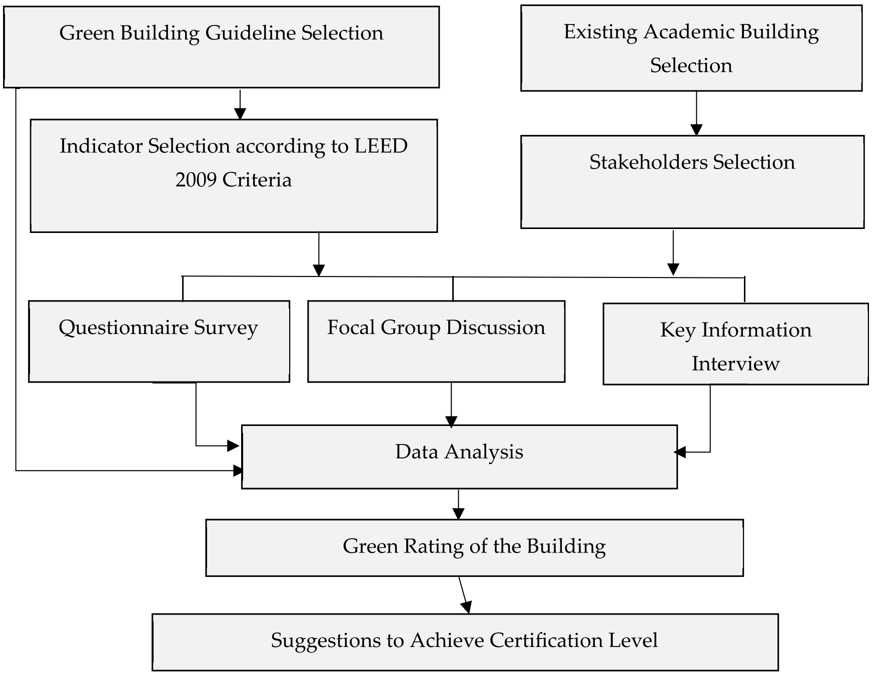

FIGURE 1
Methodological framework.

environment by optimizing competencies in resources management and operation accomplishment (Sev, 2009; Boeing et al., 2014b; Zuo and Zhao, 2014). Fowler and Rauch (2006) identified Green building evaluation tools to measure the satisfaction level of these criteria, which include the assessment of life cycle, costing, energy system, performance evaluation, productivity analysis, indoor environment quality assessment, optimization of operation, and maintenance. There are several green building assessments and rating systems practiced in different regions (Kimberly et al., 2006; Windapo, 2014). Potbhare et al. (2009) reviewed 23 developed countries that have established their own green building guidelines and argued that developing countries face challenges in implementing the practices of green building by adopting the guidelines. Shan and Hwang (2018) reviewed 15 prevailing Green Building Rating Systems and showed that only the Leadership in Energy and Environmental Design (LEED), CEPAS, and GS rating systems provide a detailed rating of different aspects of project design, construction, decoration, and operation. Li et al. (2017) found that the LEED rating system is being practiced in 41 countries worldwide and is very much compatible with developing countries such as Bangladesh. USGBC (2019) provided LEED v4 for Building Design and Construction for the construction of new buildings. Meanwhile, the LEED Campus Guidance (2014) introduced by USGBC incorporates LEED 2009 for existing building operations and maintenance guidance (2014), and this guideline is preferable for the assessment of the campus and specific buildings as well (USGBC, 2014a). The rating system is used as a reference framework for the Green Building assessment. The rating is performed based on credits and points; through each credit, the rating system evaluates the performance of the building's services and awards points if the requirements in the categories are satisfied (Fernandez-Solis et al., 2011). Points awarded in each category are summed up, and the total points earned by the building refer to the level of certification in terms of green building. The LEED 2009 system for existing buildings' operations and maintenance guidance was used as the benchmark for the rating guideline of the building under study.

TABLE 1 Points required for the certification level.

Certification level	Points required
Certified	40–49
Silver	50–59
Gold	60–79
Platinum	80–110

The points required to achieve the associated four certification levels are shown in Table 1.

2.2 Criteria and indicator selection for green rating

Based on the LEED 2009 for existing buildings operations and maintenance guidance, the seven criteria were selected: i) Sustainable Sites (SS) and Location and Transport, ii. Water Efficiency (WE), iii) Energy and Atmosphere (EA), iv) Materials and Resources (MR), v) Indoor Environmental quality (IEQ), vi) Innovation in Design, vii. Regional Priority. To earn different credits for each criterion (detailed in Tables 2–7), there were some prerequisites and indicators mentioned in the guideline (USGBC, 2014b). The prerequisite and indicators for every credit of each criterion were identified. Some of these indicators are installed physical features, some are planning and design considerations, some are building use and utilization, and some are maintenance and management. Considering these indicators, the checklists were prepared for the field survey and focal group discussion (FGD), and questionnaires were prepared for the questionnaire survey and key informant interview (KII).

2.3 Stakeholder selection

The Participatory Rural Appraisal (PRA) survey was employed to consider the perspectives of all parties involved in the building's planning, construction, uses, maintenance, and management. Students, instructors, faculty, planners, engineers, contractors, facility managers, administrative officers, maintenance staff, environmental health and safety officers, guards, and cleaners were selected by the random sampling method as the stakeholders for the study, as suggested by Darko et al. (2017a).

Planners, engineers, and contractors were focal points for the planning, design, drawing, and construction information. Facility managers reported building systems, energy consumption, and upkeep. Environmental health and safety officers dealt with indoor air quality and environmental issues. The users detailed their experiences and recommended improvements (Thatcher and Milner, 2016). Faculty and instructors discussed functionality, resource use, and usability. Maintenance staff described systems, maintenance, waste management, energy, and water use. Administrative staff advised on operations, scheduling, and management.

2.4 Data collection and analysis

The field survey and Participatory Rural Appraisal (PRA) tools were mainly used for the data collection. The reconnaissance survey was conducted to identify the location of the physical features and to find out the availability of the stakeholders for data collection. A total of 7 days of fieldwork was done, where the first 2 days were dedicated to exploring the building and the FGD, and the KIIs and questionnaire survey were conducted in the next 5 days. The field survey was conducted to find out the building's features, hardscape, interior, and exterior. It was investigated whether the prerequisite and necessary physical features for different indicators were installed or not. If the indicator was satisfied, building received points for that credit of the criteria, and if the indicator was not satisfied, it earned none.

Five KIIs were conducted, with one planner and one engineer from the Engineering and Planning division of KUET and with the three contractors who were responsible for the different construction phases of the building to find out the planning and design consideration, procurement, and material information for the New Academic Building. The KIIs apprised the information on the indicators, and thus, points were assigned according to their satisfaction with the guideline.

A total of five FGDs and 50 questionnaire surveys were conducted with the students, teachers, guards, cleaners, and workers of the building to find out the present condition of the building. The questionnaire and checklist to find out the water and energy consumption, users' habits, building comfort, indoor air and environmental quality, lighting, air and light ventilation, and other utilities from day-to-day uses were shared out. In the occupant survey, the students and teachers were the main target group in the questionnaire survey. The guards and cleaners involved in the maintenance and management of the building were questioned about the present operational and maintenance system of the building. The data and information on the pre-requisites and indicators for the credits of each category collected from the field survey, FGDs, and KIIs were analyzed by comparative analysis with the LEED 2009 for existing buildings operations and maintenance guidance following the framework presented by Fernandez-Solis et al. (2011). The fulfillment or lackings of the indicators were assessed, and according to this information, the points were assigned. In a few credits, points were assigned for having or not having the features or practices, and in a few credits, a range of points was assigned according to the level of service or satisfaction of the users from the survey data. The points gained for every credit were summed for each criterion, and thus, the total points earned by the building were assessed, as shown in Table 1, to finally determine whether the building could earn a green certification level or not.

From the rating, the gap and deficiency for each of the criteria of the building were found. Among those features and options, the possibilities for retrofitting were identified and the feasibility of these contributing toward the improvement of the building to the green building certification level.

3 Results

Based on the analyzed data compared with the guidelines of LEED 2009, the rating of the building was conducted and points for the credits of each criterion were assigned. The final points along with the presence or absence of features for the credits are described here in detail.

3.1 Sustainable sites (SS) and location and transport

The building is on the KUET campus of Khulna district located at 22°53′57.5" N 89°30′03.8" E (Figure 2). The building is 150–300 m in distance from the student hall and faculty dormitory, and so most of the users of the building can attend by walking. Small necessary products are available from the departmental store, which is just 100 m away. The Fulbarigate market is about 750–800 m away, and Khulna city center is about 12 km away, where all the national bus, train, and launch stations are. The parking facility for cars and motorcycles is at a 200 m distance. Public transport goes in front of the building, as does the varsity bus, making the transportation system very much satisfactory. In the alternative commuting transportation analysis for the study building, there were found to be opportunities for trip sharing, a free bus service, space for parking and bicycle parking, and also a walking area. On the other hand, there is no refueling point or particular changing rooms for bicycles near the building. Thus, the aforementioned features

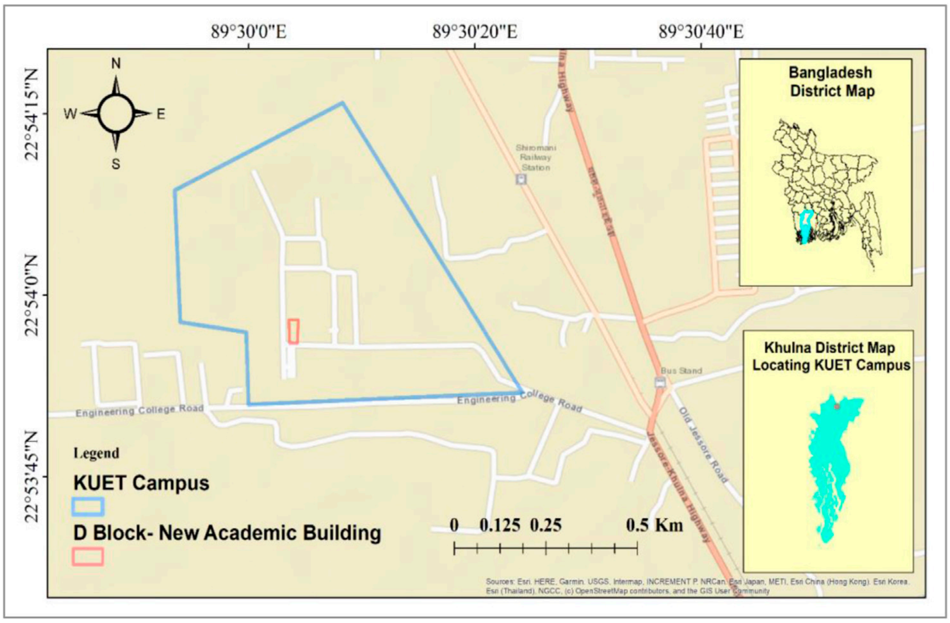

FIGURE 2
Study area map.

FIGURE 3
Building exterior.

reduces the opportunities for round trips by about 40%. Therefore, the building earns nine points out of 15 in SS Credit 4.

No LEED criteria were considered for the design, construction, and maintenance of the New Academic Building, and so no point was earned for SS credit 1. The equipment maintenance, cleaning of the building exterior and sidewalks, pavement, and other hardscapes are integrated into the plan of the building, and so the SS credit two was found to be satisfactory according to the guideline. There is no environmentally sensitive management plan to reduce chemical use, energy waste, and solid waste and to balance the ecology of the surroundings. The users also perceived a lack of an integrated pest management, erosion control, and landscape management plan; thus, the building did not earn any points for SS Credit 3.

Before the construction of the New Academic building, there were a lot of trees and small animals and birds, which were destroyed to construct the building. After the construction, no gardens or inbuilt vegetation were planted to protect or restore the surrounding habitat, and so it gained no points for SS Credit 5. Neither is there any stormwater management plan nor an existing rainwater harvesting system installed in the building that collects and reuses the runoff water. Thus, the building earned no points for SS Credit 6. There are shades from small and large trees, built terraces around the building, as shown in Figure 3, and above 50% of the parking space is shaded, which earned points for heat island reduction-non-roof for SS Credit 7.1.

The New Academic Building has no roof vegetation coverage, nor does it have high SRI index roof material for the heat island reduction-roof. Rather, just a thin limestone surface is painted, as shown in Figure 4, which is not protectable from the heat island effects, and so no point is awarded for SS Credit 7.2.

FIGURE 4
Roof without heat reduction system.

TABLE 2 Credit compliance for sustainable site.

Credit	Name	Points available	Points earned
SS Credit 1	LEED Certified Design and Construction	4	0
SS Credit 2	Building Exterior and Hardscape Management Plan	1	1
SS Credit 3	Integrated Pest Management, Erosion Control, and Landscape Management Plan	1	0
SS Credit 4	Alternative Commuting Transportation	15	9
SS Credit 5	Site Development-Protect or Restore Open Habitat	1	0
SS Credit 6	Stormwater Quantity Control	1	0
SS Credit 7.1	Heat Island Reduction-Non-roof	1	1
SS Credit 7.2	Heat Island Reduction-Roof	1	0
SS Credit 8	Light Pollution Reduction	1	1

Automatically controllable lights were used in this building and have been kept off service for 50% of the yearly nighttime. Again, the exterior lighting is also low, which does not cause any irritation but provides a clear vision for the users. Thus, the one point of light pollution reduction for SS Credit eight was well earned.

The summary of total points earned for the Sustainable Site category is illustrated in Table 2.

3.2 Study for water efficiency (WE)

Twenty-one toilets in the new academic building use water, supplied from the tank placed on the roof (shown in Figure 5), which pumps groundwater via a submersible pump. The main use of water in the building is for toilets and washing. The drinking water for the building is supplied from the water treatment plant by manual labor. In this academic building, other uses of water such as bathing, cooking, and cloth washing are not dominant. In the building, there is neither a meter to observe daily water consumption nor any measurement of the wastage of water. Thus, no point was allocated in terms of water performance measurement for WE Credit 1.

The indoor plumbing fixtures and fittings of the academic building do not have any additional features to support or stop wastage or minimize pressure on groundwater extraction or the municipal water supply (shown in Figure 5). Therefore, no points were earned for WE Credit 2.

There was a chance of reducing water usage by watering trees or gardening-based activities from the used and greywater of the buildings. No water efficiency system is installed here, and no low-flow plumbing fixtures are applied. No greywater recycling system, sensor-monitored basin or shower system, and rainwater harvesting system are installed in the building. As it does not consist of any resources other than the supply system, there are no savings from that supply, thus not reaching the minimum criteria of 50% water usage reduction to gain any point for WE Credit 3. To gain points for cooling tower water management, there is no evaporative condenser or system of recycling and reusing the wastewater by installing rainwater harvesting systems, nor are there water purification systems based on reusing the wastewater from rain, flushing, and drain water, etc. Thus, no points were earned for WE credit 4. There is no arrangement for non-potable water use or identification of any potential sources. Thus, the building could not earn the point for WE Credit five or for any water efficiency credit.

The summary of total points earned for the Water Efficiency category is illustrated in Table 3.

FIGURE 5
Typical water supply system and plumbing.

TABLE 3 Credit compliance for water efficiency.

Credit	Name	Points available	Points earned
WE Credit 1	Water Performance Measurement	2	0
WE Credit 2	Additional Indoor Plumbing Fixture and Fitting Efficiency	5	0
WE Credit 3	Water Efficient Landscaping	5	0
WE Credit 4.1	Cooling Tower Water Management	2	0
WE Credit 4.2	Non-potable water using	1	0

3.3 Study for energy and atmosphere (EA)

There are 167 fans, 223 tube lights, and 36 surface spotlights being used in the building, whereas there are no compact fluorescent bulbs (CFLs). There are 124 computers, 12 AC—of which 8 are 1.5 ton and four are 2 ton–15 projectors, three photocopy machines, 6 printers, two scanners, and 1 plotter that consumes electricity about one-third of the total time of the day. There are also six stitching machines in the apparel lab and one wet processing lab operating for about two and a half hours a day. Though there is no lift in the building, space for two lifts has been kept aside for future renovation. About 75% of the area makes use of the daylight, as can be seen in Figure 7 and Figure 8, and so the remaining 25% need tube bulbs to run in the daytime. The office rooms and computer lab need a lot of electricity for running the computers. Electricity is supplied from the main power grid of the country, and there are no solar panels or other systems that produce renewable energy. No refrigerator is used in the building.

Whether there are materials installed with energy stars or that demonstrate energy performance based on the local method was investigated to rate the building for optimized energy efficiency performance. In the building, there are no available fixtures that are rated as energy stars and no energy-saving equipment for the abovementioned energy uses, and 25% of the building area needs artificial light during the daytime. There are no existing recommissioning plans or plans to reduce energy consumption at any stage, and no steps have been taken to execute the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Level II energy audit. As the energy uses were not efficient up to 71%, no points were awarded for EA Credit one and 2.1. The allocated two points were earned for EA Credit 2.2 as the building's major energy-using systems are repaired, operated, and maintained promptly, effectively, and regularly. The guard and building management authority regularly implement the existing energy system. However, there are no adjustments and reviews of the building's energy systems to change to optimal energy efficiency and service provision, nor is there any broad planning for the future; thus, no points were earned for EA Credit 2.3.

As for the points that should be gained for Performance measurement-building automation system, there is no availability of an inbuilt computerized system providing signatures of heating, cooling, and ventilation changes, nor are there proper data to utilize in the case of any emergency; thus, no points were earned for EA Credit 3.1. For the existing system-level metering that would cover up to 40%–80% of the building's annual energy consumption, which is necessary, the building only has several electric meters that count the total energy consumption and consequent bill amounts. The data regarding energy breakdown and segregation, which were necessary for the existing system-level metering credit, was absent between usable and unusable surplus quantities; thus, no point was earned for EA Credit 3.2.

There is no on-site or off-site renewable source that provides energy for the building. While there was a solar electric power generation system developed by the students, it is now non-

TABLE 4 Credit compliance for energy and atmosphere.

Credit	Name	Points available	Points earned
EA Credit 1	Optimize Energy Efficiency Performance	18	0
EA Credit 2.1	Existing Building Commissioning-Investigation and Analysis	2	0
EA Credit 2.2	Existing Building Commissioning- Implementation	2	2
EA Credit 2.3	Existing Building Commissioning-Ongoing Commissioning	2	0
EA Credit 3.1	Performance Measurement-Building Automation System	1	0
EA Credit 3.2	Performance Measurement–System-Level Metering	2	0
EA Credit 4	On-site and Off-site Renewable Energy	6	0
EA Credit 5	Enhanced Refrigerant Management	1	1
EA Credit 6	Emissions Reduction Reporting	1	0

functional and broken. Thus, the building earned no points for EA Credit 4.

Enhanced refrigerant management is mainly comprised of reducing ozone layer depletion and also supporting the Montreal protocol. There is an existing air conditioning system only in the laboratory rooms, which is essential for preserving the laboratory materials, but there is no direct refrigerator in the building; thus, one point was awarded for EA Credit 5. There is no existing survey or reporting system established for finding out the emissions from the building. Neither has the university taken any approach to quantify the reduction of emissions of harmful elements and gases, and there is no existing tracking program. Thus, the building did not earn any points for EA Credit 6.

The summary of total points earned for the Energy and Atmosphere category is illustrated in Table 4.

3.4 Study for Materials and Resources (MR)

Locally available materials were employed for the construction of the building, meaning the transportation cost was limited. The sand of 1.5 FM value was transported from Kushtia, and the FM value of the Sylhet sand was 2.2–2.5. Bricks were brought from the brickfield of Fultola and Jessore, and 16″×16″ homogenous tiles from the RAK, AFIL, and MIR companies were used For the windows, 5 mm thick glass from NASIR was installed. The doors are wooden, with the frames made of Garjan tree and the shutters made of Partex. Enamel paint was applied to the doors. On the building's exterior, weather coat paint was used, while in the interior plastic paint was used from ASIAN and BERGER. However, no environmentally friendly finishes were applied, nor any odor removing painting or extra finishes to protect against the effects of UV rays.

The building's main purchases include sustainable and locally available materials. These materials are always available for purchase and further retrofitting or repair. Though no recycled materials were purchased, locally available materials comprised 50% of the total purchase, according to the guideline of sustainable purchase. Thus, one point was earned for MR Credit 1. All the materials were purchased after proper investigation and load testing to be durable for a 50-year period. Moreover, the furniture was purchased containing 70% material salvaged from off-site sources, and electric-powered equipment was purchased from authentic dealers to ensure durability. Thus, two points were earned for MR Credit 2.1–2.2. A sustainable purchasing program was maintained, covering materials during purchase and transportation, preparation, and use for facility renovations, as well as demolitions, refits, and new construction additions. The building's purchases contained 12% post-consumer and more than 70% off-site material. The purchase of 65% of the material was harvested and processed within a 150 km radius of the location, for which 1 point was earned for MR Credit 3.

MR Credit four demands the purchase of reduced Mercury in lamps, which is not considered, and so no points were earned as typical mercury-containing lamps are used in this building. As for the allocating points for Sustainable purchasing–food, most of the foods purchased are produced within 1 km of the site in nearby villages, and fish are available from the river at about 1–3 km distance. Thus, one point was awarded for MR Credit 5.

The Solid Waste Management - Waste Stream Audit requires an audit of the building's entire ongoing waste stream, and the audit's result has to be used to establish a baseline that will identify the types of waste making up the waste stream. However, as there was no audit of that waste, no point was earned for MR Credit 6. For Waste Management- Ongoing Consumables, the building has waste bins (shown in Figure 6) placed on every floor and room, and one person is hired for regular cleaning and waste collection. The building maintains a waste collection and proper management program that is regularly maintained with a low cost per unit, and so one point was earned for MR Credit 7. The building users do not maintain any reduction system, and there is no operation to reduce waste and toxins generated from daily use. Thus, no points were earned for MR Credit 8. There is no management system for the recovery and resouring of recyclable materials from wastes, and no wastes are reused or recycled. Thus, the building earned no points for MR Credit 9.

The summary of total points earned for the Materials and Resources category is illustrated in Table 5.

3.5 Study on Indoor Environmental Quality (IEQ)

From the floor plan in Figure 7, the features of the building are illustrated, showing 96 windows on the ground floor, 58 windows on

TABLE 5 Credit compliance for materials and resources.

Credit	Name	Points available	Points earned
MR Credit 1	Sustainable Purchasing-Ongoing Consumables	1	1
MR Credit 2.1–2.2	Sustainable Purchasing-Durable Goods	2	2
MR Credit 3	Sustainable Purchasing-Facility Alterations and Additions	1	1
MR Credit 4	Purchasing-Reduced Mercury in Lamps	1	0
MR Credit 5	Sustainable Purchasing-Food	1	1
MR Credit 6	Solid Waste Management-Waste Stream Audit	1	0
MR Credit 7	Waste Management-Ongoing Consumables	1	1
MR Credit 8	Solid Waste Management-Durable Goods	1	0
MR Credit 9	Solid Waste Management-Facility Alterations and Additions	1	0

the first floor, 60 windows on the second floor, and 48 windows on the third floor to provide daylight and fresh natural air to the building. About 75% area of the building receives daylight. Ventilators are installed in every room for air circulation. There are two small verandas and a long veranda on every floor open to the sky contributing to open spaces. There are a few small green plants on the veranda to provide good indoor air quality. The building earned one point for IEQ 1.1 because of the good indoor air quality maintenance of the building.

The ventilators and windows are placed in a very planned location to accommodate free air circulation for the building. Furthermore, there is a regular dust cleaning system to keep the indoor air fresh, and no machines or instruments are used that might pollute the indoor air. There is a regular cleaning and watering system outside of the building to protect the outdoor air from increased particle matter, and there are enough free space and large trees to maintain healthy outdoor air quality. Thus, the full point was awarded for IEQ Credit 1.2. Though there are no mechanical ventilation systems, the ventilators and windows are capable of providing additional air ventilation to improve indoor air quality and thus occupant comfort, wellbeing, and productivity. Room-by-room airflows are effectively naturally ventilated, and the minimum ventilation rates required by ASHRAE Standard 62.1–2007 section 6 of at least 90% of occupied spaces are assured. Therefore, one point was rewarded for IEQ Credit 1.3. There is a daily cleaner appointed to the building to clean and wash the rooms and floors and to spray water over the surroundings to reduce the exposure of the its occupants to dust and other potentially hazardous particulate contaminants. Thus, the building earned one point for Indoor Air Quality Best Management Practices-Reduce Particulates in Air Distribution. There are no measures or even planning for indoor air quality problems resulting from any construction or renovation project inside or outside the building. As the recommended control measures of the Sheet Metal and Air Conditioning National Contractors Association (SMACNA) IAQ Guidelines for Occupied Buildings Under Construction, second Edition 2007, ANSI/SMACNA 008–2008 are not maintained to help sustain the comfort and wellbeing of construction workers and the building's occupants, no point was earned for Indoor Air Quality Management for Facility Alterations and Additions.

FIGURE 6
Waste bins used in the building.

An occupant comfort survey was conducted to collect responses about thermal comfort, acoustics, IAQ, lighting levels, building cleanliness, and other occupant comfort issues. Corrective actions were also introduced by the team during construction. More than 80% that responded said they are satisfied with the service of the building, and so one point was for IEQ Credit 2.1. Almost 80% of the building comprises multi-occupant space, and most of the users use lighting controls, enabling adjustments to suit the task needs and preferences of individuals. Even if any lighting is not controlled after the work period, there are maintenance people to monitor and switch it off. Thus, one point was earned for the Controllability of Systems—Lighting Credit IEQ 2.2. There is no Air conditioning system in the building to control the temperature during summer or

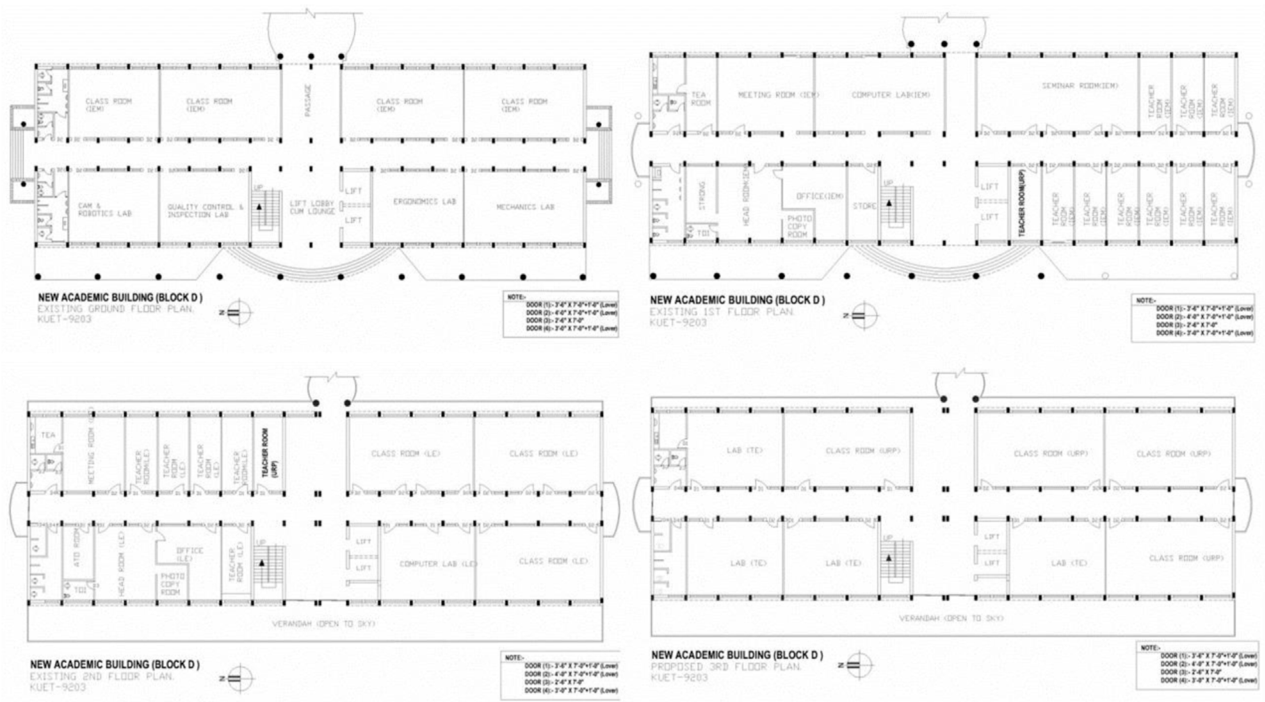

FIGURE 7
Building floor plan.

winter. Users only run ceiling fans during summer to reduce the heat and have no means in winter to control the cold weather. The building does not meet the requirements of the International Organization for Standardization (ISO) 7730, local thermal comfort criteria, nor CEN Standard EN 15251: 2007. Thus, the building did not earn any points for the Occupant Comfort-Thermal Comfort Monitoring credit–IEQ 2.3. Daylight enters the building corridor and, in the classrooms, gives a very clear view (shown in Figure 8), meaning that in the daytime there is no need for electric bulbs. The corridors and classrooms of the building achieved daylight illuminance levels of 10 footcandles (fc) (108 lux) and 500 F (5,400 lux) in a clear sky condition on September 2022 at 9 a.m. and 3 p.m., satisfying the IEQ Credit 2.4 criterion, and thus it earned one point for Daylight and Views.

There is only a typical cleaning and washing system in the building, but there is no appropriate staffing plan or training for building cleaning and maintenance personnel for green cleaning. Moreover, there is no consideration of sustainable cleaning materials, products, equipment, janitorial paper products, and trash bags to protect the occupants from potentially hazardous chemical, biological, and particulate contaminants; thus, no point was earned for IEQ Credit 3.1. In the cleaning process of the building, no Custodial Staffing Guidelines are followed, and so it earned no point for IEQ Credit 3.2. There is no arrangement to reduce the environmental impacts of cleaning products, disposable janitorial paper products, and trash bag sand, so the building earned no points for IEQ Credit 3.3. No special program or cleaning equipment is used to reduce potential hazards of chemical and biological contaminants in the building, and thus, the building earned no points for IEQ Credit 3.4. There is regular monitoring to find out any chemical and pollutant sources in the building. If any source is found, prompt action is taken to remove and clean the chemical and pollutants. Thus, one point was earned for IEQ Credit 3.5. There are no integrated methods for green cleaning, including site or pest inspections, pest population monitoring, evaluation of the need for pest control, sanitation, and structural repairs. Thus, the building earned no points for IEQ Credit 3.6.

The summary of total points earned for the Indoor Environmental Quality category is illustrated in Table 6.

3.6 Innovation in design

The credits for innovations in design are accredited to projects that have taken strategies to develop the opportunities of green building practice by enhancing innovative methods, tasks, and products in place (Leitch et al., 2013). The building was constructed and operated with the traditional practice of Bangladeshi educational institutions. There is no innovation in planning, design, construction, or operation. The building was not constructed maintaining any significant measurable environmental performance with an upgraded strategy or exemplary performance. Thus, the building earned no points for IO Credit 1. In credit 2, LEED Accredited Professional, the building was not awarded any points. None of the building project team participants was a LEED Accredited Professional (AP), and so the building could not earn any points for IO Credit 2. There is good documentation of the overall building operating costs for the previous 5 years and track changes in the overall building

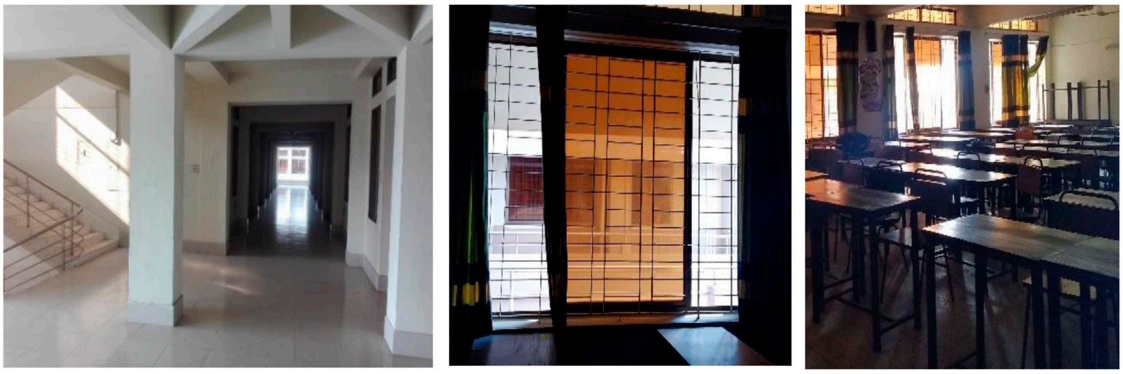

FIGURE 8
Interior daylight availability.

TABLE 6 Credit Compliance for indoor environmental quality.

Credit	Name	Points available	Points earned
IEQ Credit 1.1	Indoor Air Quality Best Management Practices-Indoor Air Quality Management Program	1	1
IEQ Credit 1.2	Indoor Air Quality Best Management Practices-Outdoor Air Delivery Monitoring	1	1
IEQ Credit 1.3	Indoor Air Quality Best Management Practices-Increased Ventilation	1	1
IEQ Credit 1.4	Indoor Air Quality Best Management Practices-Reduce Particulates in Air Distribution	1	1
IEQ Credit 1.5	Indoor Air Quality Best Management Practices-Indoor Air Quality Management for Facility Alterations and Additions	1	0
IEQ Credit 2.1	Occupant Comfort-Occupant Survey	1	1
IEQ Credit 2.2	Controllability of Systems-Lighting	1	1
IEQ Credit 2.3	Occupant Comfort-Thermal Comfort Monitoring	1	0
IEQ Credit 2.4	Daylight and Views	1	1
IEQ Credit 3.1	Green Cleaning-High-Performance Cleaning Program	1	0
IEQ Credit 3.2	Green Cleaning-Custodial Effectiveness	1	0
IEQ Credit 3.3	Green Cleaning-Purchase of Sustainable Cleaning Products and Materials	1	0
IEQ Credit 3.4	Green Cleaning-Sustainable Cleaning Equipment	1	0
IEQ Credit 3.5	Green Cleaning-Indoor Chemical and Pollutant Source Control	1	1
IEQ Credit 3.6	Green Cleaning-Indoor Integrated Pest Management	1	0

TABLE 7 Credit compliance for innovation.

Credit	Name	Points available	Points earned
IO Credit 1	Innovation in Operations	4	0
IO Credit 2	LEED Accredited Professional	1	0
IO Credit 3	Documenting Sustainable Building Cost Impacts	1	1

operating costs during the performance period. By well maintaining the financial impacts of the building, it earned one point for IO Credit 3.

The summary of total points earned for the Innovation category is illustrated in Table 7.

3.7 Regional priority

The building is constructed in the southwestern area of Bangladesh, which is in the coastal region and faces coastal atmosphere influences. The planning and design of the

TABLE 8 Credit Compliance for regional priority.

Credit	Name	Points available	Points earned
RP Credit 1	Regional Priority	4	1

building well prioritized the regional aspects such as salinity and storm surge, which were considered in every stage. Thus, it earned one point for RP Credit 1.

The summary of total points earned for the Regional Priority category is illustrated in Table 8.

3.8 Final rating of the building

According to the credit compliance from Tables 2 to 7, the points the building earned for the credits of each category is summed, and the total points it earned are its rating points of the green building assessment. Here, the precise pointing is conducted, and according to the points gained, the assessment of LEED credit compliance of the New Academic building is given in Table 9.

According to the LEED 2009 rating system, the New Academic building earned 31 points out of 110 and could not obtain any certification level.

4 Discussion and recommendations for green retrofitting

The New Academic building earned 31 points out of 110 and could not obtain any certification level. Because it has a suitable location and few transportation facilities, it gained 12 points out of 25. As there is no water efficiency system or non-potable water use, it could not obtain any score for the water efficiency category. Furthermore, for not installing any energy efficiency system or not introducing any renewable energy sources, it earned only three points for the energy and atmosphere category. By purchasing sustainable materials, it earned six points out of 10. Furthermore, for providing good air quality and ventilation systems, it earned eight points out of 15, though it could have earned more by maintaining a green cleaning system. The study shows that the traditional practices of academic buildings in Bangladesh only focus on their purpose to serve and do not consider the green building criteria. The green building assessment provided a holistic scenario of the building's features and functionality. The obstacles and deficiencies because of which the building could not achieve a green building certification level have been identified by the assessment.

The prospects of retrofitting options for the existing buildings to meet green building standards are identified, and ways are suggested to improve energy efficiency, water efficiency, resource conservation, and occupant health and comfort following the works of Darko et al. (2017b), Ahn et al. (2013), and Devine and Kok (2015). It has been demonstrated that the green performance of the building could be increased by installing some efficiency systems and incorporating green measures for reducing its negative impact (Kats, 2010).

As for the deficiency and lack of green options, some of them are costly, some are hard to install, and some of them are easy to install, cost-effective, and will earn points that will elevate the building to a green certification level. Some water- and energy-efficient feature installations can earn the building a certification level. In addition to these, a adding some heat reduction and waste management options can lead to a silver certification.

Rooftop gardening and UV-reflecting white paint can gain one point for SS 7.1, and the large tree plantation around the building and small trees on the balcony can gain one point for SS 7.2 as a form of roof and non-roof heat-island reduction, which is suggested and implemented by Siew et al. (2019) in Malaysia. Large trees also facilitate the conservation of habitats, as implemented by Farag et al. (2019) in Effat University, Jeddah, Saudi Arabia, and would gain one point for SS five to protect or restore the open habitat.

Efficiently designed washrooms can be reformed to reuse greywater for flashing and reduce freshwater use. A water-efficient plumbing system, grey water recycling, and reusing system can be installed, and this has been proven to be effective in Egypt by Darwish et al. (2021) along with rainwater harvesting technology as suggested by Das et al. (2015). A complete design can be made to have an integrated

TABLE 9 LEED rating table for New Academic building in KUET.

Category	Total points available	Total points earned
Sustainable Site	25	12
Water Efficiency	15	0
Energy And Atmosphere	35	3
Materials And Resources	10	6
Indoor Environmental Quality	15	8
Innovation in Design	6	1
Regional Priority	4	1
Total	110	31

water plan for the building and the campus too to earn five to six points for WE two and 3. The installation of a stormwater quality control system will help to reduce the quantity of pumped water and can earn one point for WE 4.2 for non-potable water use. An evaporative condenser can be installed that can control the bleed-off, chemical treatment, and other accessories of the building. Water metering can be installed to quantify the water demand, use, and wastage for the building to earn one point for WE 1, as has also been implemented by Khoshdelnezamiha et al. (2020) in Malaysia.

In the Energy and Atmosphere category, the building could gain points up to five to eight points by reducing energy consumption and using renewable sources, developing a retro-commissioning and recommissioning plan for the building's major energy-using system to reduce energy consumption, and following the guidelines of Aktas (2015) and the implementations of Liu et al. (2014) in China and Fan and Xia (2018) in South Africa. Solar panels can be installed on the huge open space on the rooftop, and installation of zero chlorofluorocarbon-based refrigerants could also make it eligible to obtain three points in EA four for on-site and off-site renewable energy, as validated by Aksamija (2015) in Massachusetts, United States of America.

Particle filters and air-cleaning devices can also be installed to improve indoor–outdoor air quality (Darko et al., 2017a). Grills, grates, or mats that catch dirt and particles can be cleaned regularly to prevent contamination of the building interior (Asif et al., 2018). Along with traditional cleaning, appropriate staff planning has to be conducted and materialized to adopt green cleaning using sustainable equipment and products (Low et al., 2014). Thus, one point could be earned for EA seven for Waste Management.

After installing new devices or systems according to the LEED requirements, the proper documentation and regular maintenance can gain one point for IO 3. For regional priority, the building obtains only one point, but consideration of the hazardous environmental risk of the Khulna coastal region, i.e., cyclones, and salinity intrusion, in the planning and design could earn one more point for RP 1 (Love et al., 2012).

Overall, by retrofitting the abovementioned suggestions, the building could earn up to three points for sustainable sites, seven to eight points for water efficiency, 8 to 11 points for energy efficiency, one point for indoor air quality, one point for innovation in design, and one point for regional priority. Therefore, a total of 20–24 points could be gained for the green rating of the building, which would upgrade it to the silver certified level. These added retrofitting steps will enable any conventional existing building to gain a LEED certification and can be followed for the same categorized building of an educational institution in developing countries with the same field of possibility. The suggestions are organized so that steps can be taken with the currently available materials according to expertise. Along with following the LEED for Existing Buildings: Operations and Maintenance Recertification Guidance (2014) for the specific buildings, the LEED Campus Guidance (2014) needs to be considered for turning the university into a green campus.

5 Conclusions

This research assessed the green rating of a building in accordance with the LEED 2009 guideline requirements to find out which green rating features it already have and if not then which features are feasible to install to earn green certification level. Despite attempts having been made, the building received just 31 points and no certification level, indicating that it does not meet the green building criteria. This study shows that this conventional buildings practice does not align with green building standards. It stresses the need for incorporating green building guidelines and criteria in universities and buildings nationwide.

This study also emphasizes the necessity of retrofitting and installing green features in existing or new structures to earn LEED certification for Green Building. It focuses on adopting green building criteria and rating systems to improve building performance and promote sustainability. This integrated strategy pledges that the study's recommendations will benefit the occupants of buildings and the community as a whole. The findings will improve building user facilities in Bangladesh. They would help to reduce resource consumption, waste, and environmental degradation, contributing to the region's resilience. This study on a Bangladeshi structure provides focused individual design recommendations and promotes sustainable architecture for academic institutions and communities. Green grading systems in every building can provide quantitative recommendations for increasing performance and making them environmentally friendly.

Environmental NGOs and governments should promote green building standards in all new constructions. New constructions can be made green by following LEED v4 for Building Design and Construction (2019). Green building requirements are crucial for the user and environmental wellbeing in the age of climate change and environmental deterioration. Indeed, traditional approaches focus primarily on their intended function. These findings will guide sustainable construction and design policies in Bangladesh and can be replicated in other developing countries. In further studies, a cost–benefit analysis for these retrofitting options can also be investigated.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Helsinki declaration. The patients/participants provided their written informed consent to participate in this study.

Author contributions

The AI conceptualized and designed the study, collected the data, and analyzed and prepared the results. The AI, IJ, and QW wrote and finalized the manuscript. IAE and DC contributing in revising the manuscript to address reviewers comment. All authors contributed to the article and approved the submitted version.

Acknowledgments

The authors would like to express their gratitude to the students, engineers, guards, and cleaners for their cordial logistic support during the field visit and data collection. This research is part of the BSc thesis submitted by AI to the Department of Civil Engineering, Khulna University of Engineering and Technology, Khulna-9203. The authors would also like to thank Md. Atiqul Islam, Assistant Professor, KUET, for his support in conceptualizing the idea.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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