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A Comprehensive Study on the Environmental Features of Green Buildings in Dhaka, Bangladesh: Prospects, Challenges and Mitigation Strategies

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ABSTRACT

The construction industry has played a significant role in causing environmental degradation, primarily due to its substantial energy use. Focusing on green building development projects is gaining momentum as a sustainable solution for mitigating environmental challenges. This study assessed several environmental features of 22 green buildings in Dhaka, the capital of Bangladesh. In addition, the challenges were discussed, and mitigation strategies were recommended. The Leadership in Energy and Environmental Design (LEED) certification technique is widely acknowledged and globally accepted as the leading green building certification standard. Three LEED versions were investigated—v3 for new construction and major renovations and v4 and v4.1 for building design and construction. Seven environmental features of three versions, including rainwater management, renewable energy, enhanced commissioning, optimize energy performance, construction and demolition waste management, water use reduction, and water efficient landscaping were considered in this work. A survey questionnaire was prepared to receive information about these LEED-certified (or applied for certification) buildings. The findings of our study suggested that the general trend for seven environmental features of the selected green buildings was positive except for renewable energy where 72.72% of buildings were in 'very poor' condition. Regarding rainwater management, enhanced commissioning, and optimize energy performance, 40.91% of buildings were in 'very good' condition. Despite satisfactory responses for several environmental features, the survey found that renewable energy integration remains challenging for all buildings. Solar energy should be extensively employed to enhance energy utilization efficiency, reduce energy demand, and minimize environmental impact. It was suggested that a few challenges including the government's lack of action and initiatives, financial incentives, investor hesitation, and knowledge gaps must be overcome to create a truly green building market in Bangladesh. Bridging this disparity requires policy reforms, public awareness, industry development, and capacity building. This study provides a basic understanding of the green building situation and guides future research and policy initiatives to accelerate Bangladesh's commitment to sustainable development goals.

Key Words	Green building, Bangladesh, LEED, Environmental features, Mitigation strategies
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INTRODUCTION

Anthropogenic activities have led to a significant increase in greenhouse gas emissions. The construction industries are substantial contributors to global emissions, although they play a crucial role in establishing necessary infrastructure, generating employment opportunities, and contributing to the nation's overall economy (Zuo & Zhao 2014). Consequently, the management of environmental effects in the construction industry has emerged as a significant concern.

The construction is plagued with various environmental issues, such as noise, dust, traffic congestion, water contamination, and waste disposal. Building construction, installation, transportation, and manufacturing all require large amounts of energy and emit large amounts of greenhouse gases, mostly carbon dioxide (CO_2) (Yan et al. 2010). 35% of the world's CO_2 emissions and 45-65% of the waste that ends up in landfills are caused by the building sector. The construction industry and its linked activities also generate considerable harmful emissions; construction-related activities account for about 30% of global greenhouse gas emissions. 18% of these emissions are attributed to the preparation and transportation of building materials alone (Lima et al. 2021). The Intergovernmental Panel on Climate Change (IPCC) predicts that by 2050, global temperatures will increase by 1.5°C (2.7°F) compared to the levels before the industrial era (IPCC 2022). The energy-related carbon dioxide (CO_2) emissions totaled 32.3 billion metric tons in 2012 and are forecasted to rise to 43.4 billion metric tons by 2040 (Zhang et al. 2017).

Green buildings or green infrastructures, have gained significant attention recently because of their potential to minimize the adverse effects of buildings on the environment and the people who use them. Although green building lacks a universally recognized and agreed-upon definition (Li et al. 2017), in the context of "green building", the term "green" denotes explicitly a symbol or concept that signifies a building that does not cause harm to the environment. It does not encompass the broader meaning of green roofs or rooftop gardens. (Zheng 2021). Instead, it refers to a form of construction that reduces its impact on the natural environment and human well-being.

The technique of designing and constructing buildings with responsible and resource-efficient methods at every stage of their life cycle, from siting to design, construction, operation, maintenance, and renovation, is known as "green building." Green buildings are designed and built using recycled materials, less water, less energy, and resource-efficient techniques; they also feature water-sensitive design to reduce their vulnerability to flooding; they minimize pollutant emissions to the air, water, and soil; and they minimize light and noise pollution (Hussin et al. 2013; Olubunmi et al. 2016). Green buildings often maintain higher indoor air quality (Darko et al. 2017).

Green building materials play a crucial role in sustainable architecture due to their low environmental impact and high resource efficiency, leading to reduced emissions and resource conservation. Achieving long-term sustainability requires ongoing innovation, supportive legislation, and collaboration among architects, builders, legislators, and consumers (Iwuanyanwu et al. 2024).

Green buildings offer significant economic and social benefits by improving energy efficiency, lowering operational costs, and promoting environmental sustainability. Economically, they result in substantial savings on energy, water, and materials, which reduces overall expenses and increases property values (Zhao et al. 2023). They cut infrastructure costs, lower waste disposal expenses, and mitigate risks, while enhancing durability and maintenance efficiency. Socially, green buildings foster healthier living and working environments, which improve occupants' health, comfort, and productivity (Vasilevna & Trofimovich 2021).

Multiple international green rating systems have been devised to assess sustainability of construction projects. The Leadership in Energy and Environmental Design (LEED) certification technique is widely acknowledged and considered the leading green certification standard globally. Although the US Green Building Council (USGBC) created LEED as a discretionary benchmark, it is widely regarded as the most extensively implemented grading scheme based on the number of countries. LEED primarily assesses environmental elements like sustainable sites, water efficiency, energy and atmosphere, materials and resources, and the indoor environment (Doan et al. 2017).

The LEED green building certification system is a voluntary and consensus-driven procedure for measuring impacts of the constructed environment and construction activities across multiple impact categories. The categories encompass crucial global environmental, social, health, and economic concerns. They offer performance measures, best practices, and procedures for enhancing buildings in these domains. Over the past decade, LEED has undergone multiple revisions with the addition of stricter sustainability criteria and credit rating systems. LEED classifies several interrelated rating systems into four main construction types (USGBC 2017, Dorsey & Hedge 2017):

i. Building Design and Construction (BD+C)
ii. Interior Design and Construction (ID+C)
iii. Building Operations and Maintenance (O+M)
iv. Neighbourhood Development (ND)

LEED v3 or LEED 2009 for New Construction and Major Renovations had seven main categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation and Design Process, and Regional Priority Credits, totaling 110 points (LEED 2009). LEED v4 (2013) comprised 21 rating systems designed to cater to various building types whereas v4.1 (2019) raised the bar on building standards to address energy efficiency, water conservation, and carbon emission reduction. The LEED rating system requires fulfilling prerequisites in all credit categories to obtain certification at any level. Additionally, optional credits can be pursued to collect points that contribute to achieving higher certification levels. Project teams can choose any combination of credits to reach the required level of certification. The weighting technique assigns 110 points to each LEED rating system, considering their respective social, environmental, and economic implications. The degree of certification for a project is determined by the number of points it has earned (Worden et al. 2020).

- Certified: 40-49 points
- Silver: 50-59 points
- Gold: 60-79 points
- Platinum: 80 points or more

Bangladesh currently lacks an officially recognized green building grading system. Bangladesh Bank has recognized LEED as the main green building rating system for the formal certification process (Saba 2019). The introduction of LEED certification fosters constructive competition to create a more environment-friendly, sustainable, and ecologically balanced Bangladesh. Most of the 177 buildings in Bangladesh that have received LEED certification are industrial structures. The composition comprises 31% platinum, 58% gold, 8% silver, and 2% certified (Assure Group 2022). Most of the commercial green buildings are in Dhaka city. The Cityscape Tower, located on Gulshan Avenue, Dhaka, is under LEED Platinum Certification. In addition, Simpletree Anarkali and Simpletree Lighthouse, situated on Gulshan Avenue, are also under LEED Gold Certification (Fig. 1)

(a) (b) (c)

Fig. 1: (a) Cityscape Tower, (b) Simpletree Lighthouse, and (c) Simpletree Anarkali

Due to the increasing need for environment-friendly construction, academia has significantly emphasized researching green buildings. Developed countries are working towards shifting to eco-friendly building technologies. Bangladesh, a developing nation, strives to increase knowledge regarding green building practices; however, the actual construction of such buildings is still limited. Construction professionals in Bangladesh rarely adhere to the many laws, regulations, and recommendations outlined in the national policies. Despite the ongoing research on green buildings in Bangladesh, the environment-related features of these buildings are not well-studied. The objective of this study was to investigate the existing condition of the environmental features of selected green buildings situated in Dhaka North City Corporation, Bangladesh. The challenges and mitigation strategies were also suggested to overcome the shortcomings of the necessary environmental features of these buildings.

MATERIALS AND METHOD

Study Area

This study considered 22 buildings in the Dhaka North City Corporation area (Fig. 2). The buildings were selected based on the accessibility to reach out the stakeholders or concerned personnel easily for collecting necessary information regarding their LEED certification. Among the buildings, sixteen of them are located in Gulshan Avenue, while the rest are in Tejgaon, North Badda, Uttara, Kazi Nazrul Islam Avenue, and Bashundhara. Table 1 lists the buildings considered during this study and their LEED certification status.

Table 1: List of considered buildings and their LEED certification status

Sl. No.	Name of the Building	LEED Certification
1.	Simpletree Anarkali	LEED Gold Certification
2.	Cityscape Tower	LEED Platinum Certification
3.	Hadi Tower	LEED Gold Certification
4.	Saiham Tower	LEED Platinum Certification
5.	bti Landmark	LEED Gold Certification
6.	Mobil House	LEED Platinum Certification
7.	SouthBreeze Square	LEED Platinum Certification
8.	Simpletree Lighthouse	LEED Gold Certification
9.	HSBC Bngladesh Gulshan Branch	LEED Platinum Certification
10.	Palmal Tower	LEED Gold Certification
11.	Shahjalal Islami Bank Corporate Headquarters	LEED Gold Certification
12.	Shanta Pinnacle	LEED Platinum Pre-certified
13.	Simpletree GSR	Registered for LEED Certification, LEED v4 BD+C CS
14.	Rangs RK Square	Applied for LEED Certification
15.	JCX Business Tower	Registered for LEED Certification, LEED v4 BD+C CS
16.	InnStar Trade Intercontinental	LEED Platinum Pre-certified
17.	Standard Bank Limited Head Office	Registered for LEED Certification, LEED v4 BD+C NC

18.	Suvastu Skyline Avenue	Registered for LEED Certification, LEED v4 BD+C CS
19.	The Pearl Trade Center	Certification in Progress
20.	Ishtiak Thal Green	Certification in Progress
21.	BIFFL Corporate Office	LEED Platinum Certification
22.	Rangs Z Square	Applied for LEED Certification

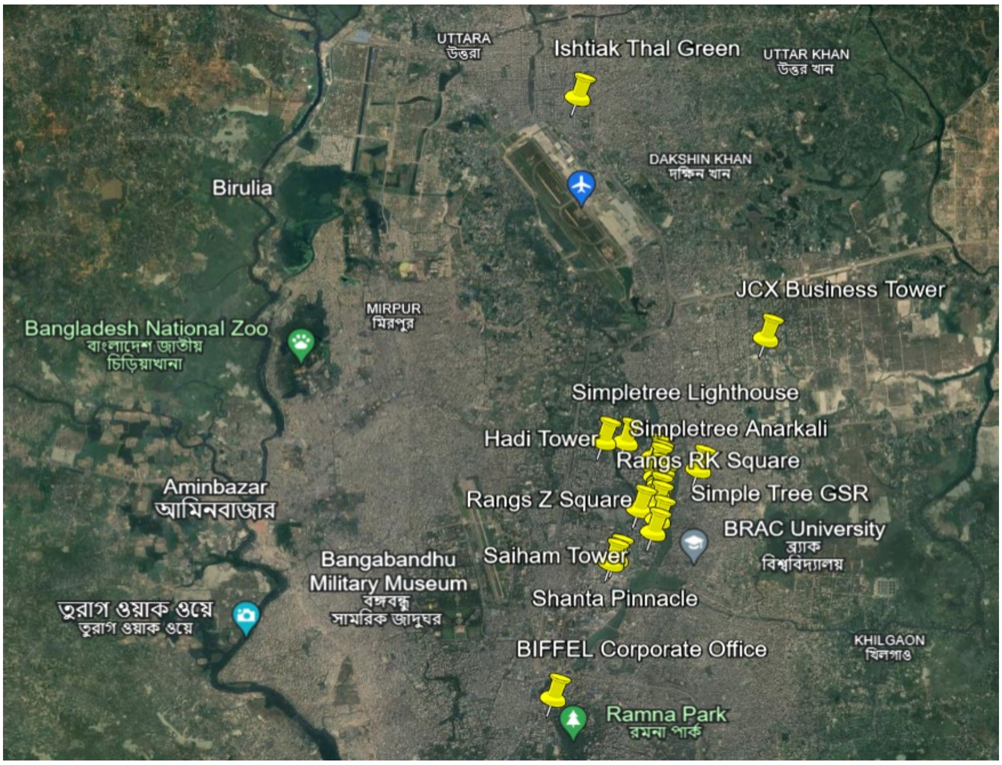

Fig. 2: Study area and location of the buildings (Google Earth)

Scope of Study Seven environmental features of the LEED rating system were considered to understand the current conditions of the selected 22 green buildings in the capital city of Bangladesh, Dhaka. The environmental features included rainwater management, renewable energy, enhanced commissioning, optimize energy performance, construction and demolition waste management, water use reduction, and water efficient landscaping. Three LEED versions – version 3 (v3) for new construction and major renovations and version 4 (v4) and version 4.1 (v4.1) for building design and construction were considered as the buildings were certified under these versions. A total LEED score of 42 out of 110 for these seven features was taken into consideration.

Data Collection

This study required collection of both qualitative and quantitative data. To begin with, a detailed analysis of research papers and articles on green buildings was carried out to prepare a survey questionnaire. The survey was intended only for research purposes on knowledge-sharing outcomes. The questionnaire featured a Likert scale with four weight categories: ‘very light weight,' 'light weight,' 'moderate weight,' and 'heavy weight.' Environmental features were weighted based on their contributions to a total LEED score of 110 points. Furthermore, the questionnaire featured a Likert scale with five points, which assessed the fulfillment of the criteria. The available alternatives were 'very poor condition,' 'poor condition,' 'neutral condition,' 'good condition,' and 'very good condition.' A Likert scale was chosen because it allowed for the systematic quantification of subjective evaluations of different environmental characteristics and their conditions. Individuals working in constructing those buildings provided most of the primary data. In addition to conducting a Likert-scale survey, technical people were also interviewed to gather their ideas and suggestions about adopting green construction practices, specifically about environmental aspects. Hence, the survey targeted engineers and technicians responsible for implementing sustainable technologies in the construction industry. The responses to the questionnaire and project data were recorded in 2023. To ensure participant anonymity and confidentiality, the survey provided anonymous responses, assured participants that their data would be used only for research, and securely stored the data, thereby enhancing the study's reliability and validity.

RESULTS AND DISCUSSION

Environmental Features

The questionnaire, featuring a Likert scale with four weight categories, assigned weights of 'very light weight,' 'light weight,' 'moderate weight,' and 'heavy weight' to the environmental features based on the percentage of total LEED score covered by each feature (Table 2 and Table 3). The following weightages were assigned:

Table 2: Environmental features and their associated weights

Percentage of LEED score covered	**Weightage**
Up to 1%	Very Light Weight
More than 1% up to 2%	Light Weight
More than 2% up to 3%	Moderate Weight
More than 3% and above	Heavy Weight

For example, according to LEED, total scorecard is 110, and the score of rainwater management is 3. The weight of rainwater management = $(\frac{3}{110}) \times 100$ = 2.73%. Therefore, it is a moderate weight criterion.

Table 3: Environmental features and their associated weights

Environmental Features	Main Category	LEED Version	Score	Weight
Rainwater Management	Sustainable Sites	v4	3	Moderate
Renewable Energy	Energy and Atmosphere	v4.1	5	Heavy
Enhanced Commissioning	Energy and Atmosphere	v4.1	6	Heavy
Optimize Energy Performance	Energy and Atmosphere	v4.1	18	Heavy
Construction and Demolition Waste Management	Materials and Resources	v4	2	Light
Water Use Reduction	Water Efficiency	v3	4	Heavy
Water Efficient Landscaping	Water Efficiency	v3	4	Heavy

Table 4 displays the five criteria considered among others for each environmental feature and Table 5 shows the conditions assigned based on the fulfillment of criteria for each environmental feature of the buildings.

Table 4: Considered criteria for each environmental feature

Environmental Features	Number of Criteria
Rainwater Management	i. Catchment, ii. Conveyance system, iii. Flush and Filter, iv. Tank and the recharge structure, v. Regular maintenance
Renewable Energy	i. Solar power, ii. Wind power, iii. Waste to electric energy, iv. Biogas, v. Maintenance
Enhanced Commissioning	i. Engage commissioning authority, ii. Design review, iii. Construction review and as-built drawing, iv. Quality, v. Durability
Optimize Energy Performance	i. HVAC system (Heating, Ventilation, and Air Conditioning), ii. Daylight system, iii. Solar heating and water saving technology, iv. CO_2 sensor and double-glazed thermal glass, v. Regular maintenance
Construction and Demolition Waste Management	i. Eliminating waste, ii. Minimize waste, iii. Recycling and salvage value, iv. Disposal and diversion, v. Govt. regulation and management

Water Use Reduction	i. Sensor type dual flush (Water Closets), ii. Sensor type (Lavatory Faucet), iii. Ultra-low flow (Urinals & Shower), iv. Sensor type (Water Pump), v. Regular maintenance
Water Efficient Landscaping	i. Native and adapted plants, ii. Smart sensors and controls for watering, iii. Healthy soil and retain moisture, iv. Rainwater and recycled wastewater, v. Regular maintenance

Table 5: Condition assigned of seven environmental features of the buildings under consideration

Rainwater Management	No or one criterion	Very Poor	0	0.00%
	Two criteria	Poor	3	13.64%
	Three criteria	Neutral	4	18.18%
	Four criteria	Good	6	27.27%
	Five criteria	Very Good	9	40.91%
		Total	**22**	**100%**
Renewable Energy	No or one criterion	Very Poor	16	72.73%
	Two criteria	Poor	6	27.27%
	Three criteria	Neutral	0	0.00%
	Four criteria	Good	0	0.00%
	Five criteria	Very Good	0	0.00%
		Total	**22**	**100%**
Enhanced Commissioning	No or one criterion	Very Poor	3	13.64%
	Two criteria	Poor	2	9.09%
	Three criteria	Neutral	3	13.64%
	Four criteria	Good	5	22.73%
	Five criteria	Very Good	9	40.91%
		Total	**22**	**100%**
Optimize Energy Performance	No or one criterion	Very Poor	2	9.09%
	Two criteria	Poor	2	9.09%
	Three criteria	Neutral	3	13.64%
	Four criteria	Good	6	27.27%
	Five criteria	Very Good	9	40.91%
		Total	**22**	**100%**
Construction and Demolition Waste Management	No or one criterion	Very Poor	3	13.64%
	Two criteria	Poor	3	13.64%
	Three criteria	Neutral	4	18.18%
	Four criteria	Good	5	22.73%
	Five criteria	Very Good	7	31.82%

		Total	**22**	**100%**
Water Use Reduction	No or one criterion	Very Poor	4	18.18%
	Two criteria	Poor	2	9.09%
	Three criteria	Neutral	4	18.18%
	Four criteria	Good	6	27.27%
	Five criteria	Very Good	6	27.27%
		Total	**22**	**100%**
Water Efficient Landscaping	No or one criterion	Very Poor	5	22.73%
	Two criteria	Poor	4	18.18%
	Three criteria	Neutral	3	13.64%
	Four criteria	Good	5	22.73%
	Five criteria	Very Good	5	22.73%
		Total	**22**	**100%**

Conditions of the Environmental Features

Table 5 shows that nine buildings are in 'very good' condition, and none are in 'very poor' condition regarding rainwater management. The maximum percentage of buildings, 40.91%, is in 'very good' condition. Sixteen buildings lie in 'very poor' condition which accounts for 72.72% of the buildings for renewable energy, as shown in Table 5. Therefore, the highest proportion is in 'very poor' condition. This data shows that renewable energy is yet to be properly implemented in green buildings in Dhaka city. Being a heavy weight environmental feature of the LEED certification system, this feature must be implemented regularly. In the case of enhanced commissioning, nine buildings are in 'very good' condition, which accounts for 40.91% of the total buildings under consideration.

Similarly, the maximum percentage of buildings, 40.91%, is in 'very good' condition for optimize energy performance. However, more than 18% of the buildings fail to fulfill even two criteria, which is undesirable, as this heavy weight environmental feature has a LEED score of 18. The maximum percentage is in 'very good' condition (seven buildings), whereas 'very poor' and 'poor' conditions are the lowest (three buildings each) for construction and demolition waste management. In the case of water use reduction, six buildings lie in both 'very good' and 'good' conditions respectively (27.27%), whereas four buildings are in 'very poor' condition. Lastly, five buildings are categorized separately into 'very good' and 'good' conditions regarding water efficient landscaping. However, almost 41% of buildings are either in 'very poor' or 'poor' condition. Being a heavy weight environmental feature, all the buildings are expected to fulfill more than two criteria for water efficient landscaping.

Fig.3 summarizes the dominant conditions of seven environmental features among 22 buildings under consideration for this investigation. The figure also indicated that most buildings have either very good or good conditions for environmental features except for renewable energy. In all the buildings surveyed, the state of renewable energy was either very poor or poor since they failed to fulfill either any criteria or just fulfilled one criterion. The main challenges behind the non-compliance of criteria for renewable energy may be a lack of proper awareness, lack of LEED construction teams, vendors, and consultants in Bangladesh, limitations in training of engineers and other technical teams, and limitations of Government incentives and enforcement. Mitigation may be possible by establishing organizational supportive policies and regulations, creating awareness through education and training programs, and deploying the appropriate green consultant to implement. Nevertheless, the seven environmental features did not inherently indicate that all buildings were in a state of sufficient condition to be considered green buildings. The actual objective of green building necessitates the enhancement of several features and the satisfaction of additional criteria.

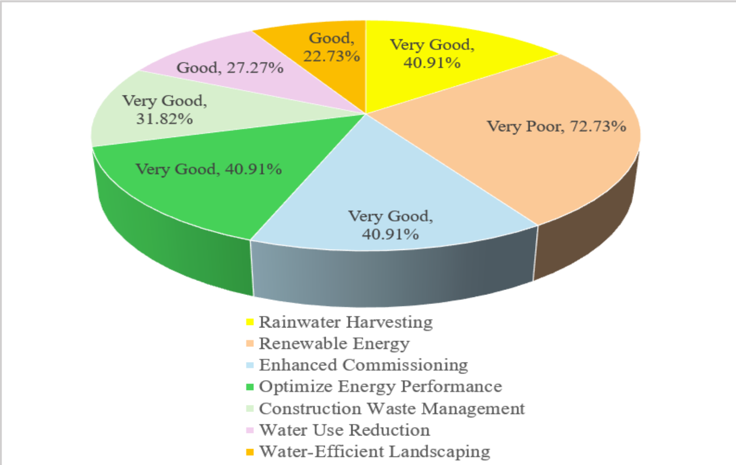

Fig. 3. Dominant condition of all environmental features in the buildings

The study found that the state of renewable energy in most buildings is quite inadequate, posing a significant obstacle to the implementation of environment-friendly structures. Renewable energy, renowned for its environmental sustainability, could be substantial for tackling the increasing need for energy and reducing the impact of global warming. This will facilitate achieving a 10% reduction in energy cost savings which is the requirement of any building for LEED certification (Dobiáš & Macek 2014). As Bangladesh is a tropical country with abundant sunlight, solar energy can significantly increase the contribution of renewable energy to a higher level. Previous studies found that the energy requirement of buildings can be met by up to 83% in the case of solar energy integration and 15% when wind energy is incorporated into buildings (Chen et al. 2024).

Active solar building integration systems can modify the attributes of buildings and mitigate the adverse environmental effects of constructing public spaces. Furthermore, the combined exploitation of solar energy with photovoltaic technology may offer a significant advantage in enhancing energy efficiency and decreasing energy consumption (Vassiliades et al. 2022).

There are numerous challenges associated with the implementation of green buildings in Bangladesh. The most likely challenges are absence of government incentives, the hesitation of building owners, and the lack of environmental awareness (Khan & Shammi 2022). Myths regarding the cost-effectiveness of green buildings, market understanding, and lack of knowledge regarding the planning and construction of green buildings are other considerable obstacles, in addition to the scarcity of resources and skills (Chowdhury et al. 2021, Al-Fahim et al. 2024).

Current construction policies incorporate sustainability, but they do not rigorously enforce it. A comprehensive strategy is necessary to resolve these issues. This necessitates increased public and academic awareness, robust government support, funds, strict laws, and industry development that emphasize skill development, material availability, and market promotion of green structures. Financial incentives, for instance, a 30% subsidy for adopting renewable technologies, could enhance the appeal of these innovations (Chen et al. 2024).

Implementing new legislation that mandates sustainable practices in new construction and government certifications for green developers is imperative. Green certification enhances innovation and motivation for more energy and water efficient equipment (Dobiáš & Macek 2014). Individuals and institutions must collaborate to share knowledge and overcome technical obstacles and material scarcity. Fostering research in engineering institutions and incorporating green construction into higher education is critical for developing a competent workforce and promoting sustainable practices.

CONCLUSION

The environmental features of 22 green buildings in Dhaka North City Corporation were studied in this work. Furthermore, this study reviewed the challenges to implementing green buildings in Bangladesh and recommended mitigation strategies. It has been shown that while some green construction features, such as rainwater management and water efficiency, are generally effectively implemented, integrating renewable energy remains a considerable challenge. The widespread use of solar energy, a form of renewable energy, is necessary to enhance energy usage efficiency, decrease energy demand, and eventually fulfill the objectives of constructing green buildings.

Various challenges should be overcome to achieve a completely green building sector in Bangladesh, including government apathy, financial incentives, investor hesitancy, and knowledge shortages. To close this gap, a multifaceted strategy encompassing policy reforms, public awareness, industry development, and capacity building. Focusing on these areas may create a long-term built environment in Bangladesh that benefits both the environment and the economy.

Green building implementation in Bangladesh must address renewable energy concerns to increase energy efficiency, lower carbon emissions, potential energy security, and improve economic outcomes. Establishing legislative frameworks, offering financial incentives like tax credits, subsidies and low-interest loans, and raising public awareness are necessary for the government to encourage sustainable construction.

This study provides a fundamental understanding of the green building scenario in Dhaka North City Corporation. It serves as a road map for future research and policy interventions to speed up Bangladesh's adoption of sustainable development goals. Future research should explore alternative green certifications for Bangladesh, public-private partnerships, and the impact of government policies and financial incentives on green building development. It should also address industry knowledge gaps and methods for integrating renewable energy, particularly solar, to enhance energy efficiency and sustainability.

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