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Perception and Barriers to Implementation of Intensive and Extensive Green Roofs in Dhaka, Bangladesh

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Abstract: Buildings are one of the biggest consumers of fossil fuels, and thus, contribute largely to greenhouse gas emissions. As a result, a large number of studies have been conducted and innovative ideas or green solutions have been invented, adopted, and implemented across the globe. These solutions are often contextual and heavily dependent on local environmental and socio-economic factors. Green roofs are such an example. Green roofs (both intensive and extensive) for buildings have been successfully adopted in many countries around the world. Bangladesh, a developing country that can benefit from green roofs, seems to remain in complete darkness regarding its potential. The objective of this study is to identify the reasons why green roofs have not been widely implemented in Bangladesh, especially in the capital Dhaka, even though, theoretically, the climatic conditions of this country favor this technology. This study focuses on the perception of the construction industry to comprehend the possible obstacles they are facing towards using green roofs in their designs. A questionnaire study was conducted among architects, engineers, construction managers, contractors, and owners who are at different levels of experience in their respective fields. The results indicate a gap in knowledge and misconceptions, which are major hindrances to the implementation of green roofs.

Keywords: buildings; energy; green roofs; mega city; Bangladesh; urban heat island

1. Introduction

Buildings account for 40% of total global energy consumption [1], 33% of raw materials, and 50% of electricity [2]. In the United States alone, commercial and residential buildings together consume almost 40% of the primary energy and nearly 65% of the electricity [3]. Much of this energy is coming form of burning of fossil fuels for which the key environmental impact is the emission of greenhouse gases (GHGs). In the last few decades, global warming and the hike in energy use, despite the energy deficiency as well as lack of energy security, have resulted challenges in the construction industry, including the unsustainable extraction of resources to meet the demand of booming construction industries, particularly in developing countries. In response to these problems,

global leaders in sustainability, environmental activists, along with civil engineers, architects, and key professionals in building industries have extensively focused on the "greening" of existing and new buildings. As a result, a number of key research works have been conducted to address these issues from various perspectives [4,5]. These perspectives include use of materials, design of substrate layers, selection of vegetation types, performance on water retention capacity, reduction of indoor thermal energy, and smart technologies for green roofs [5–10]. Green roofs retain storm water [11], improve ecosystem multi-functionality [12], act as fire protection, improve air quality [13], and mitigate the urban heat island effect [14].

There is a dearth of information regarding green roof practices in Bangladesh. To the best of our knowledge, only a handful of studies have specifically and partially addressed this topic in the context of Bangladesh [15,16]. Thus, any research in this direction can be considered as a significant step in the right direction. A study by Rashid and Khan [17] investigated the economic and environmental value of having potted plants on rooftops of residential buildings in Bangladesh. To start with, the potted plants in their research do not truly comply with the definition of a green roof. The objective of the research was to explore the thermal behavior of a green roof under the influence of vegetation kept in small pots and to identify the potentiality of vegetation types on rooftops in warm–humid tropical climates, such as in Bangladesh. The field measurements were carried out on two rooftops of multi-storied residential buildings in Dhaka, one having the designed rooftop-potted planting and the other one being bare. The results found a significant reduction in temperature for the roof with plotted plants. The other study by Rashid and Khan [18] partially focused on green roofs and their impact on environmental sustainability to promote the clean and healthy urban growth of buildings. There was no major difference in the outcomes of these studies and they lacked the inclusion of perspectives on the concept and application of green roofs. It is therefore logical to look at people's perspectives regarding the issue of green buildings to effectively overcome any hindrances in the application of green roofs as part of greening existing buildings as well as new buildings. For instance, people's preference for a landscape is based on their ability to understand the landscape, apprehend its value and potentiality, as well as the familiarity of the landscape. In other words, landscape preference affects place attachment and is influenced by experience and familiarity. Similarly, in this study, it was intended to comprehend people's knowledge and their ability to understand the benefits of green roofs in the context of Dhaka. The only difference here is that we narrowed down our samples to only "practitioners" in the construction industry, with the presumption that they perceive green roofs to be implemented or accepted at a mass scale.

Other researchers [19] have also conducted studies on people's perception to comprehend the functionality of green features. Smardon and Barnhill-Dilling [20] focused on green infrastructure attitudes and perceptions from stakeholders in Syracuse, New York. The study adopted focus group discussions and surveys, while the analysis was subjective and not based on any statistical models. Another survey was conducted with 450 respondents—mostly with students and local residents—about their preconceptions and thoughts regarding green roof design alternatives in the city Seville, Spain [21]. They were shown pictures of green roofs and the data received were processed through statistical analyses. Similarly, a group of researchers [22] studied resident perceptions and expectations of rooftop gardens in Singapore. The study conducted questionnaire surveys by taking the residents to nearby green roofs, and some respondents did not recognize the green roofs. After analysis, the results were expressed in terms of percentages. For example, when asked, "Do you think we should provide more rooftop gardens in Singapore?", about 80% of the respondents voted for more rooftop gardens. Another study [23] examined the barriers to implementing extensive green roof systems in Hong Kong and identified that a lack of promotion and incentives from the government and increasing maintenance costs were the top barriers to implementation. Eleven different barriers were identified in the literature and a survey was carried out among engineers, architects, surveyors, academician, etc. The respondents were invited to give their opinion on the relative significance of each barrier to the implementation of extensive green roof systems for existing buildings in Hong Kong.

Despite the usefulness of green roof technology, it is neither practiced in existing nor new buildings in Bangladesh, and no significant studies have been done in perspective of Bangladesh. Little effort has been given to discover its full potential through either allocation of funds or research. Green roofs can be two types: intensive and extensive based on their characteristics such as purpose, structural requirements, internal comfort, installation cost, irrigation requirements, and accessibility [5]. Intensive green roofs are often accessible, consisting of large plants, shrubs, and trees, and can be used for recreational and leisure purposes (Figure 1a). Intensive roofs are characterized by their greater weight (200–500 kg/m^2), high capital cost (\$540/m^2), high irrigation requirements, fertigation, and maintenance requirement. On the other hand, extensive green roofs are often not accessible, consisting of low-growing plants such as succulents, herbs, and grasses (Figure 1b), and are characterized by low weights (60–150 kg/m^2), low capital costs (130–165 \$/m^2), low plant diversify, and minimal irrigation, nutrient, and maintenance requirement [24,25]. A relative comparison of intensive and extensive green roofs is shown in Table 1. Basically, extensive green roofs are well suited to roofs (sloping) with little load bearing capacity and sites which are not meant to be used as green roofs. They are primarily built for their environmental benefits. Since the majority of buildings out of the 360,000 in Dhaka consist of flat roofs made from reinforced concrete coarse (RCC), the application of intensive green roof is feasible, provided the structural load is taken into due consideration with good drainage facilities. The unplanned growth of Dhaka, both horizontally and vertically, is causing a major environmental threat in terms of deteriorating air quality, lack of available green space, and managing urban runoff. Therefore, this research is an effort to analyze green roofs' suitability in order to determine the possible hindrances to its applicability in Bangladesh, particularly in Dhaka.

(**a**) (**b**)

Figure 1. Illustrative green roofs in Dhaka: (**a**) intensive green roof (Basundhara, Dhaka); (**b**) extensive green roof (Gushan, Dhaka).

Table 1. Difference between intensive and extensive green roofs.

Intensive Green Roof	Extensive Green Roof
Thickness less than 15 cm	Thickness greater than 15 cm
Often accessible consisting of large plants, shrubs, and trees	Often not accessible, consisting of low-growing plants such as succulents, herbs, and grasses
Greater weight (200–500 kg/m^2)	Low weight (60–150 kg/m^2)
High capital cost (540 \$/m^2)	Low capital costs (130–165 \$/m^2)
More irrigation, fertigation, and maintenance required	Minimal irrigation, nutrient, and maintenance
Retains water from 70–130 l/m^2	Retains water from 27–45 l/m^2

2. Green Roofs: A Perspective Based on Energy and Climate

2.1. Energy and Power Sector

Problems generated due to the energy crisis and induced effects of climate change are very common in overpopulated developing countries, and Bangladesh is no exception. Bangladesh has become one of the most densely populated countries in the world, with an area of 147,570 km^2 and a population of 149,772,364. Dhaka, the capital of Bangladesh, a fast-growing megacity of South Asia, had a population of 2.2 million in 1975, which has increased to 18 million in 2017, with a growth rate of 4.56% annually [26]. Data from the "Household Income and Expenditure Survey 2016" [27] revealed that about 28% of the population was considered extremely poor (urban: 7%; rural: 21%, individually). Limited access to essential energy services is one of the vital causes leading to low economic development and poverty in the country. The annual report from the Bangladesh Power Development Board revealed that the country's per capita electricity production was only 351 kW/h, which is quiet low compared to South Asian Association for Regional Cooperation (SAARC) countries such as India, Pakistan, and Sri Lanka. Around 83% of the population of Bangladesh has access to electricity [28]. Moreover, the electricity supply is not very reliable and often cannot meet the peak demand. It is estimated that Dhaka needs 0.12 million new housing units or flats each year based on the population growth rate of 4.56%; it would be a great challenge to meet the increasing energy needs [29].

There is a need for construction or renovation of buildings to be energy efficient and green roofs can play an important role in reducing the energy demand. But the energy demand and energy consumption patterns often depend to a great extent on weather conditions [30]. This is why decisions should be taken in accordance with the climatic conditions of a country. Green roofs can play an important role in the reduction of energy use in tropical countries influenced by hot and humid climates [31].

2.2. Climate

Bangladesh is a tropical county and its climate is characterized by heavy rainfall, high humidity and temperatures, and fairly marked seasonal variations composed of summer, rainy season, winter, and spring. The capital, Dhaka (located in central Bangladesh), experiences a wet, hot, and humid tropical climate. The city has a distinct monsoonal season, with an annual average temperature of 25 °C and average monthly temperature of 18 °C in January and 32 °C in May. Approximately 87% of the annual average rainfall (2123 mm) occurs between the month of May and October [32]. Bangladesh has been categorized as the 6th Most Vulnerable Country (MVC) among the Least Developed Countries (LDC), facing the extreme consequential effects [33]. Even though Bangladesh is under serious environmental threat, no concrete steps have been taken to address the problems. Specially, the construction industry in the country is not taking many rectifying actions. Green roofs have a great potential for reducing indoor temperatures due to the country's hot and humid climate and current environmental crisis.

3. Green Roofs to Overcome Urban Problems

3.1. Urban Flooding

Dhaka, particularly the old part of Dhaka, has been suffering from urban flooding for the last few decades. The slightest amount of rainfall can result in serious flooding and inundate old parts of Dhaka for several days, causing miserable conditions. This scenario is quite common in the monsoon season, when 80% of the precipitation occurs. The water depth in inundated areas even reaches 50–70 cm, which creates heavy traffic congestions, paralyzing city lives causing economic loss. The dense buildings with concrete paved roofs further contribute to faster runoff. Figure 2 postulates urban flooding in Dhaka. The green roofs composed of vegetation can not only retain water and reduce the rate of runoff,

but also improve the water quality [34]. Though Wang et al. [35] argue that the substrate layer of green roofs could be the source of contaminants in the case of heavy rains, the pollution can be controlled with some simple measure such as the use of a mixture of activated charcoal and/or pumice with perlite and vermiculite. Nevertheless, green roofs can effectively retain [36] storm water runoff to an average of 68–84.3% [11,37,38] depending on roof types, and allowing less water requited to be drained out. A study carried out by Murphy et al. [39] demonstrated that green roofs were more effective at reducing stormwater runoff during periods of light precipitation (51.6% runoff reduction) compared to periods of heavy precipitation (35.8% runoff reduction). It should be noted that intensive green roofs can retain water from 70–130 L/m^2 (https://zinco-greenroof.com/systems/intensiv) while extensive green roofs can retain water from 27–45 L/m^2 (https://www.urbanscape-architecture.com/how-much-does-a-green-roof-weigh/) depending on the types of vegetation and substrate used.

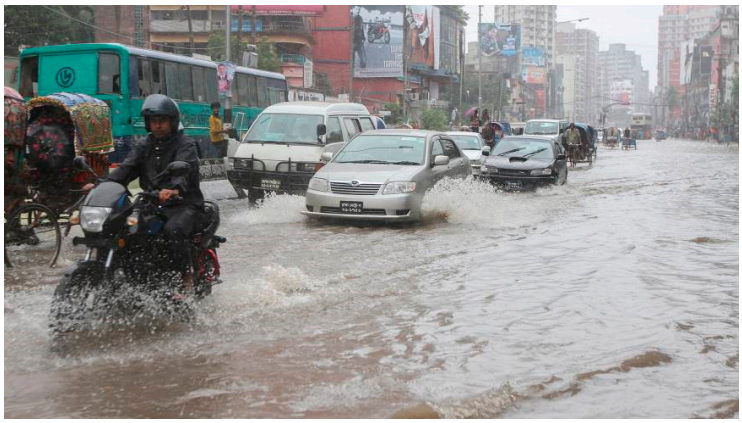

Figure 2. Flooding in Dhaka resulting from rainfall (Photo captured by Nashirul Islam/ Dhaka Tribune).

3.2. Energy Efficiency

Developers in Dhaka hardly give any emphasis on energy savings or energy efficiency during the construction of buildings. There are no building codes which focus on energy savings proposed by the Government of Bangladesh. Some studies carried out on residential buildings indicate [40] that architects and developers are ignorant of the application of various green features which can transform conventional buildings into energy-efficient buildings. The client's constant demand of having maximum space in multi-storied buildings leaves architects and designers no options for making buildings energy efficient. The Unique Building Identifier (UBID) was developed as a natural key to match building energy and attribute data for recording energy performance [41]. Note that green roofs having a 1% increase in tree canopy cover can reduce air temperature by 0.14 °C [42]. Green roofs can reduce 15.2% cooling energy demand which is more than the conventional one in a sub-tropical climate for a country like China [43], as green roofs substantially reduce heat fluxes (40% up to 75%) [44]. An addition of 30% of green roof areas can contribute to the saving of electricity consumption by 2.56 (W/m^2/day) [45]. A green roof strategy in its simplest application can provide energy savings up to 17% [46], while another study carried out under a hot–humid climate reveals energy savings in the range of 24% to 35% [31].

3.3. Urban Heat Island Effect

An investigation was carried out [47] to detect the consequences of land-cover changes on land surface temperature (LST) in the Dhaka Metropolitan (DMP) area using Landsat satellite images from 1989, 1999, and 2009. Simulations were done to predict its impact on land-cover changes for 2019 and 2029, respectively, using an artificial neural network (ANN). Based on the existing temperature trends, it is expected that 56% and 87% of the DMP area will likely have temperatures greater than 30 °C in 2019 and 2029, respectively [47]. The study concluded that the amount of built-up

area has doubled during the last two decades and is expected to increase three-fold and four-fold in the next 5 and 10 years, respectively. A study carried out by Li et al. [48] demonstrated that the urban heat island (UHI) reduced by 1 °C in the Baltimore–Washington metropolitan area by covering approximately 30% of the roof areas with green roofs. The vegetation used as green roofs can mitigate the urban heat island effect along with the expenses due to the use of heating and air conditioning [45–47,49]. The significant cooling effect of green roofs during the daytime can probably last throughout the night due to the reduced heat storage in the urban canopy [50]. Dhaka has a population of over 15 million stretched over 500 km^2, which includes 12.12% agricultural land, and as a result, the city suffers from a lack of green space, and is thereby affected by the urban heat island (UHI) effect [16].

3.4. Air Pollution Problems

The air in Dhaka is polluted from a large number of vehicles which have already exceeded their service life and are releasing poisonous gases into the environment. The huge concrete jungle in the city lacks adequate greenery. Every day the city takes another step towards its own doom. However, adding a little greenery on the roof of every building may be a step forward towards improving the city's air quality by reducing air pollution [50]. Annual carbon accumulation of green roofs is in the range of 0.375–30.12 kg carbon/m^2 [51].

A study [52] compared the economic feasibility of hourly pollutants removal, such as NO_2, SO_2, CO, PM_{10}, and ozone using various types of green roofs in the Toronto municipal area. According to their research, properly designed green roofs (grass on roofs, placing shrubs or other small plants on a roof) could boost the reduction of the effects of air pollution. Green roofs can also prove to be a good solution for the city's sound pollution. An experimental study [53] observed the influence of green roofs on sound absorption. In a street valley situation where the street is bordered by buildings on both sides creating a canyon-like environment, the facade noise load in the non-exposed faces of the buildings are largely influenced by the presence of a green roof. According to the study, a flat roof generally results in the best average shielding from noise pollution. Green roofs that are designed using local soil and locally found vegetation species can also provide safe habitats for local insects, bees, and birds; in other words, it would provide wildlife habitat and biodiversity enhancement [54].

4. Methodology

A comprehensive survey was conducted in this study to capture people's perceptions and barriers in implementing green roofs in Dhaka. Taking insights from the literature, a questionnaire consisting of 13 questions was designed that included general understanding and distinguishing between intensive and extensive green roofs; factors affecting green roof implementation; and measures to enhance green roof practice for new and existing buildings. The questionnaire was divided into two parts. To ensure that the responses of the survey were reliable, the first part was intended to gather basic information about participants and their working experiences. The second part of the survey consisted of specific questions regarding green roofs. The respondents were asked to provide their answers based on a five-degree Likert scale, such as "not at all familiar" to "very familiar", "never" to "always", and "strongly disagree" to "strongly agree". Moreover, besides the listed measures, the respondents were encouraged to provide additional guidelines/suggestions to improve implementation of green roofs. Please see the Appendix A for details of the survey questionnaire.

As mentioned earlier, the survey was restricted to construction professionals since they are the pioneers in implementing green roofs. Moreover, a very low number of green roofs indicates that perceptions about the benefits and implementation strategies of green roofs are limited.

The questionnaire was distributed to 100 construction professionals including owners, architects, engineers, project managers, contractors, and site engineers/supervisors. A sum of 63 responses was received depicting a response rate of 63%.

Data Analysis

Relative Important Index (RII) was used to evaluate the familiarity and level of agreement of green roofs using the following equation.

$$RII = \frac{\sum_1^5 W_i X_i}{4\sum_1^5 X_i} \quad (1)$$

where, i = index of response category, and i = 5, 4, 3, 2, and 1 for not at all familiar, slightly familiar, somewhat familiar, moderately familiar, and very familiar, respectively, in the case of familiarity responses, and, i = 5, 4, 3, 2, and 1 for strongly disagree, disagree, somewhat agree, agree, and strongly agree, respectively, for the responses on different factors.

W_i = weight given to the ith response and W_i = 4, 3, 2, 1, and 0, respectively.

X_i = frequency of the ith response.

Spearman's rank correlation test was also used (see Equation (2)) to assess the level of agreement among different groups of respondents.

$$r = 1 - [(6\sum d^2)/(n^3 - n)] \quad (2)$$

where, r = Spearman's rank correlation among two groups.

d = rank differences.

n = number of rank pairs.

5. Results and Discussion

Table 2 shows the background of respondents including their areas of expertise, working experience, number of completed projects, and building types, and if they were involved in projects with green roofs. Although many of the respondents were engineers, as can be seen from Table 2, there was a wide range of expertise with a significant number of participants (over 70%) having experience of more than five years. Moreover, almost three-quarters of the participants was involved in at least four completed projects. These backgrounds warrant better knowledge sharing through the provided responses. Table 2 also depicts that the majority of the buildings were either residential or commercial, which is common in Dhaka and all over the world. Furthermore, it should be noted that about half of the respondents were involved in a project with a green roof. Such a fair distribution of the responses indicates that the obtained results regarding the factors affecting green roof implementation in Dhaka were representative. Note that all the participants (irrespective of their expertise) were given equal weightage for their responses.

The next part of the survey started with gathering information about familiarity with the two types of green roofs and if those were being implemented in the buildings of Dhaka. At this point, two pictures were shown to the respondents: the first one was a picture of an intensive green roof (commonly known as a rooftop garden) and the second picture was an extensive green roof (please refer to the Appendix A). Table 3 depicts the familiarity of green roofs among the participants. As can be seen from the first part of Table 3, familiarity was categorized based on RII values calculated from all responses. Participants were found somewhat familiar with intensive green roofs, which is typical of rooftop gardens. Nevertheless, they were not very familiar about extensive green roofs, even though all the respondents were construction professionals. This depicts the scenario of a very low level of awareness regarding extensive green roof systems despite the fact that this type of roof was found to be effective by many means [55]. The remaining parts of Table 3 compare familiarity levels by separating responses of participants who were involved in some green roof projects and the participants who were not involved with any green roof projects. As expected, it was found that participants who had no experience with working with green roofs were not familiar with extensive green roofs at all.

Table 2. Respondents' background.

Item	No. of Respondents	Percentage
Profession		
Architect	8	12.7
Company Owner	3	4.8
Contractor	2	3.2
Project Manager	9	14.3
Site Engineer/Supervisor	20	31.7
Structural Engineer	21	33.3
Years of experience		
0–5	17	27.0
6–15	25	39.7
16–25	17	27.0
25+	4	6.3
Number of projects done		
0–3	14	22.2
4–6	13	20.6
7–10	19	30.2
10+	17	27.0
Type of building		
Residential		55.6
Commercial		30.9
Governmental		7.9
Educational		2.9
Hospital		2.3
Other		1.1
Number of building stories		
1–2 story		44.52
Multi-story		55.48
Involved in a project with a green roof?		
Yes	29	46.0
No	34	54.0

Table 3. Familiarity with green roofs.

Type of Green Roof	RII	Familiarity
All responses		
Intensive	0.50	Somewhat familiar
Extensive	0.17	Not at all familiar to slightly familiar
Participants were involved in green roof		
Intensive	0.60	Familiar
Extensive	0.28	Slightly familiar
Participants were not involved in green roof		
Intensive	0.43	Somewhat familiar
Extensive	0.09	Not at all familiar

Table 4 shows how often green roofs were seen in buildings in Dhaka. As evident from Table 4, the RII values that reflect how often participants saw two types of green roofs are very close to the RII values in Table 3. This confirms that the knowledge of green roofs (i.e., familiarity level) was closely related as people see them being implemented in the buildings.

Table 4. Presence of green roofs in Dhaka.

Type of Green Roof	RII	Familiarity
All responses		
Intensive	0.49	Sometimes
Extensive	0.17	Never to Rarely
Participants were involved in green roof projects		
Intensive	0.57	Sometimes
Extensive	0.23	Rarely
Participants were not involved in green roof projects		
Intensive	0.42	Sometimes
Extensive	0.12	Never to Rarely

The survey results in Table 5 depict people's general perception about green roofs by categorizing positive and negative outcomes. The indicators of gain or loss of implementing green roof were ranked based on the RII values. Most of the participants agreed that benefits can be gained by implementing green roofs. Improving public health and adding value/marketability of the property were ranked top, with close RII values of 0.779 and 0.778, respectively. Air quality, energy efficiency, and urban heat island effect can be significantly improved by implementing green roofs which was evident from the literature [31,45,46,49,50]. These were found as the other major benefits according to the survey results. However, improving rainwater runoff problems was ranked as the least beneficial.

Table 5. General perception about green roofs.

Item	RII	Overall Perception	Rank
Positive perception			
Improve public health in the city	0.779	Agree	1
Add value/ marketability of the property	0.778	Agree	2
Improve air quality	0.75	Agree	3
Improve energy efficiency of building	0.74	Agree	4
Reduce urban heat island effect	0.73	Agree	5
Increase wildlife and biodiversity	0.71	Agree	6
Increase aesthetics	0.64	Agree	7
Improve noise absorption	0.60	Agree	8
Improve rainwater runoff problems in the city	0.40	Somewhat Agree	9
Comparison of intensive versus extensive green roof			
In terms of benefit of green roofs, there is no difference between intensive green roofs (rooftop gardens) and extensive green roofs	0.56	Somewhat Agree	-
Negative perception			
Dampen the roof/affect roof life	0.46	Somewhat Agree	1
Add unnecessary cost without much benefit	0.40	Somewhat Agree	2

When responses regarding the negative effects of green roofs were analyzed, they ranked as the lowest. This implies that the general perception about green roofs was very positive with little concern about dampening of roof and cost of implementing green roofs.

Table 5 also depicts participants' general judgment about intensive and extensive green roof systems. They generally agreed that there was no difference between these two roof systems in terms of benefits that can be gained from green roofs. The study by Tam et al. [55] also found that both green roof systems have similar benefits. Nevertheless, they argued that extensive green roofs have higher cost savings compared to intensive green roofs, yet the implementation of extensive green roofs is low. They further investigated constraints and solutions in implementing extensive green roofs in

the perspective of Hong Kong. It is also evident from Tables 2 and 3 that practice of extensive green roof systems in Dhaka is very low.

The next part of the survey examined the constraints or difficulties in implementing extensive green roofs in perspective of Dhaka, Bangladesh. The ranking of the factors affecting the implementation of extensive green roofs is presented in Table 6. Lack of incentive from the government was found to be one of the major constraints, ranked 1st and 4th for existing and new buildings, respectively. Although increased maintenance cost was ranked 2nd according to the survey result, it could be a misperception among the participants. This is opposite to the findings of Tam et al. [55] who showed that maintenance cost for extensive green roof is less compared to intensive green roof. Another concern was additional construction cost which ranked 8th. This is particularly characterized by the nature of the construction industry in Bangladesh. As mentioned in Shams et al. [56], private developers are the major contributor in constructing housing units in Dhaka, who are reluctant to spend any extra money on greening buildings if it does not directly translate to any profit.

It is worth mentioning that among all the constraints, incapability of implementing extensive green roofs, such as lack of knowledge, lack of skilled manpower, design difficulties, and construction difficulties, were ranked the lowest. Therefore, more emphasize should be given to other constraints such as regulatory control (e.g., building codes), lack of owner/client's interest, and lack of awareness about sustainable environment.

Table 6. Difficulties or constraints in implementing extensive green roofs.

Item	RII	Level of Agreement	Rank
Lack of incentive from the government to owners for existing building	0.80	Strongly agree	1
Increase in maintenance cost	0.75	Agree	2
Require regular maintenance	0.71	Agree	3
Lack of incentive from the government to developers	0.71	Agree	4
Lack of owner/client's interest	0.65	Agree	5
Not included in the building code	0.60	Agree	6
Lack of awareness about sustainable environment	0.56	Somewhat Agree	7
Additional construction cost	0.53	Somewhat Agree	8
Increase in structural loading	0.51	Somewhat Agree	9
Additional design cost	0.45	Somewhat Agree	10
Lack of knowledge	0.43	Somewhat Agree	11
Lack of skilled manpower	0.40	Somewhat Agree	12
Difficulties in design	0.40	Somewhat Agree	13
Construction difficulties	0.33	Disagree	14

Table 7 suggests that implementation of extensive green roofs is very much feasible after realizing the benefits it offers and through encouragement from the government.

Table 7. Feasibility of extensive green roofs in Dhaka.

Item	RII	Level of Agreement	Rank
Do you think government should promote extensive green roofs in Dhaka?	0.80	Strongly agree	1
Would you support to construct a green roof on the building where you live?	0.80	Strongly agree	2
Do you support the implementation of extensive green roofs for existing buildings?	0.70	Agree	3
Do you think extensive green roof systems are feasible to implement for existing buildings?	0.66	Agree	4

To further enhance the implementation of extensive green roofs, several measures were identified and assessed based on the survey responses. Table 8 depicts the effectiveness of each measures in terms of RII values and level of agreement. As can be seen, incentive from government to developers of new buildings ranked 1st. Other effective measures were found to be regulation on

keeping green spaces for new development, increase public awareness about sustainable environment, educate construction professional about green roofs, and government incentives to the owners of existing building, which ranked 2nd–5th, respectively. However, new building codes incorporating green roof requirements, and green roof regulations to improve rainwater runoff problems ranked the lowest. The findings in Table 8 imply that the participants preferred voluntary approaches over mandatory approaches to improve the implementation of extensive green roofs.

Table 8. Measures to enhance the implementation of extensive green roof systems for new and existing buildings.

Item	RII	Level of Agreement	Rank
Incentives from government to developers	0.80	Strongly agree	1
Percentage of green spaces which should be mandatory for property development projects	0.77	Agree	2
Increase awareness about sustainable environment	0.76	Agree	3.5
Include green roofs in the educational curricula for anyone entering the construction industry	0.76	Agree	3.5
Incentives from government to owners of existing buildings	0.76	Agree	5
Bonus to developers (e.g., reduced government fee) who construct certain green roof areas	0.70	Agree	6
New building codes for developers/contractors	0.61	Agree	7
Green roof regulations to improve rainwater runoff problem	0.49	Somewhat Agree	8

The survey results were further synthesized to see if the participants who were involved with green roof projects had different views than the participants with no experience of green roof. Spearman's rank correlations for different categories of responses are presented in Table 9. The table shows that the correlation values were very high for the response categories of general perceptions about green roofs and constraints in implementing extensive green roofs, which implies that there was no large differences in the views between the two groups of participants. The correlation values were slightly lower for feasibility and measures to enhance implementation of extensive green roof systems, which depicts that the two groups of respondents had different views in some responses.

Table 9. Spearman's rank correlation between the respondents involved and not involved in green roof projects.

Item	Spearman's Rank Correlation
General perception about green roof	0.932
Difficulties or constraints in implementing extensive green roofs	0.882
Feasibility of extensive green roofs in Dhaka	0.800
Measures to enhance the implementation of extensive green roof systems for new and existing buildings	0.786

Apart from answering the listed survey questions, participants were encouraged to provide suggestions/guidelines to improve the implementation of extensive green roofs and the survey received few suggestions accordingly. One of the important suggestions was to make proper campaigns since people were not aware about the benefits of green roofs. A lack of technical know-how and poor knowledge resulting from inadequate information on the benefits of green roofs act as significant barriers to its installation. Moreover, there were a few concerns that might hinder the implementation of extensive green roofs, such as maintenance requirement and load-bearing capacity of existing buildings to install extensive green roof systems. Some respondents showed serious concerns about mosquitos and bugs growing on the green roofs. Similar concerns were also found in Smardon and Barnhill-Dilling's [20] study and they identified it as a misconception.

6. Conclusions

It is evident from literature that green roofs are an important part in greening buildings and can contribute significantly to environmental sustainability, especially in urban areas by many means, such as improvement in the urban heat island effect, energy savings, urban flooding, air quality, etc. Nevertheless, green roof implementation in the cities of Bangladesh, especially in the metropolitan Dhaka area where the environment is deteriorating at a rapid pace, is very low. This study explored people's perceptions, constraints, and measures in improving implementation of green roofs, particularly, extensive green roofs. A survey was conducted among construction professionals to gather general understanding and implementation strategies for green roofs. The survey revealed that some roof top gardens (intensive green roofs) are seen in the buildings of Dhaka. However, general understanding and the presence of extensive green roofs is very low, even though the cost saving is higher for such roof systems compared to intensive green roofs.

In general, respondents agreed that green roofs offer more benefits than the negative impact such as affecting/dampening roof life. It was found from the survey results that lack of government incentives, higher maintenance requirements, lack of owner/client interest, and lack of awareness about sustainable environment were the major hindrances in implementing extensive green roofs. The study also provided some guidelines/measures to enhance implementation of extensive green roof systems for new and existing buildings.

The study provided a comprehensive understanding of green roof scenarios in Dhaka, and the barriers and opportunities for improving extensive green roof implementation. The findings of this study may serve as a guide for the relevant stakeholders of building projects in Dhaka to work with the major constraints following the provided recommendations. Therefore, it can be suggested that stakeholders should consider implementing extensive green roofs along with intensive green roofs, which is a current practice in Dhaka. Further study is necessary to develop specific regulatory controls and guidelines, structure of government incentives for developers and building owners, and necessary education for construction professionals as well as the residents in general.

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Appendix A

Questionnaire Survey on Green Roofs in Dhaka

Part 1: Basic Information

1. What is your profession?
   ☐ Architect ☐ Structural Engineer ☐ Site Engineer (supervisor)
   ☐ Contractor ☐ Company Owner ☐ Project Manager ☐ Other (please specify):
2. Are you working for government of private organization?
   ☐ Government ☐ Private
3. How long have you been in this profession?
   ☐ 0–5 years ☐ 6–15 years ☐ 16–25 years ☐ 25+ years
4. How many projects have you been involved in?
   ☐ 0–3 ☐ 4–6 ☐ 7–10 ☐ 10+
5. Among them, please classify the type of building(s) (give in percentage)
   a.

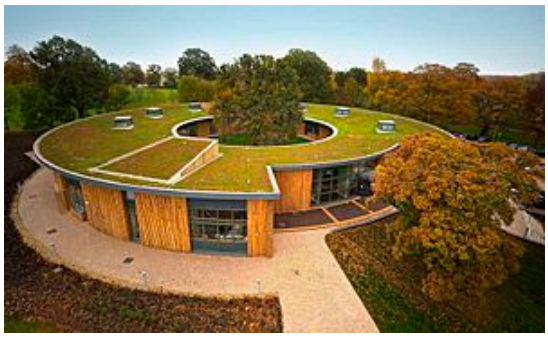
   1–2 story: Multistoried:

b.

Residential:	Commercial:	Governmental:
Hospital:	Educational:	Other (please specify):

Part 2: Green Roof

6. How familiar are you about two types of green-roofs as shown in figure?



(**a**) Extensive green roof

(**b**) Intensive green roof (rooftop gardening)

	Not at all familiar	Slightly familiar	Somewhat familiar	Moderately familiar	Very familiar
(a) Intensive green roof	☐	☐	☐	☐	☐
(b) Extensive green roof	☐	☐	☐	☐	☐

7. How often do you see each type of green roof in Dhaka city?

	Never	Rarely	Sometimes	Often	Always
(a) Intensive green roof	☐	☐	☐	☐	☐
(b) Extensive green roof	☐	☐	☐	☐	☐

8. Have you ever been involved in a project with a green roof?

☐ Yes ☐ No

9. General perception about green roofs

	Strongly disagree	Disagree	Somewhat agree	Agree	Strongly agree
(a) Increases aesthetics	☐	☐	☐	☐	☐
(b) Reduces urban heat island effect	☐	☐	☐	☐	☐
(c) Improves rainwater runoff problems in the city	☐	☐	☐	☐	☐
(d) Improves air quality	☐	☐	☐	☐	☐
(e) Increases wildlife and biodiversity	☐	☐	☐	☐	☐
(f) Improves energy efficiency of building	☐	☐	☐	☐	☐
(g) Improves public health in the city	☐	☐	☐	☐	☐
(h) Improves noise absorption	☐	☐	☐	☐	☐
(i) Adds value/marketability of the property	☐	☐	☐	☐	☐
(j) Dampens the roof/affect roof life	☐	☐	☐	☐	☐
(k) Adds unnecessary cost without much benefit	☐	☐	☐	☐	☐
(l) In terms of benefit of green roofs, there is no difference between intensive green roofs (rooftop gardens) and extensive green roofs (refer to the above figures)	☐	☐	☐	☐	☐

10. Difficulties or constraints in implementing extensive green roofs

	Strongly disagree	Disagree	Somewhat agree	Agree	Strongly agree
(a) Lack of knowledge	☐	☐	☐	☐	☐
(b) Lack of awareness about sustainable environment	☐	☐	☐	☐	☐
(c) Lack of owner/client's interest	☐	☐	☐	☐	☐
(d) Not included in the building code	☐	☐	☐	☐	☐
(e) Additional design cost	☐	☐	☐	☐	☐
(f) Additional construction cost	☐	☐	☐	☐	☐
(g) Lack of incentive from the government to developers	☐	☐	☐	☐	☐
(h) Lack of incentive from the government to owners for existing building	☐	☐	☐	☐	☐
(i) Increase in structural loading	☐	☐	☐	☐	☐
(j) Difficulties in design	☐	☐	☐	☐	☐
(k) Construction difficulties	☐	☐	☐	☐	☐
(l) Lack of skilled manpower	☐	☐	☐	☐	☐
(m) Increase in maintenance cost	☐	☐	☐	☐	☐
(n) Require regular maintenance	☐	☐	☐	☐	☐

11. Feasibility of extensive green roof in Dhaka

	Strongly disagree	Disagree	Somewhat agree	Agree	Strongly agree
(a) Do you think the government should promote extensive green roofs in Dhaka city?	☐	☐	☐	☐	☐
(b) Do you think extensive green roof systems are feasible to implement for existing buildings?	☐	☐	☐	☐	☐
(c) Do you support implementation of extensive green roofs for existing buildings?	☐	☐	☐	☐	☐
(d) Would you support to construct a green roof on the building where you live?	☐	☐	☐	☐	☐

12. Measures to enhance implementation of extensive green roof systems for new and existing buildings

	Strongly disagree	Disagree	Somewhat agree	Agree	Strongly agree
(a) Increase awareness about sustainable environment	☐	☐	☐	☐	☐
(b) Incentives from government to developers	☐	☐	☐	☐	☐
(c) Incentives from government to owners of existing buildings	☐	☐	☐	☐	☐
(d) Bonus to developers (e.g., reduced government fee) who construct certain green roof areas	☐	☐	☐	☐	☐
(e) Percentage of green space should be mandatory for property development project	☐	☐	☐	☐	☐
(f) New building codes for developers/contractors	☐	☐	☐	☐	☐
(g) Green roof regulations to improve rainwater runoff problem	☐	☐	☐	☐	☐
(h) Include green roof in the educational curricula for anyone entering the construction industry	☐	☐	☐	☐	☐

13. Please suggest any other measure you feel important to apply extensive green roof system

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