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Green Roofs as an Approach to Enhance Urban Sustainability: A Study of Public Perception in Riyadh, Saudi Arabia

Ali Alqahtany

Department of Urban and Regional Planning, College of Architecture and Planning, Imam Abdulrahman Bin Faisal University, Dammam 31441, Saudi Arabia; amalqahtany@iau.edu.sa

Abstract: This study focuses on highlighting the major effects and challenges being faced in the implementation of the green roof technique in Riyadh, Saudi Arabia. Green roofs have proven to be energy efficient, environment friendly, and economical in a long run. Due to the increasing global environment temperature, it has become necessary to implement such sustainable methods that help in the achievement of urban sustainability. Saudi Arabia has seen some reluctance in the implementation of green roofs in buildings. The reasons for not adopting this system have not been reported as yet. To study the level of awareness among the public and the challenges they are facing regarding green roofs, this study was taken up. A survey questionnaire was designed with a high level of flexibility covering the key issues, including the related areas that are affected in the daily life of a resident and also the challenges faced by the general public in the installation of such systems in their existing or new buildings. An extensive literature review and a reconnaissance survey were performed before shortlisting the major factors and challenges to be included in the survey questionnaire. An overwhelming response was received from the people of Riyadh City. Almost 94% of people agreed to the fact that green roofs enhance the aesthetics of the building, and the same number of people agreed that they play a role in controlling the air quality. On the other hand, 91% of the respondents identified the climate of the area as the biggest challenge in implementing green roofs on the buildings. The study concludes with strong recommendations for the local authorities to plan quick actions. The study shall help the building owners, city planners, and policy makers in identifying the major hurdles being faced by the residents in adopting green roofs and will help them to provide solutions to these issues.

Keywords: green roofs; sustainable urban planning and design; urban development; public perception; urban policy and governance; Saudi Arabia

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1. Introduction

Humans have been interested in green elements since ancient times due to the close connection between them and their surrounding nature. Plants have been the main source of food and medicine, starting from the stages of grazing and picking fruits, then the beginning of agriculture, settlements, and then the formation of societies and urban areas. Green infrastructure approaches, whether natural or semi-natural, are often seen as common approaches to increasing green urban areas [1]. The green roofs technique is one of these approaches to enhance a range of ecosystem services that provide environmental, social, and economic advantages via natural solutions [2–4]. Among these services are the regulation services such as local climate regulation [5,6] and air quality improvement [7]; provisioning services including food and urban agriculture; the habitat services such as suitable living spaces for wild plants and animals; and cultural services, including aesthetic improvement and recreational spaces [4]. Nevertheless, although there are many advantages of the green roofs technique [2,8,9], it remains untapped on the urban scale [1].

The main structural part that determines the building's relationship with the surrounding nature is the roof of the building [10]. Green roofs are one of the strategic tools that can play an important role in creating sustainable and resilient cities [11]. Green roofs are also named roof gardens, living roofs, and eco-roofs and are roofs with plants in their final layer [12]. Green roofs can be defined simply as living vegetation installed on the roofs of buildings and can offer various environmental and social, as well as economical, advantages. They can be installed either by pre-cultivated systems, modular systems, or complete systems [13]. The classic features of various types of green roofs can be measured based on purpose, vegetation type, substrate thickness, irrigation requirement, supporting structural requirements, and maintenance requirement [13–15], as reproduced in Table 1 below. The concept of green roofs revolves around covering ordinary roofs with vegetation to improve thermal insulation, protect against climatic conditions, and help absorb rainwater [16]. It is a practical means of expanding the amount of vegetation in urban cities [13]. There are several types of green roofs, including intensive, semi-intensive, and extensive. The main differences between intensive and extensive green roofs are the type of vegetation planted and the depth of the substrate [17].

Table 1. Main features of green roof types [13–15].

Criteria	Specific Use	Semi-Specific Use	General Use
Purpose of Use	Parks and Gardens	Vegetation	Protection Layer
Depth of Growth Media	Deep (Min. 500 mm)	Medium (150 to 500 mm)	Shallow (20 to 150 mm)
Self-Weight Category (Saturated)	Heavy (200 to 500 kg/m^2)	Medium (120 to 200 kg/m^2)	Light (60 to 120 kg/m^2)
Self-Weight (Dry)	140 to 325 kg/m^2	90 to 140 kg/m^2	45 to 90 kg/m^2
Type of Plantation	Small Trees, Shrubs	Grass, Herbs, Shrubs	Low Growing
Installation Cost	High	Medium	Low
Irrigation Requirement	Regular	Periodic	Little to No Requirement
Water Holding Capacity	200 L/m^2	120 L/m^2	60 L/m^2
Maintenance Requirements	High	Periodic	Very High
Structural Requirements	Additional Structural Support	Additional Structural Support	Existing Structures

Generally, there are five major components of a green roof system, which include the grass, growth substrate, filtration layer, a layer for waterproofing, and root barrier [18]. A detailed green roof system and all its layers are shown in Figure 1.

The green roofs approach is now widely used as a tool in urban planning strategies due to its significant role in sustainable urban development [19]. Indeed, it has become an increasingly popular choice in urban planning over the past two decades [20]. In dense urban areas, the concept of green roofs has become one of the standard ways to introduce vegetation to these areas [21]. Green roofs provide numerous benefits to the urban built environment and offer a set of environmental, social, economic, and urban benefits [18]. The most prominent are the mitigation of urban air and noise pollution and increased air quality [19,22], reduction of the urban heat island effect in cities [23], reduction of building energy consumption [24–26], reduction of stormwater runoff [27,28], increase of biodiversity and habitats [21,29,30], and provision of more spaces for amenity and recreation [21]. Some executed examples of green roofs are shown in Figure 2.

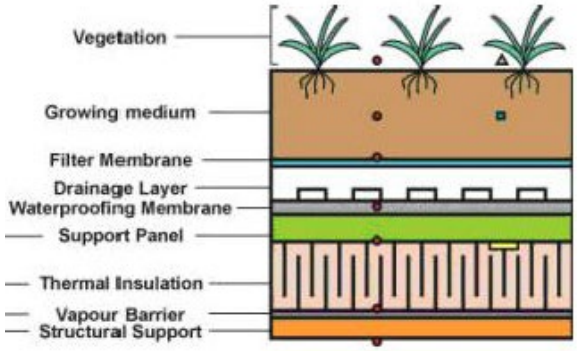

Figure 1. Typical cross-section of a green roof [31].

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

Figure 2. Examples of green roofs: (**a**) British Horse Society Headquarters, UK, and (**b**) Chicago City Hall, USA [31].

The high heat of the external air in the summer is transmitted into the building through the roof, which requires the use of a significant amount of energy to condition the building's interior [32]. Additionally, according to the laws of thermodynamics, in the winter, the internal heat of the building is lost and transferred into the cold external air surrounding the building [33,34]. Hence, energy consumption bills remain high irrespective of the weather [35,36]. Several studies have shown that green roofs can help reduce annual energy demand, which is either the demand for cooling in the summer or the demand for heating in the winter [10,37–40]. For instance, Jaffal et al. [40] pointed out that green roofs help to reduce the fluctuation amplitude of the roof slab temperature in the summer by 30 °C and decrease the summer indoor air temperature by 2 °C, in addition to reducing roof heat losses during the cold days in the winter and reducing the annual energy demand by 6%.

Green roofs have also appeared as an appropriate technique to fight the consequences of pollution, traffic, and lack of green spaces because of the numerous environmental problems facing today's society, particularly in urban areas [41]. Although the idea of green roofs is not new, as it was first used in Babylon and ancient Syria, it was not commonly used in modern cities until the beginning of the seventies of the last century [42]. It is considered one of the appropriate measures to increase the environmental resilience of cities that depend mainly on nature [43]. Several recent studies considered green roofs as one of the important aspects of mitigating the microclimate in urban areas. Berardi mentioned in his study that green roofs have positive effects both on the residents' thermal comfort, because it reduces the air temperature by 0.4 °C, and the building energy consumption, as it can also be reduced by 3% [44]. Moreover, the combination of greenery at the pedestrian level with green roofs can increase the advantage of the surrounding microclimate with an ambient temperature decline up to 2 °C, according to Alcazar et al. [45].

2. Literature Review

Numerous studies have explored the economic advantages arising from the application of the idea of green roofs. For instance, Wong et al. [46] compared the installation cost of green roof systems with traditional thermal and waterproofing roof treatments and found that the cost of a green roof system is lower considering the lifespan of the building. Other authors [47,48] concluded that the most effective benefit of green roof systems is energy saving, which results in an economical and sustainable environment inside and outside the building. Clark et al. [49] pointed out that the layers of green roofs protect the roof, which can increase the longevity of the roof from 20 to 40 years. Furthermore, green roofs can reduce exposure to sound inside and around the building [50] and, consequently, can increase the real estate value of the building from 6 to 15% [3]. In the sustainability context, Hegyi et al. [51] pointed out that green roofs successfully meet the principles of sustainable development. In a global context, there has been a growing interest in urban greenery in recent years, even in water-limited climatic regions [21]. As mentioned earlier, green roofs help in reducing energy consumption during hot climates, the energy consumption reduction values turned out to be between 6.5 and 17% for a case study in Guangzhou, China [52], a four-story representative building in Amman, Jordan [16], and a three-story building in Iran [53]. Another study in Madrid, conducted by Oberndorfer et al. [54], reported that green roofs could reduce the cooling requirement by 6% in the summer for an eight-story residential building. The study showed that the required cooling was reduced by 25%, 9%, 2%, and 1% for the first four floors, respectively, located just below the green roofs and was reduced by 10% for the entire building. Furthermore, green roofs have been recommended, required, and subsidized in several cities, including Tokyo, Stuttgart, Basel, Portland, and Toronto [12,18].

In many well-developed countries such as Singapore, the applications of green roofs in building construction are well established [13]. The first major green roof installed in Singapore was on the existing roof of a multistory car park. The project, sponsored by the Housing Development Board, was meant to encourage the application of green roofs in the country, in which the results showed that the installed green roof had to decrease the visible radiation significantly recorded on the facades of the residential area. Australia is also one of the developed countries that have adopted green roof implementation. Alexandri and Jones [55] reported that most major cities in Australia have hot and dry summers, which is very suitable for developing green roofs, as it will reduce the temperatures of these cities and reduce energy consumption as well. However, on the other hand, most developing countries are still exposed to many issues related to land constraints, which lead to increased competition for land between green areas and infrastructure developments [13]. Therefore, currently, there is interest in the subject of green roofs, and this interest is evident through associations, conferences, and competitions all over the world [12].

In the Kingdom of Saudi Arabia (KSA), most of the buildings use reinforced concrete on their roofs, which is not suitable for the air temperature in the region that reaches 50 °C, as it is considered a structural element with a high thermal conductivity coefficient. Therefore, it was found that 70% of the total electricity consumption in buildings in KSA is to meet the demand for air conditioning [10]. Several other studies [56–60] emphasized the need to review the requirements for the design and construction of the building roofs in KSA in terms of thermal conductivity and to identify the modifications and structural specifications necessary to improve its efficiency, especially concrete ones, whether it was according to the traditional methods using steel rebar, or it is strengthened according to modern methods using steel fiber reinforced concrete or nonmetallic fiber reinforced concrete. One of the environmentally preferred options is to convert traditional roof designs into green roofs that comply with the country's approved thermal conductivity standards and are compatible with the atmosphere of the region, with attention to the impact of that on the mechanical properties of the reinforced concrete or the plain concrete [10].

Although some nongovernmental or official bodies have called for the need to implement strategies that promote the creation of sustainable and resilient cities such as green

roof systems, especially in residential buildings that represent the largest sector, there is still a significant delay in this field compared to other countries. Recently, the Saudi construction sector in general, and the residential sector, in particular, have witnessed steady and remarkable growth [61]. The residential sector is growing in parallel to the steady increase in the population, which has been proposed to be around 2.5% per year [62,63]. As a result of the region's climate, the residential sector in KSA consumes high levels of energy to meet the high demand for cooling and heating, which results in high rates of CO_2 emission [60]. According to Asif [64], nearly 50% of the total national energy generation is consumed by residential buildings alone. This can be attributed to the energy cost in KSA, which is relatively cheap when compared to other parts of the world due to its rich oil and gas reserves and government subsidies [61,65].

However, the situation has changed swiftly over the past few years, especially after the surfacing of the Saudi Vision 2030, approved by the Saudi Council of Ministers in 2016. The vision encompasses three major themes: a vibrant society, a thriving economy, and an ambitious nation. The energy conservation strategies are part of the first theme [64]. The vision has adopted many programs, initiatives, and construction projects that enhance the efforts to achieve the desired goals, and there were targets to remove about USD $53 billion of energy subsidies by 2020 [61,66]. KSA is now keen to reduce the increasing demand from the building sector, especially the residential sector, through the use of sustainable and energy-efficient strategies [61,65]. The concept of green roofs can be promoted as one of the options for energy saving in KSA through which energy consumption can be beneficially managed, along with the adoption of educational programs, to enhance people's perception and attitudes toward this option.

People's perception can be viewed as how people interpret, distinguish, critique, and analyze their environments according to their core values of adaptation to those environments [67]. People's expectations and preferences regarding green roof technology are very important especially for planners and designers when designing support systems for this type of technology or when setting up mandatory planning permissions [21]. Previous studies on people's perception of green roof technologies in urban areas have shown that it is highly correlated with people's socioeconomic factors, such as the level of income [68]. There are also some studies [69,70] that indicate that people's perception of the idea of green roofs in urban areas is related to the extent of knowledge about the system. However, this study hypothesizes that there are differences in the perception of green roof technologies and systems among different members of society due to other reasons, which the study seeks to discover.

The green roofs technique is relatively new in KSA, and it is believed that there is a lack of studies that shed light on the different aspects of this technique. Mahmoud et al. [61] pointed out that the green roofs technique is one of the sustainable building techniques that has not been appropriately explored and highlighted up to now. Therefore, the present study's target is to fill this research gap and build upon the literature. The present study aims to explore people's awareness of the green roof technique as a tool for urban sustainability and their willingness to adopt such a technique in KSA using Riyadh, the capital of KSA and the largest city, as a case study. Moreover, this study analyzes the relationship between demographic features and expectations of people concerning the contribution of green roofs to urban life quality and determines the benefits of such a technique. The first part of the study presents an overview of related concepts, such as green roofs, urban sustainability, and people's awareness, which will be discussed within the literature. This will be followed by describing the main methodology for data collection and analysis. Subsequently, the paper presents and discusses the main findings of the study and concludes with some recommendations for improvement and better planning.

3. Research Methodology

3.1. Study Area

The current study is focused on Riyadh, KSA. It is located in the eastern part of the central region, which lies in the middle of KSA, as shown in Figure 3. Riyadh is located between 34°38′ North and 46°43′ East [71]. The city is the capital of the country and is considered to be one of the fast-developing cities in the world [72].

Figure 3. Location of Riyadh, Saudi Arabia, on a world map.

The population of Riyadh was estimated to be about 7.4 million in 2020, and it is expected to reach 10 million in the next few years, and they live in a total area of about 2435 km^2 [60]. Riyadh has an arid hot climate, where the average monthly temperature reaches 45 °C during the summer. This high temperature leads to high energy consumption for cooling indoor environments, which ultimately leads to high rates of carbon dioxide emissions, especially in residential buildings not only in Riyadh but in most major cities in the country.

In the past five decades, Riyadh has experienced significant demographic and physical growth and faced numerous issues in the process of urbanization. The rapid urban expansion of the city, in addition to the limited spaces in the built environment, led to a decrease in the percentage of green areas in Riyadh, which led to the emergence of many urban problems, including environmental and visual pollution, which, in turn, affected the rise in temperatures and the emergence of the so-called urban heat island phenomenon. Despite the presence of green spaces in Riyadh, represented by gardens and parks, it is relatively few compared to the size and expansion of the city, especially in light of the difficulty of creating additional spaces within the existing built environment. Therefore, due to the small amount of green space in Riyadh, as well as the lack and shortage of available land in the city and the issues of land use allocation, the development of green roofs is considered one of the important and useful approaches that can be adopted.

3.2. Methodology and Data Collection

This study aims to explore people's perceptions of the green roof technique as a tool for urban sustainability and their willingness to adopt such a technique in KSA using Riyadh as a case study; thus, the population interested in this study is Riyadh residents.

The questionnaire survey technique was employed for this study, which is considered to be one of the widely used methods for the collection of data, as already experienced

by various researchers [73–75]. Alqahtany [60] indicated that the questionnaire survey is one of the useful tools for collecting data about people, their opinions, perceptions, and attitudes in a systematic way on a particular issue.

The basic data were collected by conducting a reconnaissance survey from the study site regarding the problems and challenges being faced by the residents related to green roofs and their applications. The residents included the general public who represent the domestic and commercial sectors of the area. The data included the list of problems being faced by the residents regarding green roofs. The shortlisted factors were obtained by comparing the response of the people recorded during the reconnaissance survey. The common factors found in both phases were considered to be the most important factors to be included in the online survey questionnaire.

The questionnaire was intended to be understandable for ordinary people and was designed around four key sections, including respondents' general social and demographic characteristics, characteristics of the respondents' houses, people's perceptions of the green roofs technique, and people's aspirations and willingness to adopt the technique. Open and closed-ended questions were designed for the questionnaire to achieve the required objectives. The survey was distributed randomly to the public coming from various walks of life. The respondents were given the opportunity of keeping their identity anonymous, and they were able to leave the survey at any time if they felt they could not answer any questions. Additionally, people had the opportunity to write additional responses that went beyond these predefined choices and expressed their opinions. The methodology followed for the study is shown in Figure 4.

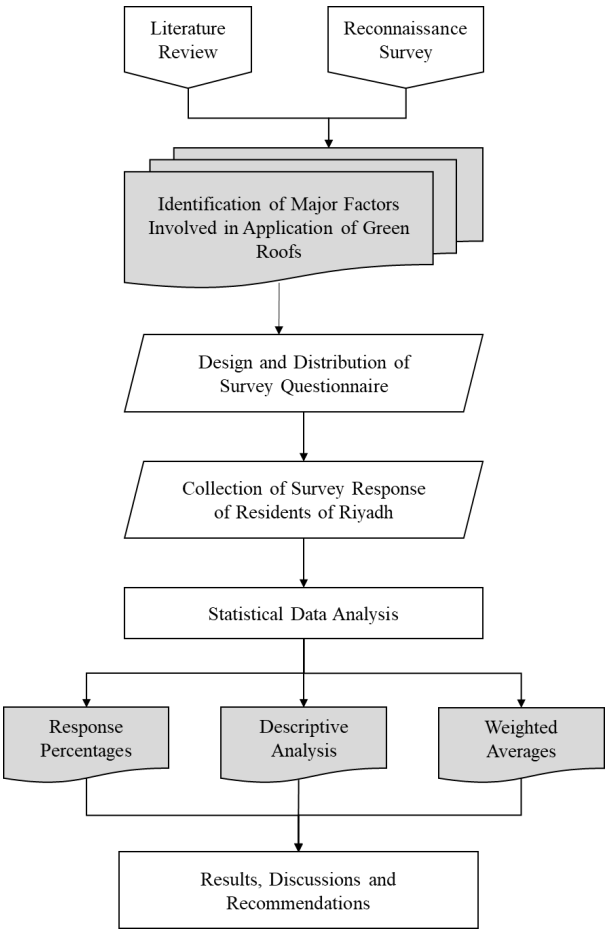

Figure 4. Research methodology followed for the study.

The survey questionnaire consisted of two types of questions. Both questions were based on a Likert scale, and the respondents were required to answer on a scale of 1 to 5 representing Strongly Disagree, Disagree, Do Not Know, Agree, and Strongly Agree, respectively, for Q-1, whereas 1 to 5 represented No Effect, Low Effect, Medium Effect, High Effect, and Very High Effect, respectively, for Q-2. The format of the online survey questionnaire is shown in Table 2.

Table 2. Survey questionnaire used for the study.

Sr. No.	Question	Scale				
		5	4	3	2	1
Q-1	**In your opinion what are the effects of adopting Green Roofs on the general environment of the building related to the following areas?**					
a	Increase in the Value of Building	○	○	○	○	○
b	Availability of Additional Space for Recreation and Amenities	○	○	○	○	○
c	Improvement in Aesthetic Features of Building	○	○	○	○	○
d	Reduction in Rainwater Runoff	○	○	○	○	○
e	Reduction in Electricity Bills	○	○	○	○	○
f	Reduction in Energy Consumption of Building	○	○	○	○	○
g	Enhancement of Ecology and Sustainability in Built Environment	○	○	○	○	○
h	Improvement of Air Quality and Reduction in Air & Noise Pollution	○	○	○	○	○
i	Positive Effect on City's Climate	○	○	○	○	○
Q-2	**To what extent do the following factors affect the application of green roof systems in buildings?**					
a	Safety and Security	○	○	○	○	○
b	Climate of the City	○	○	○	○	○
c	Irrigation System	○	○	○	○	○
d	System Weight	○	○	○	○	○
e	Maintenance	○	○	○	○	○
f	Installation Cost	○	○	○	○	○

For statistical analysis, the response mean and response standard deviation were calculated by using Equations (1) and (2), respectively [76].

$$\bar{x} = \frac{\Sigma x}{n} \tag{1}$$

$$\sigma = \sqrt{\frac{\Sigma (x - \bar{x})^2}{n - 1}} \tag{2}$$

where x is the corresponding value provided by the respondent, and n is the total number of respondents for a specific question.

Moreover, the response percentage obtained for all questions was assessed separately, and the factor that received the highest number of selections was considered on highest priority. Along with this, the response to all questions was compared together as well, by using the method of weighted averages (WA). The following equation was used to calculate the WA of each factor.

$$A_w = \frac{\sum (R_i\, n)}{\sum R_i} \tag{3}$$

where A_w is the weighted average, R_i is the number of respondents for a specific level n of the Likert scale, and n ranges from 1 to 5.

4. Results and Discussions

A total of 380 people submitted their responses, which included people of all ages, gender, and professions living in Riyadh. The demographic data of the respondents, as shown in Figure 5, show that almost 65% of the respondents belong to the age group of 35–45 years, which is a young and experienced class of highly educated people who have a

good understanding of the environmental sustainability and are well aware of advanced technologies and the effect of green roof buildings. More than 75% of the respondents are employed in various sectors, and almost 55% of them are earning USD 30,000 or more per annum.

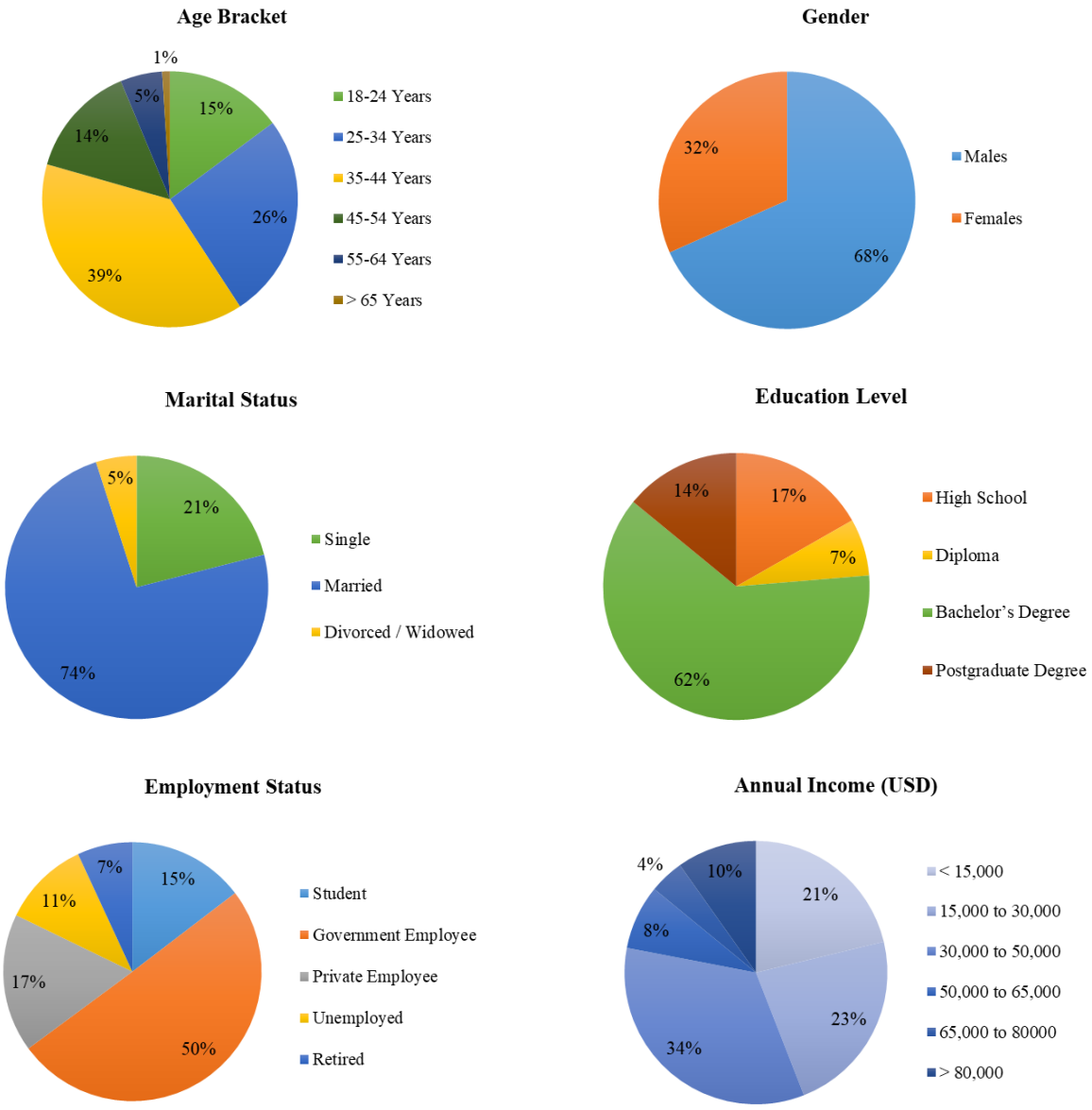

Figure 5. Demographic details of the respondents.

A few initial questions were designed to know the current status of residents regarding their living in Riyadh, as shown in Figure 6, and 73% of people were found to be living in comparatively bigger houses like villas or detached duplexes, while 64% of people disclosed that they own the property in which they are living. Regarding the size of the houses, 51% of people are having a house size of 250 to 500 sq. m., whereas 33% of the people living in a house having an area of more than 500 sq. m. These stats show that the respondents seem well settled and have a good standard of living and are well educated; hence, the acquired responses for Questions 1 and 2 are considered reliable and well justified.

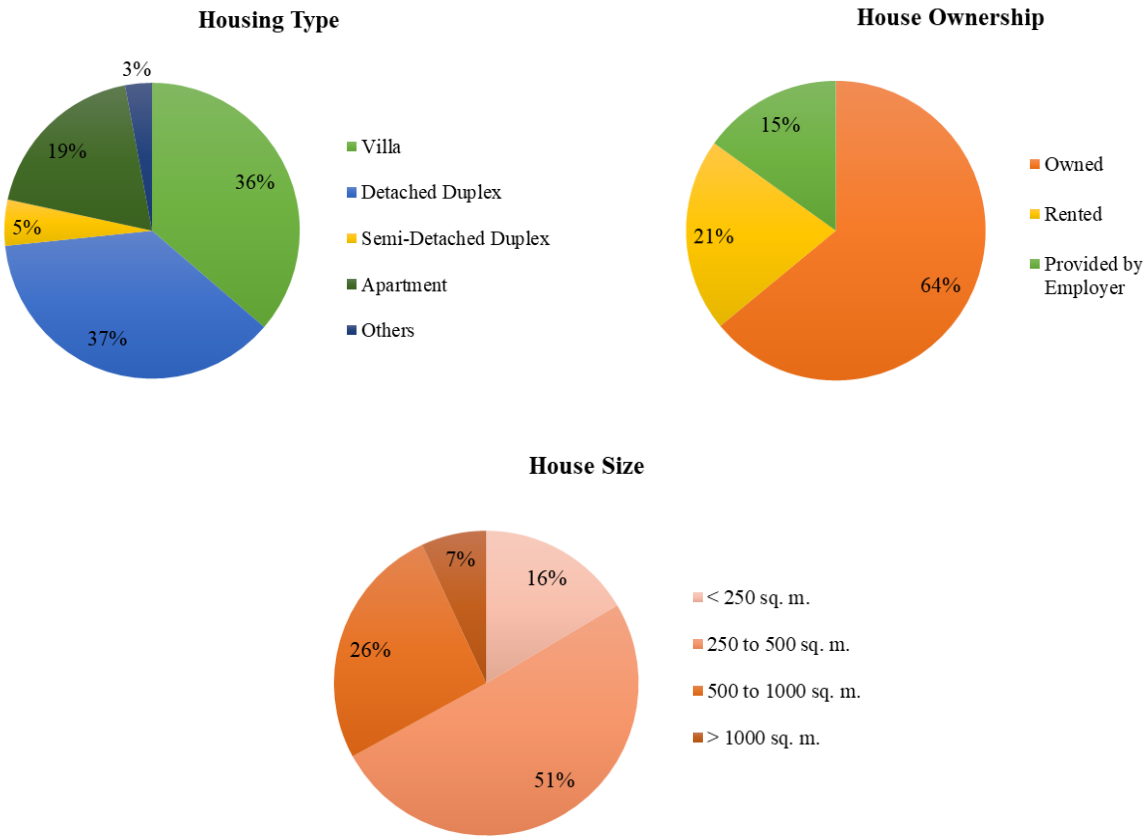

Figure 6. Existing housing stats of the respondents.

A descriptive statistical analysis was also performed for the demographic and existing housing stats of the respondents, as shown in Table 3. The values mentioned in the Response Mean column are the average of the Likert scale values opted by the respondents. For better clarification, the second column shows the interpreted average value of each parameter. The lower values of response standard deviations show that the responses are quite close to each other, which implies that the opinion of one resident does not deviate from the others to any larger extent.

The average values of the characteristics of the respondents in Table 3 show that the respondents are well mature, with an average age of 41 years, are well educated, and earn a good annual income. Additionally, the average number of respondents reside in duplex houses of suitable size. Hence, the data obtained from the sample of the population who completed the survey are eligible for further analysis.

Table 3. Descriptive statistical analysis results.

Parameter	Response Mean ($\bar{x}$)	Average Value	Response Standard Deviation (σ)
Age Bracket	2.72	41 Years	1.11
Education Level	2.74	Bachelor's Degree	0.9
Employment Status	2.45	Employed	1.08
Annual Income	2.79	USD 46,000	1.48
Housing Type	2.15	Detached Duplex	1.18
House Size	2.23	615 sq. m.	0.81

A brief discussion is presented on the response to the major questions of the survey. Question 1 was designed to get public opinion on the effects of adopting the concept of green roofs in the building. The overall study of the results obtained for Question 1

shows that people were excited and pleased with the concept. However, a significant trend can be seen in the results, shown in Figure 7, that the public is concerned with the aesthetics of the building enhanced by green roofs more than its technical benefits. The points related to the improvement in aesthetics of the building, availability of space for recreation, and improvement of air quality received more positive responses than any other options with a value of at least 94% of people agreeing to them. On the other hand, the points related to the technical aspects of the green roofs, including the increase in the value of the building, reduction in rainwater runoff, energy consumption, and electricity bills remained comparatively low opted points, with a value of almost 75% each. It is also necessary to mention that these points received a neutral response from almost 15–17% of people. The reason could be that 15% of people are less than 25 years of age, as they are students studying in high school and have not taken any technical studies yet, as shown in Figure 5, so this high percentage of neutral responses can be ignored, and the value of 75% is still considered reliable and comparative to all other options.

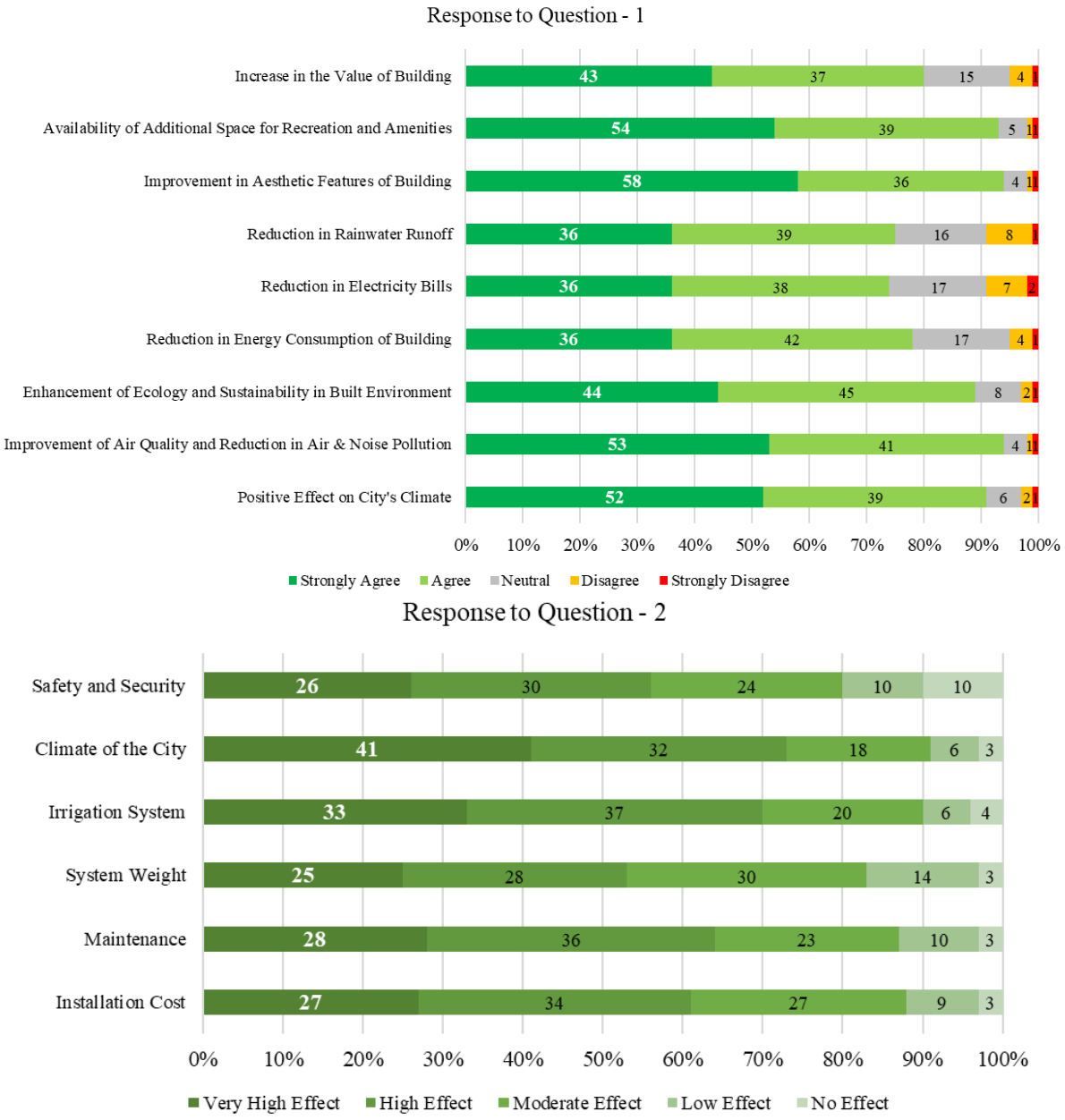

Figure 7. Response percentages for survey Questions 1 and 2.

Question 2 was designed to observe the public opinion on a few factors that they might take as a challenge in adopting the concept of green roofs in their houses. Almost 73% of people said that the climate of the city is the most challenging factor in Riyadh, as shown in Figure 7. As the city lies in an arid and hot climate zone, the environmental temperature genuinely affects various other factors related to it as well, including irrigation of green roofs and the selection of the type of grass and plants that can sustain the hot weather, including its maintenance. These both points stand second and third in the list with 70% and 64%, respectively. People are least concerned with the weight of the green roof system on the structural elements of the buildings. Only 53% of people showed this concern.

For a better comparison, the responses obtained for Questions 1 and 2 were converted to weighted average (WA) by using Equation (3) to obtain one of the listed factors having the maximum influence as per the public opinion, as shown in Figure 8. It can be seen that the WA for a few of the options is peaking as compared to others.

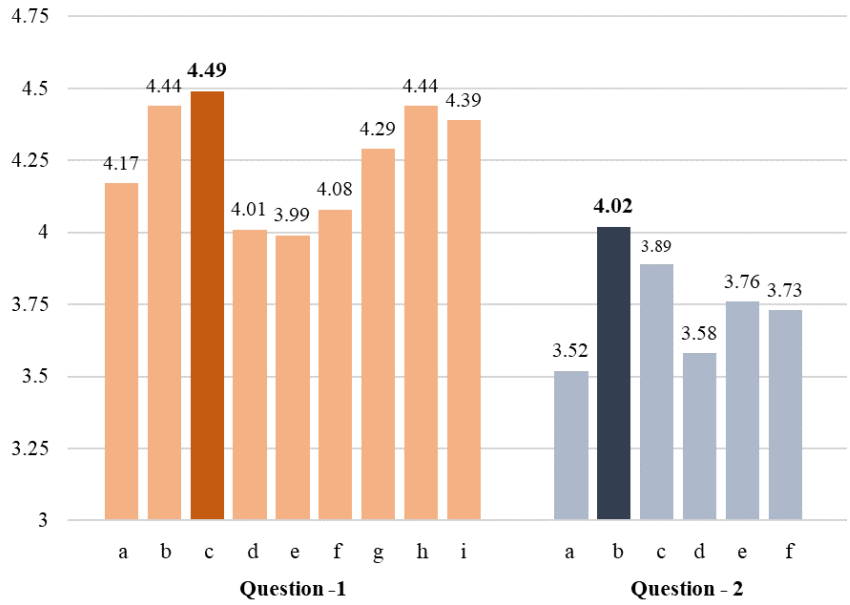

Figure 8. Weighted averages for responses on Questions 1 and 2.

These options having the highest WA were rated the highest priority by the respondents. The highest strength of response was found for Q-1(c) with a WA value of 4.49, where people agreed to the fact that green roofs increase the aesthetics of the building. As the second priority, people selected green roofs to provide additional space for recreation, and it also helps in decreasing air and noise pollution with a WA of 4.44. Figure 8 shows a peak WA value of 4.02 for Q-2(b) as well, where people consider the climate of the region as the biggest challenge in adopting green roofs.

At the end of the survey, two very direct but important supplementary questions were asked of the respondents. The first one was to get their willingness in installing green roofs on their houses, and the second was related to their opinion regarding recommending someone to install this system on their building. A very interesting response was obtained for these questions, as shown in Figure 9. Despite knowing all the benefits and positives of green roofs, people are hesitant to adopt this system in their homes as yet. Although the majority of the respondents are willing to adopt this system and were positive in recommending others to adopt it too, there is a significant number of people who are still confused and have opted for the third option of Do Not Know. The percentage of people who agreed to recommend green roofs to others was 61%, which is higher than the percentage of people who were willing to apply this system in their houses, which stands at 50%. This is completely understandable and shows that the people are aware of the benefits of such systems, but their financial liabilities are high and prevent them from

applying it for themselves at their homes. Moreover, it was observed that many existing buildings have mechanical equipment fixed on the roofs, including outdoor units of split air conditioners, chillers, water pumps, and water tanks, which the owners think would be a huge task to relocate. This is counted as another reason for the comparatively low willingness level of owners to install green roofs at their existing buildings.

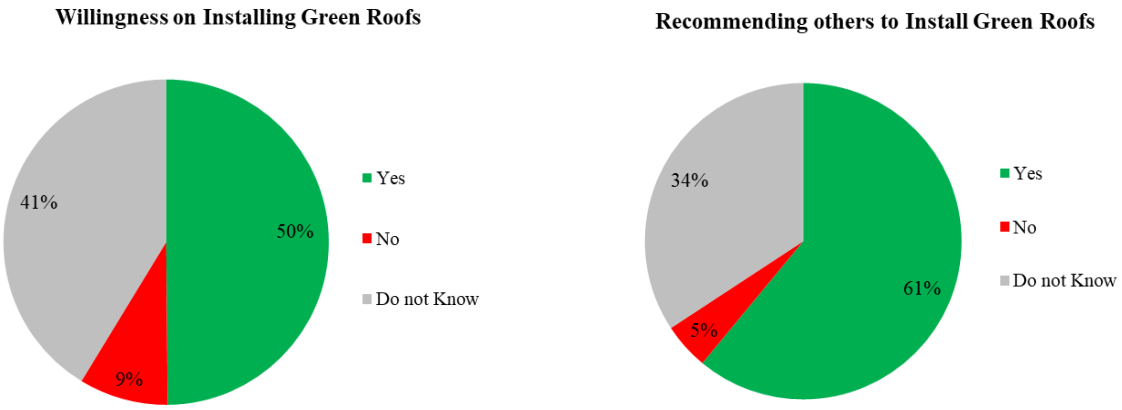

Figure 9. Response to supplementary questions.

5. Research Extension and Future Considerations

The study mentioned in this research article is completely extendable, and a lot more options can be included in future research of a similar kind. It was seen during the results and analysis phase that, although a good amount of people were highly educated who submitted their responses, there is an opportunity of including people with low education levels who own big houses or commercial properties in future research. More female respondents can also be targeted, or there may be separate analyses for male and female respondents, and research presenting analytical comparisons of the responses based on gender can be produced. The current research would help future researchers prepare a complex survey questionnaire for further study. Moreover, the current results are based on 380 responses, the target of minimum responses could be set to at least 600 responses for future works. Increasing the sample size would produce many reliable results.

6. Conclusions and Recommendations

In this study, an extensive literature review followed by a survey analysis was performed to explore the idea of implementing green roofs and the relevant challenges being faced by the general public. Based on the literature, the study found that the green roofs technique is a practical means of expanding the amount of vegetation in urban areas, and it has become a well-known approach in sustainable urban development approaches in recent decades. In this study, it is believed that green roofs can provide a lot of advantages, for instance, the mitigation of urban air and noise pollution, increase in air quality, reduction of the urban heat island effect in cities, reduction of building energy consumption, reduction of stormwater runoff, an increase of biodiversity and habitats, and provision of more spaces for amenity and recreation.

The public response received through the survey was a mix of different opinions. Clearly, the majority of the population of Riyadh understands the benefits related to green roofs, and they have shown a positive response to a few factors. Almost 94% of people agreed with the fact that green roofs enhance the aesthetics of the building, and the same number of people agreed that they play a role in controlling the air quality. Similarly, 93% of people that green roofs provide additional recreational space in the building. On the other hand, 91% of the respondents identified the climate of the area as the biggest challenge in implementing green roofs in the buildings. However, despite knowing the benefits, a good number of people are still hesitant in installing such systems in their houses with 41% of people who are still not sure if they should go for green roofs on their buildings or

not. This is because there is still not much awareness in the general public and there is no applied example in the area as yet.

Based on the results, it is recommended that the local authorities must initiate strong campaigns in favor of such technologies at least for the new buildings or the buildings under construction. They must educate people about the benefits these green roofs can provide. In addition to this, the authorities must facilitate the residents and house owners in designing, executing, and installing such systems. With their help, the process shall progress quickly.

The study strongly believes that, in Riyadh and KSA in general, the possibilities of adopting the concept of green roofs are increasing, as there is awareness of the sustainable built environment and urban sustainability in general, especially in light of the Saudi Vision 2030. A little interest from the local authorities is required to provide it with a wider reach.

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