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ARTICLE

Understanding the Challenges of Implementing Green Roofs in Multi-Family Apartment Buildings: A Case Study in Khulna

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ABSTRACT

Green roofs are widely recognized for their multifaceted benefits to the environment, economy, and society, constituting the fundamental pillars of sustainability. These roofs contribute to the enhancement of bio-physical diversity, provision of food resources, regulation of temperature and rainfall-runoff patterns, creation of wildlife habitats, and augmentation of aesthetic and recreational value. While Bangladesh, with its favourable climatic conditions and rapid urbanization, possesses immense potential for harnessing the advantages of green roofs, their adoption remains limited in both research and practical applications within the country. Addressing this research gap, the present study aims to investigate the barriers impeding the implementation of green roofs in existing or new multi-family apartment buildings, focusing specifically on the city of Khulna. Through a combination of case studies and a comprehensive questionnaire survey administered to diverse stakeholders including apartment dwellers/owners, architects, developers, and government officials with varying levels of expertise, this research sheds light on the obstacles hindering Green Roof Implementation (GRI). The identified barriers encompass a lack of governmental policies, inadequate technological advancements, inaccurate estimation of economic benefits, and individual resistance. In light of the perspectives of various GRI stakeholders, strategic proposals encompassing policy, technical, economic, and social dimensions are presented to surmount these barriers. The outcomes of this study contribute to the dissemination of knowledge pertaining to the impediments to GRI implementation, thereby inspiring further research endeavours and enabling decision-makers to formulate robust policies facilitating the widespread adoption of green roofs.

Keywords: Barriers; Green roof; Implementation; Khulna; Public perspective; Sustainability; Sustainable development; Urban green

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1. Introduction

Cities worldwide are grappling with a range of social and environmental challenges, including global warming, energy shortages, deforestation, local climate change, air pollution, and natural hazards [1,2]. These issues are exacerbated by the inevitable process of urbanization aimed at improving living standards and economic prosperity, particularly in developing countries. To tackle these challenges and ensure urban resilience and livability, numerous measures have been implemented. For instance, many cities have developed plans for sustainable or low-carbon eco-cities with resilient homes, aiming to reduce environmental, economic, and social impacts and minimize resource consumption [3]. These initiatives span various sectors, such as urban greening through city forests [4], urban flooding mitigation through sponge cities [5], green roof implementation (GRI) [6], sustainable transportation systems to reduce energy consumption and carbon footprints [7], and sustainable construction for eco-friendly human settlements [8]. Green roofs, also known as eco-roofs, living roofs, or roof gardens, serve as additional layers on rooftops and are considered an ecological and sustainable approach to enhancing the urban and built environment [9]. Therefore, it is crucial to explore the implementation of green roofs (GRI) in practice to address pressing urban issues and promote sustainability.

Bangladesh, a tropical nation known for its abundant rainfall, high humidity, and notable seasonal variations such as summer, monsoon, winter, and spring, encounters unique difficulties. Specifically, Khulna endures a damp, scorching, and humid tropical climate. The presence of climate migrants occupying available spaces for shelter contributes to an increase in land surface temperatures in the region [10]. Within the group of Least Developed Countries (LDCs), Bangladesh is ranked as the 6th Most Vulnerable Country (MVC), exposing it to severe consequences [11]. In Bangladesh, rooftops are conventionally utilized for various purposes such as cloth drying, barbecuing, and occasional social gatherings. However, contemporary approaches to greening buildings emphasize integrating plant life and the infrastructure that sustains it into the building's design without compromising its conventional utility [12]. Particularly in cities where space is limited, green roofs offer significant private and public social, economic, and environmental benefits. Green plants are recognized for their therapeutic value [13], provision of urban wildlife habitats, enhancement of air quality, thermal insulation [10], natural filtration, increased city biomass, mitigation of climate change impacts, and regulation of indoor building climates through insulation against extreme weather conditions [14]. It is imperative to improve environmental quality by reintroducing nature into urban areas.

Information on green roof practices in Bangladesh is currently limited. Only a few studies have touched upon this subject to some extent within the context of Bangladesh [15,16]. Therefore, any research in this field would be considered a significant advancement. Despite the benefits offered by green roof technology, its implementation is not widespread in either existing or new buildings in Bangladesh, and there has been limited research specifically focused on the country's context. While green roofs are not a new concept in Bangladesh, their utilization in residential areas of Khulna remains unsatisfactory. Hence, this study examines the feasibility of green roofs and identifies potential barriers to their implementation in Bangladesh, with a specific focus on Khulna. To understand potential barriers, this study aims to assess residents' perceptions and formulate strategic recommendations for implementing green roofs on both new and existing apartment buildings, considering policy, technical, economic, and social factors.

2. Literature review

2.1 Definitions relevant to GRI

The loss of open spaces, along with the desire for greening, has ushered in the green roof (GR) idea, in which rooftops are used as alternative locations for planting vegetation [6]. The GR refers to building roofs that have a growth media and are entirely or

partially covered in vegetation [9]. Additionally, GR also referred eco roof, living roof, and roof garden, serves as an extra layered structure on rooftops [12]. It is a cutting-edge design method for attaining multiple objectives in terms of the environment, the economy, and society. By placing trees on the rooftops, green roofing first appeared in the Roman Empire and the Gardens of Babylon [17]. Construction of GR on multi-story buildings with large flat roofs is now possible due to advancements in methods and expertise in material (such as concrete and cement) and structure (such as reinforced and pre-stressed) [18].

Green roofs (GR) are mainly classified into two major groups: extensive and intensive roofs, also referred to as naturalistic or self-established vegetation [19,20]. The term "green roof" encompasses various definitions. According to Jim [21], it refers to any human-made building product installed on a roof, involving the construction of a structural framework with adequate mechanical strength. Another definition by Yu et al. describes a green roof as a roof that is either entirely or partially covered with vegetation and a growth medium [22]. This roof can have a flat or sloped surface, serving both as a functional roof and as a support system for vegetation. A green roof is composed of various elements that work together. These components include plants, a substrate enriched with nutrients, a water supply to support root growth, and a drainage layer to eliminate excess water (as shown in **Figure 1**).

Green roofs provide an ideal environment for supporting plant growth. **Table 1** presents a classification and comparison of the two main types of green roofs based on their intended functions and associat-

Table 1. Comparison between intensive and extensive GR [23].

Intensive GR	Extensive GR
Thickness less than 15 cm	Thickness greater than 15 cm
Accommodates large plants, shrubs, and trees	Accommodates low-growing plants such as succulents, herbs, and grasses
Weight: 200-500 kg/m²	Weight: 60-150 kg/m²
Approx. cost: 540 $/m²	Approx. costs 130-165 $/m²
Retains water from 70-130 l/m²	Retains water from 27-45 l/m²
More irrigation, fertilization, and maintenance required	Minimal irrigation, nutrient, and maintenance

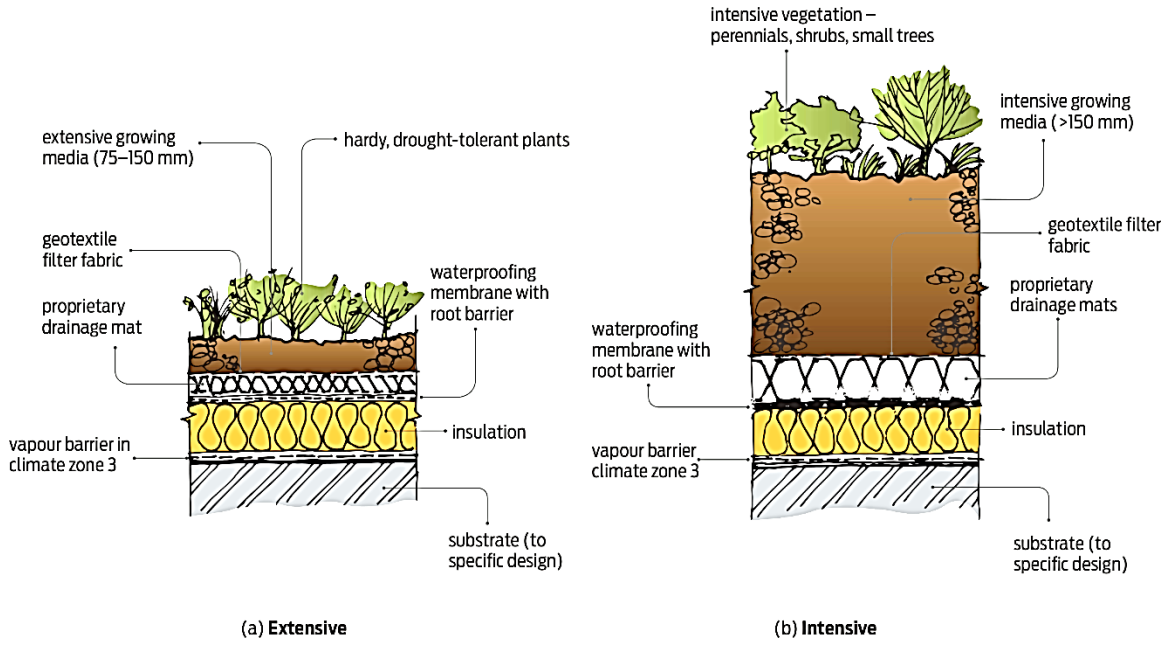

Figure 1. Green roof types [24].

ed costs. This comparison considers factors such as structural systems, types of vegetation, vastness, and installation costs. It is important to acknowledge that the overall cost of green roofs can vary across countries and among different green roof installers due to variations in material types and availability. Despite the potential advantages they offer, the implementation of green roofs, also known as Green Roof Implementation (GRI), has not received widespread attention. Therefore, it is crucial to consider strategies to encourage users to adopt and utilize green roofs, specifically GRI, in order to realize environmental, economic, and social advantages.

2.2 Identification of the barriers

The implementation of green roofs faces barriers in the economic, social, technical, and political domains, which hinder its widespread adoption. Rowe (2011) found that while green roofs have the potential to reduce pollutants, there are technical challenges that need to be addressed, such as plant selection, development of planting substrates, and the use of grey water [6]. Additionally, political and economic obstacles also need to be overcome. One of the challenges associated with green roofing is the high initial and ongoing costs, as well as the risk of roof leakage, despite its potential benefits in reducing urban flooding, rainwater runoff, energy consumption, and improving environmental performance. Ascione et al. (2013) conducted a study on the technical and economic feasibility of green roofs and concluded that in areas with insufficient rainfall, the additional costs for irrigation make green roofs less economically viable compared to conventional roofing systems. Even in regions with sufficient rainfall, offsetting the initial installation cost of green roofs became challenging [1]. These findings support the claim that green roofs face difficulties in becoming a cost-effective alternative to conventional roofing systems [25].

After conducting a comprehensive literature review, this study identifies a list of potential barriers, which can be categorized into four main areas: lack of government policy, inadequate technological advancements, incorrect assessment of economic benefits, and individual unwillingness (as shown in **Table 2**).

Table 2. Barriers to green roof implementation from literature review.

Categories	Barriers	Reference
Administrative	● Insufficient policy incentives for developers and owners to prioritize green roofs. ● Outdated local reports and guidelines on Green Roof Implementation (GRI) hinder widespread adoption. ● Limited scientific data is available to assess the feasibility of green roofs in the local context. ● Structural limitations of older buildings pose challenges for retrofitting green roofs.	[26,27,28,29] [30] [31,29] [32]
Technological	● Weak wind resistance of extensive green roof systems. ● Limited rooftop space for green roofs on high-rise buildings. ● Potential for bacterial and mosquito breeding on green roofs. ● Potential pollution caused by roofing materials	[26] [26] [30] [33,34, 35]
Economic	● Financial involvement in design, construction ● Cost of maintenance and irrigation ● Inadequate assessment of the full life cycle cost of green roof performance.	[36,37] [36,38,39,40,29] [41,42]
Social	● Limited awareness of extensive green roof systems in both public and private sectors. ● Insufficient promotion and support from the government and social communities. ● Lack of willingness from individuals to bear the costs associated with implementation.	[26] [43,44] [45]

3. Materials and methods

Previous research studies aimed at identifying root barriers, also known as fundamental barriers, have employed various methods such as literature review [46], interviews, questionnaire surveys, and focus group discussions (FGD) [26,31]. Given that social interaction is subjective and dependent on interpretation, a social constructivist approach has been adopted in this study. According to Robson (2011), this approach is best suited for scenarios where there are multiple versions and perceptions of reality rather than a single "reality". Researchers consider multiple perspectives and integrate individual realities to construct an overall understanding. Since this research aims to capture observations and individuals' subjective experiences, it is inherently qualitative in nature.

The research methodology employed in this study combines a literature review, FGD, and questionnaire surveys to identify barriers. The literature review provides a theoretical basis for identifying potential barriers, while field studies validate the findings from the literature review. Data collection is conducted through questionnaire surveys, FGDs, and observations to analyze the significance of each potential barrier. A comprehensive literature review of previous studies was conducted to identify potential barriers to the implementation of green roofs. A purposive sampling technique was used for the FGD, targeting specific individuals in different stakeholder groups. The stakeholder groups included multi-family building users, architects involved in green roof implementation, developers interested in or working on green roof projects, and government personnel responsible for green roof initiatives.

After performing a literature review and focus group discussion, a thorough survey was carried out in the research area to learn about people's perceptions and obstacles to installing green roofs on Khulna's multi-family apartment complexes. To gather data and ensure the validity of the survey results, a questionnaire consisting of 14 questions was designed, incorporating insights from the literature. The questionnaire covered various aspects, including the participants' general understanding of and ability to distinguish between intensive and extensive green roofs, barriers affecting green roof implementation, and measures to enhance green roof practice for both new and existing buildings. In order to ensure the reliability of the survey results, the questionnaire was divided into two sections.

The questionnaire consisted of two sections. The first section aimed to collect basic information about the participants and their previous employment, serving as a foundation for the survey. The second section delved into specific inquiries regarding green roofs. Participants were asked to rate their responses on a five-point Likert scale, covering familiarity, frequency, and agreement ranging from "not at all familiar" to "very familiar", "never" to "always", and "strongly disagree" to "strongly agree". They were also encouraged to provide additional guidelines and suggestions beyond the questionnaire options to enhance green roof implementation. Please see Appendix A for details of the survey questionnaire. Additionally, field observations were conducted on multi-family apartment buildings in the Khulna residential area. Interviews with architects involved in the design and construction of these buildings were also conducted to complement and verify the observational findings, providing further insights.

3.1 Study area

Being the third largest metropolitan city in Bangladesh, Khulna is geographically marked in the southwest region of the country. It is located on the banks of the Rupsha and Bhairab Rivers, and serves as an important port city. Positioned along the axis of Jessore-Mongla port, Khulna is also the second largest seaport in Bangladesh. With almost a million residents, the city has an area of around 65 square kilometres. Only a few planned residential areas have been developed by Khulna Development Authority (KDA) in Khulna city corporation area. The planned residential areas developed by KDA are Nirala, Boyra and Sonadanga residential areas. Sonadanga is developed in three phases is being developed now. To examine the barriers to implementing green roofs, Sonadanga (Phase II) (**Figure 2a**) and Nirala

Residential area (**Figure 2b**) have been taken in this research study area.

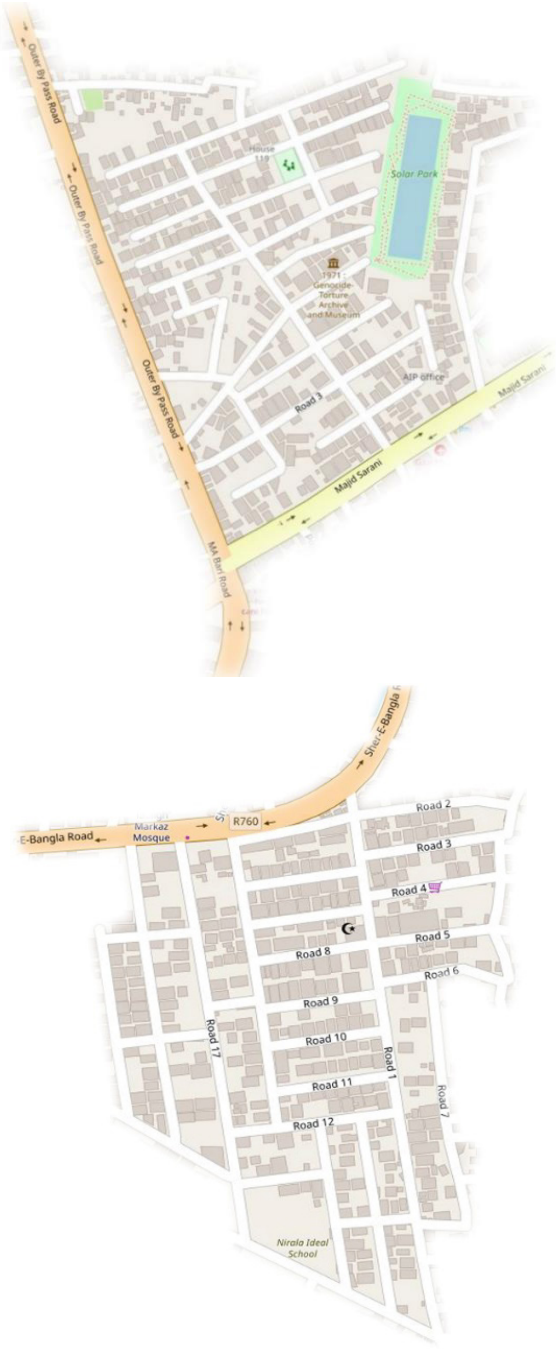

Figure 2. Study area: a. Sonadanga Phase II, b. Nirala.

3.2 Analysis

The following Relative Important Index (RII) were applied for analysis regarding the stakeholders (architects, builders, building users, etc.) connected with the case study, as well as their prior experience from comparable types of projects. It should be noted that input for the research was obtained on a (1-5) Likert scale. As a result, because parametric approaches are impractical and inapplicable for analysing respondents' preferences, the relative important index method was employed to determine the relative importance of the factors affecting green roof implementation in Khulna.

The Relative Important Index (RII) is a non-parametric approach frequently used by construction and facilities management academics to analyse structured questionnaire responses for data including ordinal attitude assessments. Relative Important Index (RII) was used to evaluate the level of agreement of green roof implementation using the following equation.

$$RII = \sum 5\ 1\ WiXi\ /4\sum 5\ 1\ Xi \quad (1)$$

where, i = index of response category, and i = 5, 4, 3, 2, and 1 for strongly disagree, disagree, somewhat agree, agree, and strongly agree, in the case of agreement responses. Wi = weight given to the ith response and Wi = 4, 3, 2, 1, and 0, Xi = frequency of the ith response.

4. Results

The survey conducted among professionals and apartment dwellers in Khulna, Bangladesh, aimed to identify the barriers to green roof implementation. The participants included architects, builders, government personnel, and apartment dwellers/owners. The findings revealed that while professionals were generally aware of green roofs and some had experience with them, not all apartment dwellers were familiar with the concept. Despite the awareness among participants, the implementation of green roofs remained a challenge. The survey results, presented in **Table 3**, ranked the barriers affecting green roof implementation in Khulna. The lack of building standards and regulations emerged as the primary constraint, ranking first. The perception of increased construction and maintenance costs was ranked second, although it may be a misconception among the participants due to the nature of the construction in-

dustry in Bangladesh.

Table 3. Barriers to green roof implementation in multi-family apartments.

Barriers	RII	Level of agreement	Rank
Lack of building standards and regulations	0.80	Strongly Agreed	1
Incentives and guidelines from governments	0.75	Strongly Agreed	2
Increase in construction and maintenance cost	0.71	Agreed	3
Lack of willingness	0.67	Agreed	4
Lack of scientific research	0.65	Agreed	5
Lack of awareness about sustainable environment	0.60	Agreed	6
Limited local expertise	0.56	Somewhat agreed	7
Poor accessibility to the rooftop	0.53	Somewhat agreed	8
Adaption of plants	0.40	Disagreed	9
Plants and plantation techniques	0.40	Disagreed	10

Other barriers, such as the lack of a sense of community, challenges related to plant adoption and plantation techniques, and insufficient experience and knowledge, were ranked lower. It is important to note that these barriers should not be overlooked, and attention should be given to addressing them. However, greater emphasis should be placed on addressing regulatory control issues, promoting a willingness to adopt green roofs, and increasing awareness about the benefits of a sustainable environment.

5. Discussion

The survey conducted among 65 multi-family apartment residents and professionals yielded valuable insights regarding the barriers to green roof implementation. By triangulating the data from the literature review, survey responses, and participant suggestions, several common barriers to green roof implementation in Khulna were identified. These barriers include limited technical expertise, inadequate knowledge and information, high construction and maintenance costs, a lack of awareness and willingness, misconceptions about green roofs, and challenges related to plant adoption and plantation techniques. One of the major barriers highlighted by the participants was the absence of proper building standards and regulations specifically for green roofs. This suggests a need for comprehensive guidelines and regulations that specifically address the implementation and maintenance of green roofs. Additionally, participants emphasized the importance of promoting the benefits of green roofs to increase awareness and encourage their adoption. Participants expressed that inadequate information and a shortage of technical expertise hindered the successful implementation of green roofs. Addressing this barrier would require providing training and educational resources to professionals and individuals involved in the construction and maintenance of buildings.

To overcome these barriers, it is crucial to focus on developing and implementing building standards and regulations specific to green roofs. Providing technical training and increasing knowledge sharing platforms can help enhance the technical expertise in implementing green roofs. Efforts should also be made to raise awareness about the benefits of green roofs among stakeholders and the general public. By addressing these barriers, the implementation of green roofs can be promoted in Khulna and contribute to a more sustainable urban environment.

- The government doesn't have any regulatory control over building standards and regulations on green roofs. Current building codes like Bangladesh National Building Code (BNBC 2020), there has no provision for including facilities for green roofs in apartment buildings. Thus, the provision can be made in BNBC and can be enacted to make green roofs mandatory for apartment buildings.
- Lack of incentives and guidelines from the government. Therefore, the government could include some means of incentives and guidelines to promote green roof implementation on a large scale.
- Increase in construction and maintenance costs in green roof implementation, seems a misconception stated by professionals and could apply some local methods to minimize

the cost of it.

- Building owners' and professionals' ignorance about sustainable environments. Articulation of multiple benefits of green roofs towards urban sustainability among the respondents is needed to encourage its implementation.
- Absence of willingness among apartment owners. Providing building regulations and incentives could influence the adoption of green roof implementation among apartment owners.
- Limited local expertise in the context of Khulna.
- Although the climate in Bangladesh is conducive to the installation of green roofs, there is a lack of scientific study in this area.

6. Conclusions

The study clearly highlights the significant contributions of green roof implementation to environmental sustainability. Although Khulna is relatively new to the concept of green roofs, there is potential for improvement by addressing the barriers that hinder their implementation. The research paper explores these barriers specifically in the context of multi-family apartment buildings in Khulna. The survey results reveal that the lack of government standards and regulations, higher construction and maintenance costs, lack of awareness and willingness, and limited research in this area are the major obstacles to implementing green roofs. It is evident from the responses of both residents and professionals (architects, builders, and government personnel) that green roofs offer more benefits than hindrances. Therefore, overcoming these barriers becomes crucial in order to encourage building owners and professionals in Khulna to adopt green roofs. The findings of this paper provide a comprehensive understanding of the current green roof scenarios in Khulna and shed light on the barriers to their implementation. These findings can serve as a foundation for future research, suggesting specific regulatory controls and necessary educational initiatives to overcome the identified barriers. In conclusion, the study emphasizes the need to address the barriers to green roof implementation in Khulna and highlights the potential for future research and action. By overcoming these barriers, the adoption of green roofs can be encouraged, leading to a more sustainable and environmentally friendly built environment in the city.

Author Contributions

The principal author, Ishmat Ara formulated the research problem and started the first phase of method identification under her Masters in Human Settlement post-graduation thesis under Khulna University. She elaborately shared the problem identification and formulated an overall problem-solving framework. She also wrote the first draft of the research article.

On the other hand, Sourav Zaman carried out the survey and interviews on-site. He re-wrote the article and put his thoughts on the data processing and analysis.

Conflict of Interest

There is no conflict of interest.

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Appendix A

Questionnaire survey on multi-family apartment in Khulna

Dear Concerns:

Thank you very much for participating in the questionnaire survey. This is to investigate the barriers of the implementation of green roofs in practices. Please feel free to contact us through ishmatara-13Ku@gmail.com or write2souravzaman@gmail.com for more information if you need. You are highly appreciated for your great help and support.

In the questionnaire, you may select the degree of agreement and disagreement with "✓" for each barrier. For example, as shown in the following table, if you do not agree P is a barrier, please mark "✓" in the column of "Disagree"; if you strongly agree Q is a barrier, please mark "✓" in the column of "Strongly agree".

For making sure of the reliability of the questionnaire, please select your work type first.

Part 1: Basic Information:

1. Which field do you belong to?
- Architects
- Residents/Owner
- Developer
- Researcher

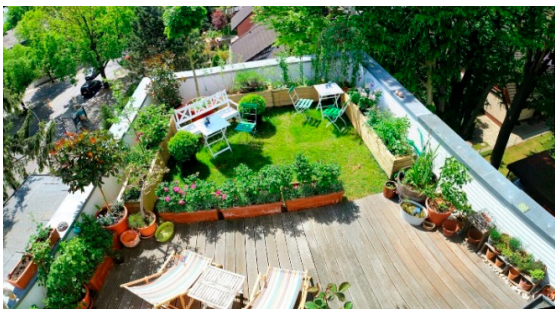
2. Are you working for the government or private Organization?

3. How many multi-storeyed apartment projects have you been involved in?

Part 2: Green Roof

1. How familiar are you with the types of green roofs:

(a) Extensive green roof



(b) Intensive green roof

Green roof types	Not at all familiar	Slightly familiar	Somewhat familiar	Moderately familiar	Very familiar
(a) Extencive Green roof					
(b) Intensive Green roof					

2. How often do you see each type of green roof in Khulna?

Green roof types	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**
a.Extencive Green roof					
b. Intensive Green roof					

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

4. General perception about green roofs:

	Strongly disagree	**Disagree**	**Somewhat agree**	**Agree**	**Strongly agree**
Increases aesthetics					
Reduces urban heat island effect					
Improves rainwater runoff problems in the city					
Improves air quality					
Increases wildlife and biodiversity					
Improves energy efficiency of building					
Improves public health in the city					
Improves noise absorption					
Adds unnecessary cost without much benefit					
Adds value/marketability of the property					

5. Technological barriers to implementing GR:

Barriers	**Strongly disagree**	**Disagree**	**Somewhat agree**	**Agree**	**Strongly agree**
Technical difficulty during construction process of green roof systems					
Weak weight capacity of existing buildings for applying green roof systems					
Weak affordability of green roofs to withstand wind load					
Difficulty in the adoption of vegetation in green roofs					
Supplemental irrigation on the roof of buildings					
Nutrient leakage from the green roof on runoff water quality					
Inadequate construction technique					
Poor drainage of green roof systems					
Lack of experience and knowledge					

6. Standard and code barriers in implementing GR:

Barriers	**Strongly disagree**	**Disagree**	**Somewhat agree**	**Agree**	**Strongly agree**
Lack of consolidated standards and regulations for designing and installing green roof systems					
Lack of consolidated standards and regulations for manufacturing and adopting green roof materials					
Incomplete standards and regulations relevant to green roofs					

7. Cost Barriers to implementing Green Roofs:

Barriers	Strongly disagree	Disagree	Somewhat agree	Agree	Strongly agree
Increase design and construction cost					
Increase of maintenance cost					
Increase of purchase cost of premises					
Increase of operating cost					

8. Attitude Barriers to implementing Green Roofs:

Barriers	Strongly disagree	Disagree	Somewhat agree	Agree	Strongly agree
Concerns over the water leakage of the roofs among property owners					
Concerns over the safety of buildings among property					
Lack of green awareness among public					
Concern on overspending the cost of green roof systems among property owners and developers					

9. Feasibility to green roofs in Khulna:

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

10. Measure to enhance implementation of green roof system for new and existing apartment buildings:

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

11. Please suggest any other measure you feel is important to apply green roof.
