

The Implementation of Green Roof Buildings Towards Sustainable Environmental in Kuala Lumpur: Key Player Perspective

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Abstract

Rapid population growth and urbanization have intensified environmental challenges, including excessive greenhouse gas emissions, and urban heat island effects driven by the construction sector's energy demands and the loss of green spaces. Therefore, the study aims to identify the factors of green roof implementation towards sustainable environmental, to investigate the challenges and strategies to enhance the implementation of green roof in Kuala Lumpur. This study employed a qualitative method, with primary data collected through semi-structured interviews with experts in green roof building. The qualitative data collected from the semi-structured interviews analyzed using thematic analysis techniques. The identified themes organized and analyzed to develop a comprehensive understanding the factors of green roof implementation towards sustainable environmental, challenges and strategy to enhance the green roof implementation in Kuala Lumpur. The research focused on five respondents with significant experience in green roof projects, including project managers, green roof building consultants, and architects involved in green roof construction within Kuala Lumpur, to ensure reliable insights. The findings reveal that green roofs contribute significantly to sustainability by reducing carbon emissions, improving energy efficiency, and managing urban heat islands. Despite these benefits, challenges such as high installation and maintenance costs, water retention issues, and limited public awareness hinder widespread adoption. Strategies proposed include government incentives, public education, and integrating green roofs into standard construction practices. The study provides valuable recommendations for policymakers, construction professionals, and urban planners to promote green roofs as a sustainable solution, enhancing environmental quality and urban resilience in Kuala Lumpur.

1. Introduction

This study examines the implementation and impact of green roofs in Malaysia, particularly Kuala Lumpur, focusing on their potential to promote sustainable urban development. Green roofs, also known as eco-roofs or roof gardens, consist of multiple layers, including membranes, drainage, and vegetation, offering environmental benefits like reducing carbon emissions, enhancing energy efficiency, and mitigating urban heat islands (Ismail *et al.*, 2018; Shah Mohammad *et al.*, 2022; Vo *et al.*, 2021). In Malaysia, extensive and intensive green roofs are the most used types (Hamid *et al.*, 2023). The study explores the current state of green roofs, the challenges in their adoption, and their benefits, aiming to promote their integration into urban infrastructure for a more sustainable and resilient environment (Quaglia Rini *et al.*, 2019; Cascone, 2019; Rahmat *et al.*, 2018). Global population growth and urbanization contributed to environmental concerns, with the construction sector playing a key role in excessive energy use and greenhouse gas emissions. As urban areas develop, green spaces are being replaced by impermeable constructions, worsening the urban heat island effect and increasing flood hazards. (Yien, *et al.*, 2023). Population growth and urbanization have resulted in greater levels of greenhouse gases such as carbon dioxide, methane, and nitrous oxide, which are mostly caused by activities such as fossil fuel burning and deforestation. These gases trap heat in the atmosphere, increasing the greenhouse effect and contributing to global warming and climate change. (Kweku, 2018).

To overcome these challenges and maximize the potential of green roofs in urban sustainability, collaborative efforts are essential. Governments, building owners, developers, and communities must work together to provide financial incentives, raise awareness about the societal benefits of green roofs, and mitigate the negative environmental impacts of urbanization. By fostering partnerships and implementing comprehensive strategies, stakeholders can create an environment conducive to the widespread implementation of green roofs, ultimately leading to more resilient and sustainable urban landscapes. (Li, *et al.*, 2019) The problem statement highlights how rapid population growth and urbanization exacerbate environmental concerns, including greenhouse gas emissions and urban heat island effects, emphasizing the need for collaborative efforts among stakeholders to implement green roofs as a sustainable solution to mitigate these challenges. The objective of this study is to identify the factors of green roof implementation towards sustainable environmental protection in Kuala Lumpur, to investigate the challenges of implementing green roofs in Kuala Lumpur, and to suggest strategies to enhance the implementation of green roofs in Kuala Lumpur.

The study aimed to examine the factors of green roof implementation towards sustainable environmental. Green roofs in Kuala Lumpur might help solve concerns about carbon emissions, and energy consumption by incorporating green technology into urban infrastructure. This method aims to reduce degradation of the environment and promote sustainable development by reducing carbon emissions, increasing energy efficiency, and promoting regional well-being (Vo *et al.*, 2021).

The study was conducted in Kuala Lumpur, Malaysia, a rapidly urbanizing state, and investigated the current condition of green roof implementation. Kuala Lumpur has experienced significant population expansion and urban development, necessitating the implementation of long-term solutions such as green roofs to reduce environmental impact and improve urban resilience. The study promotes green roofs in Kuala Lumpur to address environmental challenges caused by urbanization, industry, and population increase.

2. Literature Review

2.1 Green roof building overview

Green roofs are rooftop systems with vegetation layers that provide environmental, social, and economic benefits. They consist of components like waterproof barriers, insulation, drainage systems, soil, and plants, which help manage rainwater, reduce urban heat islands, and improve air quality (Shah Mohammad *et al.*, 2022).

Green roofs offer numerous advantages, such as filtering pollutants, trapping carbon dioxide, managing stormwater, and mitigating urban heat islands (Pianella *et al.*, 2017). They also create green spaces that enhance mental health and community well-being, extend the lifespan of roofs, lower energy costs, and increase property values (Cascone, 2019). However, challenges like high installation and maintenance costs, as well as a lack of awareness about their benefits, hinder their adoption, especially in developing countries (Hamid *et al.*, 2023; Ismail *et al.*, 2018).

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2.1.1 Benefits of green roof implementation

Green roofs are vital for sustainable urban development, offering significant environmental and economic benefits. They improve air quality by filtering pollutants like carbon dioxide, mitigate the urban heat island effect through insulation and cooling, and manage stormwater by absorbing rainwater and reducing runoff, which lowers flood risks. (Kader *et al.*, 2022). Economically, they reduce energy costs by improving thermal insulation, extend roof lifespans by protecting them from weather, and enhance property values with their aesthetic appeal, which can attract businesses and residents, boosting local economies (Shafique *et al.*, 2018). As rapid urbanization impacts biodiversity and natural resources, green roofs provide vegetated spaces that support diverse organisms, reinforcing their role in fostering sustainable and resilient cities (Perivoliotis *et al.*, 2023).

2.1.2 Issue of green roof implementation

According to Amalia Azmi (2023), Haze: Air quality in Cheras, Kuala Lumpur, and Nilai has reached severe pollution levels, with readings as high as 163, largely due to local emissions and transboundary pollution. Kuala Lumpur's reliance on personal vehicles, driven by low gas prices and affordable car ownership, contributes to high emissions of pollutants like nitrogen oxides (NO_x) and particulate matter (PM2.5). Industrial activities in the Klang Valley also release harmful substances such as sulfur dioxide (SO₂) and volatile organic compounds (VOCs), worsening air pollution and impacting public health. (Azmi, 2023), New Straits Times.

2.2 Factors of green roof implementation towards sustainable environmental in Kuala Lumpur.

2.2.1 Reduce the Greenhouse gas effect

Green roofs play a crucial role in reducing greenhouse gases and addressing climate change in urban areas by lowering energy demand for air conditioning, mitigating the urban heat island effect, and improving air quality through carbon dioxide absorption via photosynthesis (Arabi *et al.*, 2015; Nejat *et al.*, 2015). Additionally, the transportation sector significantly contributes to greenhouse gas emissions through fossil fuel use, exacerbated by population growth and urbanization, as seen in China's projected increase in transport emissions by 2040. (Chin *et al.*, 2023)

2.2.2 Reduce the Urban Heat Island effect

The Urban Heat Island (UHI) effect occurs when cities are hotter than rural areas due to materials like concrete, less greenery, and heat from traffic and industries. This increases energy use for cooling, air pollution, and health risks. (Yang *et al.*, 2016) Green roofs help reduce this effect by lowering heat absorption and improving thermal management. The plants on green roofs provide shade and reflect sunlight, keeping the roof surfaces cooler than regular roofs. Green roofs also act as natural insulators, with layers of soil, plants, and membranes reducing heat transfer. Green roofs can lower summer energy use for cooling by up to 25%, making them a highly energy-efficient choice for buildings. (Arabi *et al.*, 2015)

2.2.3 Improve Air Quality

Green roofs help solve urban environmental issues like air pollution and climate change by reducing carbon dioxide (CO₂), the main greenhouse gas causing global warming. Plants on green roofs absorb CO₂ through photosynthesis, turning it into oxygen and organic matter. They also store carbon, and this capacity increases with deeper soil layers that promote more plant growth. (Nejat *et al.*, 2015) Although green roofs don't store as much carbon as large ecosystems like forests, they play an important role in cities where green spaces are limited. (Rezazadeh, 2021).

2.2.4 Improved thermal regulation

Green roofs improve thermal performance and help cool buildings, especially in tropical areas. Research shows that green roofs with deeper soil layers can lower air temperatures by 1-2°C compared to bare roofs. Thicker soil keeps the temperature lower, holds moisture better for plant health, and maximizes cooling benefits. This cooling reduces the need for air conditioning, saving energy and money. These benefits can encourage policymakers and urban planners to include green roofs in building designs, supporting sustainability and energy efficiency in cities. (Mirnezhad *et al.*, 2017)

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2.3 Challenges of green roof implementation

2.3.1 Challenges of green roof implementation towards economic growth

According to Berardi *et al.*, (2014), implementing green roofs in Kuala Lumpur faces significant economic challenges, mainly due to high installation costs for materials such as waterproofing, drainage systems, and vegetation. These costs can deter property owners and developers, especially in a cost-sensitive market, and without financial incentives or subsidies, the implementation of green roofs remains limited. This slows the realization of long-term benefits like energy savings, improved property values, and market expansion for green technologies. Additionally, older buildings may require costly upgrades to handle the weight of green roofs, further reducing their feasibility.

Maintenance costs also pose a challenge, as green roofs require regular care, including irrigation and plant upkeep, which are more complex and expensive than traditional roofs. The tropical climate in Kuala Lumpur adds difficulty in selecting and maintaining suitable plants, raising costs and reducing survival rates. Addressing these issues through coordinated policies, subsidies, and public education can boost green roof implementation and enhance urban sustainability (Shaharudin *et al.*, 2019; Berardi *et al.*, 2014).

2.3.2 Challenges of green roof implementation towards environmental

Green roofs face challenges in managing water retention and drainage effectively. While they aim to collect rainwater to reduce the runoff and pressure on drainage systems, too much water retention can add extra weight and risk structural damage. (Graceson *et al.*, 2013) A proper balance is needed to prevent waterlogging, especially during heavy rains, by using efficient drainage systems. Green roofs can improve water quality by filtering impurities from rainwater but may also introduce pollutants like metals and fertilizers. Careful selection of plants and soil types is essential to ensure runoff water remains clean. (Vijayaraghavan, 2016).

2.3.3 Challenges of green roof implementation towards social

Implementing green roofs faces social challenges like limited public access and low community engagement. These roofs are designed mainly for environmental benefits, which often restricts their use for community activities. Many people are unaware of the advantages of green roofs, which reduces interest and support. (Nguyen Dang *et al.*, 2022)

Another challenge is the lack of skilled workers to install and maintain green roofs. These projects require knowledge of horticulture, water management, and technical skills like waterproofing and irrigation. Without proper training, issues like pest control and seasonal care can arise, and a lack of understanding about their environmental and economic benefits makes it harder to gain stakeholder support. (Yen *et al.* 2021)

2.4 The strategies to enhance the implementation of green roofs.

2.4.1 Stormwater Management Strategy

The integration of green roofs into urban environments is facilitated by nature-based solutions (NbS), particularly in efficiently managing stormwater. Green roofs, a key component of NbS, reduce surface runoff, promote infiltration, and capture rainwater. This replication of natural hydrological processes helps minimize floods and eases the burden on the existing stormwater infrastructure. Green roofs are especially beneficial in densely populated urban areas as they utilize existing building surfaces without requiring additional land. This approach not only improves stormwater quality but also mitigates the urban heat island effect and fosters resilient and sustainable urban environments. (Monteiro *et al.*, 2023)

2.4.2 Thermal Performance Enhancements

Green roofs provide considerable thermal performance benefits and temperature mitigation capabilities, particularly in tropical areas, by efficiently reducing building ambient and surface temperatures. Thicker substrates help to maintain lower soil temperatures and greater moisture levels, which are critical for plant health and maximising cooling effects. This cooling effect improves interior thermal comfort while simultaneously reducing the demand for air conditioning, resulting in significant energy savings. This technique promotes long-term sustainability and resilience in urban environments while meeting critical cooling and energy efficiency requirements (Mirnezhad *et al.*, 2017).

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2.4.3 Awareness and Education

According to Rahman *et al.*, (2013), a comprehensive approach is needed to maximize the implementation of green roofs, beginning with raising awareness and education. This involves conducting extensive awareness campaigns to educate both the public and professionals about the benefits of green roofs. Moreover, specialized training

programs tailored for architects, landscape architects, developers, urban planners, and government officers should be developed to address the technical aspects of green roof installation and maintenance.

2.4.4 Government Incentives

Governments can encourage green roof adoption by implementing strategies that integrate financial incentives with supportive regulations, while highlighting the long-term benefits of sustainability. Financial tools like grants, subsidies, tax breaks, and low-interest loans can reduce upfront costs and make green roofs more affordable, while clear information on their benefits, such as energy savings, improved air quality, biodiversity, and stormwater management, can increase stakeholder interest (Chen *et al.*, 2022). Streamlining approval processes and reducing administrative costs for green roof projects can also enhance implementation, helping governments advance urban sustainability and resilience (Liberalesso *et al.*, 2020).

3. Research Methodology

This study outlines the methodology for investigating the implementation of green roof building in Kuala Lumpur. The study employs qualitative research methods, particularly semi-structured interviews with project managers, green roof building consultants, and architects involved in green roof building projects within Kuala Lumpur

Table 1: *Research Design Method*

No	Research Objectives	Method
1	To identify the factors of green roof implementation towards sustainable environmental protection in Kuala Lumpur.	<ul style="list-style-type: none"> • Literature Review • Qualitative (Semi-structured Interview)
2	To investigate the challenges to implementing green roofs in Kuala Lumpur.	
3	To suggest a strategy to enhance the implementation of green roofs in Kuala Lumpur.	

3.1 Research Design

This study benefited from using qualitative methods, as data were collected through interview sessions with individuals holding relevant positions in related companies.

3.2 Research Process

The research method for this study is divided into five separate stages, each of which serves a particular role in directing the study's completion. The first phase focuses on establishing the research background, defining the problem statement, identifying research questions and objectives, determining the scope of the study, recognizing its relevance, and detailing the research technique to be used.

The third phase is the data collection phase. In this phase, there is an information-collecting process consisting of primary and secondary data. Primary data was obtained using qualitative data methods through structured interviews. These interviews specifically aim to meet objectives one and two. The target interviewees were among the relevant experts and experienced green roof building consultants and architects. Meanwhile, secondary data was collected through articles, journals, online supporting documents, and books.

In the fourth phase, data analysis was carried out utilizing content analysis methods to give conceptual and relational insights based on the data collected. Finally, the final phase is the study's conclusion and recommendations stage, in which the data analysis results are summarized, and conclusions are formed. Furthermore, recommendations and suggestions for future research enhancements are provided.

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3.3.1 Primary Data

Primary data research, involving the direct collection of fresh and original information, addresses specific research questions through methods like interviews, case studies, observations, surveys, and questionnaires (Adah *et al.*, 2023; Ajayi *et al.*, 2023). In this study, semi-structured interviews were conducted with project managers, green roof building consultants, and architects involved in green roof building projects within Kuala Lumpur. Depending on participants' preferences and availability, the interviews take place in person or via video

conferencing platforms. To ensure accuracy, all interviews were audio-recorded with consent, and comprehensive field notes were taken to capture non-verbal cues and additional observations, enriching the transcription and analysis process.

3.3.2 Secondary Data

Secondary data was available, but not pure because it had undergone content analysis. Governmental papers, websites, books, journal articles, and internal records were examples of secondary data sources (Ajayi *et al.*, 2023). Secondary data research focused on data analysis and discussion of the findings while utilizing data gathered by other researchers for various objectives. Also permitted were systematic reviews and meta-analyses by students (Adah *et al.*, 2023).

3.4 Research Population

A research population is typically a sizeable group of people or things that serve as the primary subject of a research study. Research is carried out to benefit the targeted population. (Taherdoost, 2022) The research population consists of project managers, green roof building consultants, and architects involved in green roof building projects within Kuala Lumpur.

3.4.1 Research Sampling

For the qualitative interviews, purposive sampling was employed to select project managers, green roof building consultants, and architects with relevant expertise and experience in green roof building.

3.5 Research Instrument

A research instrument is a tool that is needed in the research process to gather, measure, and analyze the data. In this way, methods and tools like interviews, tests, questionnaires, checklists, and observations can be used to gather information (Busetto *et al.*, 2020). Semi-structured interview guides were developed for qualitative interviews, covering topics such as green roof building challenges, the impact of green roof building, and the potential of enhancing green roof building.

3.5.1 Semi-Structured Interview

A semi-structured interview is an approach to gathering data that involves asking a series of open-ended questions to participants and then asking follow-up inquiries to gain insight into their answers and the research issue. Semi-structured interviews are a hybrid of structured and unstructured interviews used in qualitative research when some questions are predefined while others are not (Magaldi *et al.*, 2020). Other than that, semi-structured interviews provide the opportunity to explore any relevant issues that may come up while enabling us to remain focused on the area of interest. This method is a tool commonly used by qualitative researchers to get new information and understand participant opinions on a given subject. In this research, a semi-structured interview was conducted involving the project manager which expertise in green roof building implementation in Kuala Lumpur because they have real experience and give relevant and constructive feedback during the interview session. There are four sections of interview questions used for the data collection phase that are listed below:

Section A: Respondent's Background

Section B: Factors of green roof building implementation towards sustainable environmental

Section C: Challenges of green roof building implementation

Section D: Suggestions to enhance the green roof building implementation.

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3.6 Data Analysis

Data analysis involves organizing, ordering, and giving significance to the vast amount of gathered data (Raheja *et al.*, 2017). This process begins only after all necessary data is collected and includes identifying and removing errors and unwanted information. Data should be collected in its raw, detailed form to identify patterns. Data analysis helps organize complex information, making it clear and useful for informed decision-making. Asking the right questions is crucial to focus the analysis on the primary goal (Bhatia, 2017). In this study, qualitative data from semi-structured interviews are analyzed using content analysis techniques. Identified themes were organized and analyzed to understand the factors of green roof implementation towards sustainable

environmental goals, challenges of green roof implementation, and strategies to enhance the green roof implementation in Kuala Lumpur.

4. Results and Discussion

4.1 Respondents' Background

The study included five respondents with significant expertise in green building practices. Their profiles were summarized in Table 2, which includes their companies, positions, years of experience, and involvement in green roof projects. All respondents had considerable experience, ensuring data relevance and reliability.

Table 2: Respondents' Background

Respondents (R)	R1	R2	R3	R4	R5
Company's Name	A	B	C	D	E
Positions	Director	Project manager	Director	Project manager	Architect
Age	35	45	46	40	43
Education level	Construction Management (Bachelor)	Civil Engineering (Master's degree)	Architecture (Master's degree)	Construction Management (Bachelor)	Architecture (Master's degree)
Years of experience in the construction industry	11 years	15 years	14 years	11 years	13 years
Working experience in green roof building projects have been involved	Green building consultant Office	5 years Residences	9 years of green building Shopping mall	3 years Residences	4 years Residences

4.2 The Factors of Green Roof Implementation Towards Sustainable Environmental In Kuala Lumpur

Table 3 highlights the key factors contributing to the implementation of green roofs towards achieving a sustainable environment in Kuala Lumpur. These factors include reducing greenhouse gases by lowering energy consumption, mitigating the urban heat island effect through improved insulation and cooling, enhancing air quality by filtering pollutants, and providing effective thermal regulation to keep buildings cooler naturally.

Table 3: The Factors of Green Roof Implementation Towards Sustainable Environmental In Kuala Lumpur

Factors	R1	R2	R3	R4	R5
Greenhouse Gas Reduction					
Energy Efficiency and Carbon Reduction	✓	✓		✓	✓
Lower Greenhouse Gas Levels Indirectly by Reducing Energy Consumption for Cooling Systems	✓	✓	✓	✓	✓

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Urban Heat Island Effect						
Cooling Down Urban Areas by Reducing Temperatures Around Buildings	✓	✓	✓	✓	✓	✓
Reduce The Heat Compared to Regular Roofs by Providing Insulation	✓	✓	✓	✓	✓	✓
Air Quality Improvement						
Improves Air Quality by Filtering Dust and Pollutants Through Their Plants	✓	✓	✓	✓	✓	✓
Reducing air pollution depends on the selection of plants	✓	✓	✓	✓	✓	✓
Thermal Regulation						
Helps Keep Buildings Cooler	✓	✓	✓	✓	✓	✓
Lowers Energy Use for Cooling Building	✓	✓	✓	✓	✓	✓

All respondents agreed that green roofs indirectly reduce greenhouse gas emissions by lowering energy consumption and reliance on air conditioning. Additionally, Respondent 3 stated that green roofs do not directly reduce greenhouse gas emissions. However, by decreasing the need for air conditioning through better insulation, they indirectly help lower carbon emissions.

“Green roofs help reduce heat entering buildings, which lowers energy use and indirectly reduces the city's carbon footprint. They also lower greenhouse gases by reducing the need for air conditioning and mechanical systems that emit carbon dioxide.” (R3)

Regarding air quality improvement, all respondents agreed that green roofs enhance air quality by filtering pollutants, trapping dust, and releasing oxygen. However, they stated that the effectiveness of this benefit depends on selecting the right plants. Similarly, all respondents agree on the thermal regulation benefits of green roofs, which act as natural insulators to keep buildings cooler, reduce energy consumption, and lower cooling costs.

Respondent 2 highlighted that green roofs filter harmful particles and release oxygen, improving the air. However, the efficiency of this process is influenced by the types of plants chosen for the roof.

“The right plants can make green roofs more effective at cleaning the air by trapping dust, dirt, and harmful pollutants. Certain plants have leaves and surfaces that catch and hold onto these particles, preventing them from spreading in the air. This helps improve air quality by reducing pollution.” (R2)

All respondents agreed that green roofs help regulate building temperatures and reduce energy use. Respondent 1 stated that green roofs act as insulation, preventing heat from entering buildings and keeping them cooler naturally. This reduces the need for air conditioning.

“Green roofs help keep buildings cooler by acting as a natural barrier. The soil and plants on the roof work together to block heat from entering the building. The soil absorbs some of the heat, and the plants provide shade, which keeps the temperature inside the building lower. This layer of plants and soil acts like insulation, preventing too much heat from getting inside, so the building stays cooler.” (R1)

4.3 The Challenges for Implementing Green Roofs in Kuala Lumpur

Table 4 highlights the key challenges faced in implementing green roofs towards achieving a sustainable environment in Kuala Lumpur. These challenges include high initial installation costs requiring specialized materials and skills, increased maintenance demands such as irrigation and drainage management, water management difficulties due to heavy rainfall, and limited public awareness about the benefits of green roofs. Addressing these challenges is crucial for advancing green roof implementation in Kuala Lumpur.

Table 4: *The Challenges for Implementing Green Roof In Kuala Lumpur*

Challenges	R1	R2	R3	R4	R5
Economic Challenges					
High Initial Installation Costs			✓	✓	✓
Higher maintenance cost	✓	✓		✓	✓
Environmental Challenges					
Water management and drainage system	✓	✓	✓	✓	✓
Social Challenges					
Limited awareness and community engagement about the benefit of green roof	✓	✓	✓	✓	✓
Lack of specialist skills and knowledge in green roof implementation	✓	✓	✓	✓	✓

The second part of this section focuses on the challenges of implementing green roofs in Kuala Lumpur based on insights from respondents. Their feedback highlights economic, environmental and social challenges that impact green roof projects. Respondent 3 pointed out that the high costs can discourage property owners, especially those who don't have large budgets. They feel this is one of the main challenges to implementing green roofs.

"Although the initial cost is high, with long-term financial planning, these expenses can be covered over time. Green roofs require special materials and skills, which make them more expensive to install. While they do provide energy savings, it takes time for those savings to offset the upfront cost." (R3)

Respondents R1 and R2 disagreed that initial costs are a major challenge, suggesting that proper planning, the use of local materials, and efficient designs can mitigate expenses. Respondent 1 argued that the real challenge lies in the lack of awareness about green roofs and their benefits. Respondents R3, R4, and R5 agreed that the high initial cost is a significant challenge, particularly for property owners with limited budgets, and collectively suggested promoting financial support and the use of affordable materials to enhance the accessibility of green roofs.

Respondent 1 and respondent 2 mentioned that the high initial cost of installing green roofs is a challenge, but they believe this can be reduced through careful planning and efficient design. They argued that the bigger issue is the lack of awareness and knowledge about green roofs, rather than the cost itself.

"The initial cost of installing a green roof may seem expensive, but it can be reduced if there is careful planning and smart design. The real challenge, however, is not so much the cost but the lack of awareness and understanding about green roofs. Many people may not know enough about their benefits or how to make them more affordable, which can make it harder to get started with green roof projects. By improving knowledge and planning, the overall cost can be made more manageable." (R1)

"Although the initial cost of installing a green roof is high, careful financial planning and long-term strategies can help reduce these costs over time. Green roofs need special materials and expertise to install, which is why the installation expenses are higher compared to regular roofing. However, by planning well and thinking about the long-term savings and benefits, such as energy efficiency and lower maintenance costs, the higher initial investment can be balanced out in the future." (R2)

Respondent 4 agreed that the initial cost is a significant concern for many property owners. The expense can make it difficult for people to consider installing green roofs, even though they offer long-term benefits.

"The high cost is a major challenge for many property owners. The need for special materials increases the cost, and while the savings over time are enough to make up for it, they aren't immediate." (R4)

Maintenance costs also present a significant challenge. Respondents R1, R2, R4, and R5 agreed that the need for regular upkeep, such as plant care, drainage management, and inspections, can be costly and resource-intensive. Respondent 1 points out that maintaining green roofs can be expensive because they need regular care. This includes checking and taking care of the drainage system and the health of the plants. If these aren't properly maintained, it can lead to bigger issues over time.

"Maintenance can be costly because it involves regular tasks like trimming plants, cleaning drainage systems, and checking for leaks. While plants need consistent care, proper planning during construction can help reduce how often maintenance is needed. It's not always necessary to have experts, but workers should receive basic training to understand the system and maintain it correctly." (R1)

Regarding maintenance costs, respondent 3 (R3) did not directly view the costs as a significant challenge but emphasized that effective techniques and good practices during construction and maintenance can help minimize expenses over time.

"Maintenance can become costly if the right techniques and good practices are not followed. However, if the green roof is built properly, it doesn't require many specialized workers. Heavy rainfall can cause water seepage issues, so regular checks are needed." (R3)

All respondents (R1 to R5) agreed that well-designed drainage systems are crucial to prevent waterlogging and structural damage. They emphasized the importance of educating property owners and workers about best practices to ensure proper drainage and waterproofing. Respondent 1 explains that if the roof's surface isn't level or the drainage system isn't good, water can get stuck and cause problems.

"Managing water retention can be tricky in Kuala Lumpur due to heavy rainfall. If the levelling is wrong or the drainage system is inadequate, water can stagnate. While heavy rain makes it harder, good drainage systems can solve this problem. Drainage must be carefully designed to prevent waterlogging and other issues. Poor drainage or levelling can lead to leaks or other defects." (R1)

Another significant issue is the lack of public awareness and education about green roofs. All respondents (R1 to R5) stated that many people are unaware of their environmental and energy-saving benefits, which leads to misconceptions about costs and maintenance. They agreed that raising awareness through educational programs, workshops, and public campaigns is essential to promoting green roofs. Respondent 3 stated that the lack of awareness makes it harder to convince people to install green roofs.

“There is limited public awareness about green roofs. Teaching people from a young age can help raise understanding of their benefits. However, worries about the cost and complexity of installation and maintenance are holding back their use. By addressing these concerns and educating the public, more people might be encouraged to implement green roofs.” (R3)

All respondents agreed that the lack of specialized skills and knowledge is a significant challenge for the successful implementation of green roofs. Respondent 1 points out that many projects fail because people does not have the right expertise during important stages, like design and building.

“There is a clear lack of expertise when it comes to designing and maintaining green roofs. Many projects fail because of poor planning, such as choosing the wrong materials or not properly designing the drainage system. While workers don’t need to be specialists, it’s important that they receive proper training on how to maintain and inspect green roofs. Without expert advice, projects are more likely to fail, which can discourage people from implementing green roofs in the first place. (R1)

4.4 The Strategies to Enhance the Implementation of Green Roof In Kuala Lumpur

Table 5 highlights the key strategies to enhance the implementation of green roofs towards achieving a sustainable environment in Kuala Lumpur. These strategies include promoting effective water management systems to handle heavy rainfall, raising public awareness through educational campaigns and training programs, providing government incentives such as subsidies and tax breaks to reduce financial barriers, and emphasizing the thermal and environmental benefits of green roofs to encourage their implementation. These strategies aim to address challenges and promote widespread implementation of green roofs in Kuala Lumpur.

Table 5: The Strategies to Enhance the Implementation of Green Roof In Kuala Lumpur

Strategy	R1	R2	R3	R4	R5
Stormwater Management Strategy to Reduce Runoff During Heavy Rains	✓	✓	✓	✓	✓
Thermal Performance Enhancement to Reduce Indoor Heat by Limiting Heat Transfer	✓	✓	✓	✓	✓
Raising Awareness and Education	✓	✓	✓	✓	✓
Government Incentive Such as Subsidies, Tax Breaks, or Loans to Encourage the Implementation	✓	✓	✓	✓	✓

The third part of this section focuses on the strategies to enhance the implementation of green roof in KL based on insights from respondents. The respondents emphasized key strategies to address maintenance challenges, raise public awareness, and promote green roof implementation through government incentives in Kuala Lumpur. All respondents (R1 to R5) agreed that green roofs are effective in managing stormwater by reducing runoff and lowering flood risks, but they emphasized the importance of proper drainage systems to handle heavy rainfall effectively.

“Green roofs are helpful for managing rainwater because they can reduce the amount of water that flows off a building and slow it down. This helps prevent flooding and reduces pressure on drainage systems. However, green roofs aren’t a complete solution for managing stormwater, especially during heavy rainfall. They work well for smaller amounts of rain but may struggle to handle large volumes of water. Other systems, like bioswales or rainwater harvesting, can manage larger amounts of water more effectively. Combining green roofs with these systems creates a more balanced approach, using the strengths of each to manage stormwater better.” (R1)

All respondents (R1 to R5) agreed that green roofs enhance thermal performance by reducing heat gain, lowering indoor temperatures, and contributing to energy efficiency. Respondent 1 stated that green roofs act as natural insulation, limiting heat transfer into buildings and reducing the need for air conditioning.

“Green roofs help keep buildings cooler by reducing the amount of heat that enters the building. By limiting heat gain, they lower the need for air conditioning, which can lead to lower energy costs. Thicker soil layers improve insulation and thermal performance, making the building even more energy efficient. However, the weight of these layers must be considered to ensure the building’s structure can support them. Overall, green roofs help maintain a comfortable indoor temperature by reducing temperature fluctuations and minimizing heat gain from the outside.” (R1)

Raising public awareness and providing education were also identified as critical strategies. All respondents agreed that raising public awareness is essential for promoting green roofs. Respondent 1 mentioned that educating the public on the benefits of green roofs increases their acceptance and implementation.

“Raising awareness is essential for encouraging the implementation of green roofs. When people understand how green roofs improve buildings by providing environmental and energy-saving benefits, they are more likely to appreciate and consider using them. Educational campaigns play a vital role in spreading this knowledge to the public, helping them see the value green roofs bring to both individuals and the community. Training programs are equally important, as they ensure that architects and builders have the necessary skills and expertise to design and construct green roofs effectively. Additionally, people’s motivation to implement green roofs often depends on their priorities.” (R1)

Government incentives were also identified as crucial for supporting green roof implementation. All respondents agreed that government incentives, such as subsidies, tax breaks, and grants, are vital for increasing green roof adoption. They all recognized that financial support could ease the burden of high upfront costs and make green roofs more accessible. Respondent 3 stated that low-interest loans as a viable option for easing the financial burden on developers and smaller property owners.

“Government subsidies, tax breaks, and low-interest loans can help reduce the financial burden on developers and property owners, making green roofs more affordable and encouraging their implementation. These financial incentives are especially useful for small property owners who may find the high initial costs of green roofs challenging. For developers, loans provide a way to manage the upfront costs of installation without putting too much pressure on their finances, making it easier to invest in sustainable building solutions.” (R3) 648

5. Conclusion & Recommendations

The objectives of this study were successfully achieved through the findings, which identified the factors contributing to green roof implementation towards a sustainable environment, investigated the challenges, and proposed strategies to enhance their implementation in Kuala Lumpur. It emphasizes the significant environmental, economic, and social benefits of green roofs, such as reducing the urban heat island effect, improving air quality, and enhancing thermal performance. These objectives were achieved through a qualitative method, specifically through semi-structured interviews with experts in green roof building, complemented by an extensive literature review of journals, books, conference proceedings, reports, and previous research studies. The findings provide a comprehensive understanding of the factors influencing green roof implementation,

highlight the challenges that need to be addressed, and propose practical recommendations for promoting green roofs as a sustainable solution in urban development.

The research also provides practical recommendations for integrating green roofs into urban infrastructure. Construction companies are encouraged to implement green roof systems as standard designs, collaborate with experts to improve designs, and advocate for government support, such as subsidies and tax incentives. Training programs for architects and builders can bridge skill gaps, ensuring successful design, installation, and maintenance. These strategies aim to make green roofs a key feature of sustainable urban projects, improving environmental quality and creating better living spaces in Kuala Lumpur and beyond.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Law Jing Wei, Zailawati Khalid; **data collection:** Law Jing Wei; **analysis and interpretation of results:** Law Jing Wei, Zailawati Khalid; **draft manuscript preparation:** Law Jing Wei, Zailawati Khalid. All authors reviewed the results and approved the final version of the manuscript.

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