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Challenges of Facilities Management in Managing Intensive Green Roofs in High-rise Residential

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ABSTRACT

Implementing green roofs is becoming a growing trend in high-rise residential buildings, providing numerous benefits such as biodiversity, energy efficiency, and sustainable urban living. These green roofs are categorised into extensive and intensive types and require regular maintenance to ensure optimal performance and longevity. However, facilities management (FM) needs help with these maintenance practices, leading to leakages, mould growth, and building defects. The design of green roofs also poses challenges, as maintenance and sustainability are not considered during the initial design and construction stages. Additionally, a lack of knowledge among FM staff about green roofs can hinder the effective management and maintenance of these systems in high-rise residential buildings. Thus, this study was carried out to improve FM practices for intensive green roofs in high-rise residential buildings in the Klang Valley. The research objective was to investigate FM's challenges in managing intensive green roofs in these buildings. This research used qualitative methods, including semi-structured interviews with five FM professionals managing intensive green roofs in the Klang Valley area high-rise residential buildings. The findings reveal that FM's foremost challenges include financial constraints, maintenance issues, limited expertise, and a need for more knowledge among FM staff. To address these challenges, the study proposes recommendations such as income generation initiatives, preventive maintenance programs, landscape improvement, and technology implementation to streamline intensive green roof maintenance and monitoring processes. This approach addresses current challenges in FM practices and promotes a holistic approach to managing intensive green roofs in high-rise residential buildings.

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INTRODUCTION

In recent years, the implementation of green roofs has increased, especially in high-rise buildings. Green roofs, also known as planted roofs or living roofs, have been popular recently due to their various benefits (Shafique et al., 2018). Implementing green roofs in high-rise residential buildings gained significant awareness as a new urban green infrastructure development strategy (Rahman, 2023). Besides that, El-Ahwal et al. (2016) mentioned that green roofs give several benefits towards the environment, people, and economy; these benefits address various issues, including psychological and physical health, the reduction of the urban heat island effect, improved rainwater management, improved air and water quality, reduced building energy consumption costs, as well as sustainability, and aesthetic advantages.

To ensure green roofs function efficiently, facilities management (FM) needed to contribute to the effective management of green roofs by addressing numerous issues such as maintenance, stormwater management, and environmental, economic, and public perception factors. FM played a critical role in improving the environmental benefits of green roofs by ensuring their appropriate design, installation, and maintenance to maximise their potential in mitigating environmental impacts and resilience. In this context, the study by Saharuddin et al. (2020) prioritised maintenance criteria for green roofs in high-rise residential buildings, highlighting the importance of drainage, waterproofing, and irrigation. Furthermore, Goda et al. (2023) highlighted the importance of green roofs, revealing the need for FM to adopt more sustainable approaches and alternative strategies to ensure the longevity of green roofs. Therefore, understanding FM's challenges in managing intensive green roofs is crucial for enhancing their effectiveness in high-rise residential buildings.

Definition of Green Roofs

Saharuddin et al. (2019) define a green roof as a rooftop structure specifically designed to support vegetation. On the other hand, Hilde et al. (2017) defined green roofs as constructed rooftops that sustained vegetation and suggested them as one such “natural” solution to enhance urban sustainability. Meanwhile, a rooftop garden was defined as one on a roof, including intermediate levels and the top of the building (Town Planning Department Guideline, 2011). To summarise, both definitions of green roofs and rooftop gardens give the exact meaning of plants incorporated at the intermediate or top levels of a building.

Besides that, green roofs were popular for several reasons, mainly due to their advantages as a sustainable building practice. Green roofs and rooftop gardens mitigate the "heat island" effect often observed in urban areas where concrete and asphalt absorb heat that is not readily dissipated. This not only helps to lower ambient temperatures but also reduces the amount of cooling energy required by the building. In other words, green roofs help to mitigate the urban heat island effect by providing natural insulation and shade through layers of vegetation, soil, and other substrate materials. Lundholm et al. (2010) mentioned that the vegetation on green roofs absorbs sunlight for photosynthesis and releases moisture through evapotranspiration, which cools the surrounding air. As a result, green roofs can significantly lower the ambient temperature around the building, reducing the overall energy consumption. This leads to reduced greenhouse gas emissions and lower building operational and maintenance costs (Shafique et al., 2017). Moreover, green roofs are an excellent example of this, as they serve as natural water management systems that reduce stormwater runoff and help filter pollutants out while absorbing the rain. Krebs et al. (2015) have demonstrated that green roofs can retain a significant portion of rainfall, with some studies reporting retention rates of up to 100% during small storm events. This capacity for stormwater management alleviates pressure on urban drainage systems and contributes to the overall ecological health of urban areas by mimicking natural water cycles (Paulista et al., 2019). Green roofs also provide an attractive and aesthetic appearance, which improves the visual aspect of cities by turning unused spaces into green gardens; maintaining vegetation helps maintain people's well-being (Sutton, 2015).

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In addition, green roofs were designed and built specifically to accommodate the growth of vegetation, and they were categorised into two main types: extensive and intensive green roofs (Andenæs et al., 2018). The extensive green roof typically supports low-growing, drought-tolerant plants and requires minimal maintenance. Extensive green roofs are also light and covered by a thin layer of vegetation. They consist of a substrate layer with a maximum depth of about 150mm, including vegetables and plants, making it shallower in depth and requiring less maintenance. Other than that, the weight of the extensive was about 60-150 kg/m2 and did not require any irrigation system. The plant communities that have been applied include moss, sedum, herbs, and grasses. An extensive green roof comes cheaply and serves as an ecological protection layer. Figure 1 shows an example of applying extensive green roofs at Heriot-Watt University.

Fig. 1. Extensive Green Roof at Heriot-Watt University

Source: Heriot-Watt University website (n.d.)

On the other hand, intensive green roofs, generally known as roof gardens, could be built on the roofs of buildings that were strong enough to support additional loads, heavier, and could support small trees and shrubs. The depth of intensive green roofs was above 200 mm, which was more expensive and could often provide accessible areas (Penkova, 2020). Intensive green roofs weighed about 180–500 kg/m2 and required an irrigation system. The plant communities that have been applied, such as lawns, perennials, shrubs, and trees, also contain several components that have been allowed in intensive green roofs for facilities and amenities like a toilet, swimming pool, table, benches, rock garden, gazebo, playground, dustbin, barbeque grill, indoor court, outdoor fitness, etc. ((Rahman, 2023). Moreover, these intensive green roofs are also designed to create an attractive natural environment with better biodiversity while providing recreational space (Wardhani, 2020). Figure 2 shows the intensive green roofs at the Manhattan high-rise building, and Figures 3 and 4 show the facilities and amenities that allowed for intensive green roofs.

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Fig. 2. Intensive Green Roof at Manhattan High Rise Building

Source: Hanson (2012)

Fig. 3. Swimming Pool at Intermediate Level – The Henge Residence

Source: Town Planning Department Guideline (n.d.)

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Fig. 4. Outdoor Fitness at The Rooftop Garden – DK Impian Residence

Source: Town Planning Department Guideline (n.d.)

Definition of Facilities Management (FM)

Facilities management (FM) was a specialised field focused on serving individuals. FM must also ensure that all the facilities and amenities in or outside the building function efficiently and safely (IFMA, 2022). This is because by ensuring all these facilities were in good condition and could be run, people in the building would feel more comfortable, safe, and enjoyable. This indicates that the FM team successfully managed the building. Besides that, according to Nenonen et al. (2023), FM is essential in helping organisations achieve their goals. It must ensure all the facilities and services are run smoothly, effectively, and ready for any changes. Therefore, IFMA's definition of FM differs from others, emphasising FM's role in aligning strategy with the organisation's overall plan. It also suggests that FM should work with specific departments to align with the strategy. FM was crucial for managing management responsibilities, enhancing performance, and reorganising processes to gain a competitive advantage. On the other hand, FM encompasses various activities in a large field with operational, tactical, and strategic levels (Nenonen et al., 2023). The strategic level involves policy formation, benchmarking, and business planning. Tactical budget control, resource management, and monitoring are all involved. Meanwhile, operations involve daily tasks like maintenance and audits. Both in-house and outsourced FM practices are possible (Salleh et al., 2021). In Malaysia, both in-house and outsourcing FM practices are currently in use.

Facilities Management Practices in Managing Intensive Green Roofs

Aside from that, to ensure the buildings, facilities, and equipment stay functional, efficient, and safe, FM practices were required. According to Baharum (2017), FM practices refer to procedures or processes to maintain buildings and infrastructure. Moreover, FM practices have the most significant responsibility to maximise building performance because they provide a diverse range of multidisciplinary functions that enable the efficient operation of support services incorporated to improve the core business of an organisation, which includes the management of buildings as well as their maintenance, cleaning, caretaking, security, and energy (Chen et al., 2019). Delivering good practices could enhance the performance of the buildings.

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Intensive green roofs also require FM practice to maintain their state and ensure long-term durability. Due to their complexity and demands, intensive green roofs require certain FM practices that differ significantly from managing other industrial-engineering structures. As shown in Figure 5, there were several FM practices in managing green roofs, and they were divided into four categories: financial management, operation and maintenance management, behavioural management, and technology.

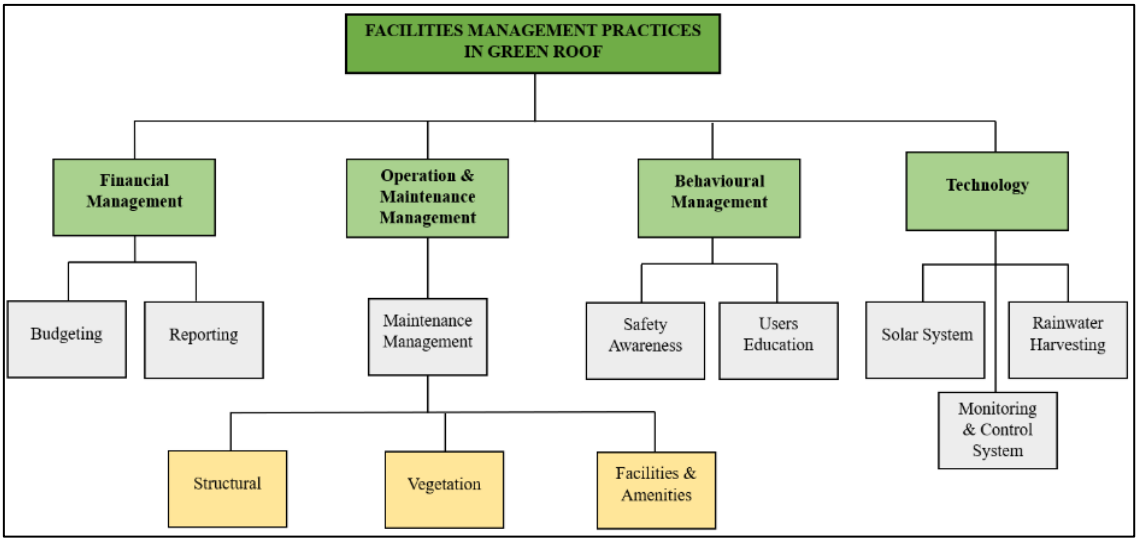

Fig. 5. FM Practices for Intensive Green Roofs

Source: Patanapiradej (2012)

Financial management in high-rise buildings is crucial for green roof management, including budgeting, cost analysis, utility management, and reporting. FM is critical for allocating maintenance fees and analysing expenses related to vegetation, irrigation systems, drainage maintenance, structural elements, and facilities and amenities (Perera, 2016). They also manage utilities such as electricity and water consumption to minimise costs. Additionally, FM tracks expenditures and monitors performance to enhance maintenance strategies and reduce expenses.

Next, operation and maintenance management of green roofs is divided into structural management, vegetation management, and facilities and amenities. According to Salahuddin et al. (2020), FM focuses on maintaining the structure of green roofs, preventing leaks and structural damage, while vegetation management involves maintaining vegetation and plants on green roofs to ensure they stay healthy. FM must inspect drainage and water retention systems to ensure proper water flow (Saharuddin et al., 2019). Maintenance of facilities and amenities includes cleaning and repairing them, ensuring their functionality and safety for people.

Furthermore, behavioural management involves raising safety awareness among occupants and providing educational materials to promote responsible behaviour (Behm, 2012). FM provides information on safety features like signage, handrails, and emergency procedures. FM also educates users about green roofs, promoting responsible behaviour and the proper use of facilities and amenities (Everett et al., 2019). Lastly, technology, such as building automation systems, energy management, and water management, could help monitor green roof areas, ensuring efficiency and reducing operational costs (Rogerson, 2023).

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This sustainable approach contributes to the environmental sustainability of green roofs and reduces operational costs and water bills (Cascone, 2019).

Challenges Faced by FM in Managing Intensive Green Roofs

Intensive green roofs pose a unique challenge to FM teams. Ismail et al. (2018) point out that these challenges cover a range of technical, environmental, and operational aspects. Thick soil layers and various plant species were typical features of intensive green roofs. Intensive green roofs require more maintenance and resources compared to extensive ones. This added complexity brings up several issues that FM teams must handle to ensure the functionality and longevity of these green spaces. Here are some of the main challenges that Ismail et al. (2018) highlight:

(i) Maintenance and Operation

Ismail et al. (2010) found that 43% of respondents found managing intensive green roof areas complicated due to a lack of supervision during construction, particularly in waterproofing. This could lead to leaks in the floor structure and affect the units below, requiring significant financial investment. Besides that, the location of intensive green roofs in the rooftop area exposes them to harsh and unpredictable conditions, such as strong winds and direct sunlight. Rahman et al. (2022) emphasise the importance of maintenance in intensive green roof areas, as they are exposed to unpredictable conditions that could damage plants and facilities. Kadhim et al. (2023) also highlight that the lack of supervision and poor artistry during the construction stage could lead to leaking, while factors like over-watering and over-fertilisation could cause plant loss. Therefore, maintenance planning was crucial to prevent plant loss and ensure the long-term success of green roofs.

(ii) Financial

According to Shafique et al. (2018), the financial challenge in managing intensive green roofs was worsened by rising material supplies and inflation, making it difficult to allocate funds for non-prioritised maintenance tasks. Maintenance for intensive green roof areas was primarily focused on priority services like swimming pool services and landscaping, making beautifying these areas difficult due to financial constraints. Human behaviour and unpredictable weather in Malaysia also contribute to higher maintenance costs, as vandalism, flower picking, and extreme weather could result in significant expenses. The current economic situation limits intensive green roofs' ability to increase maintenance costs, making it difficult to obtain sufficient funds for thorough maintenance and affecting their long-term viability and quality. Ismail et al. (2021) found that nearly 47% of respondents strongly agree that financial constraints pose a significant challenge for FM in managing intensive green roofs, particularly in Malaysia. The country's lack of intensive green roof installers and specialist companies further increases the cost of installing and maintaining materials for intensive green roofs.

(iii) Limited Expertise

Ismail et al. (2021) highlight the challenges FM faces in managing intensive green roofs in Malaysia, with 53% of respondents agreeing that limited expertise and inexperienced professionals contribute to poor implementation. This lack of experience among FM and maintenance teams leads to poor maintenance and unsolved problems. Limited expertise in

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managing intensive green roofs could increase maintenance costs, as inexperienced professionals may make incorrect decisions, such as selecting unsuitable plants for Malaysian weather and soil depths. This could lead to plant loss, damage to floor structures, and increased maintenance costs. Therefore, it was crucial to have experts in green roofs specialising in installation, maintenance, and problem-solving. Ziaee et al. (2022) highlight that hiring inexperienced workers could result in poor maintenance approaches, worsening existing issues, and decreasing the condition of green roofs. Hence, having expertise in managing intensive green roofs was crucial, especially in Malaysia, where there was inadequate expertise.

(iv) Lack of Knowledge

According to Ismail et al. (2010), the problems with existing green roofs in Malaysia are due to a lack of knowledge from FM. Experts specialising in managing green roofs should handle the maintenance of green roofs to prevent problems. When the staff lacks knowledge, they tend to improperly use plant handling techniques, which could lead to plant mortality and the unsuccessful establishment of the green roof (Au-Yong et al., 2019). Other than that, it was essential to have a knowledgeable FM to select plants in intensive green roof areas (Cao et al., 2022). The selection of plants cannot depend on how beautiful they are, but they must be suitable for the soil depth to prevent the roots from penetrating the roof slab. They also need to be considered in terms of weather. This is because Malaysia faced unpredictable weather, which means not all plants were suitable for planting in intensive green roof areas. If the FM lacks knowledge of plant selection, it might result in plant loss and require a high maintenance cost to replace the suitable plants. Therefore, FM should be adequately educated on the type of green roofs and their purpose, as well as the types of plants suitable to be planted in the intensive green roof areas. This could also help the client understand the maintenance requirements for the green roofs.

(v) Inadequate Drainage

Other than that, according to Au-Yong et al. (2019), inadequate drainage also challenges intensive green roofs, and it could result from unsuitable drainage or improper installation of drainage components. Aside from plant loss, inadequate drainage conditions may overload the roof, and water would be imposed into the building through door thresholds, skylights, or hatches. Inappropriate drainage was the most common reason for green roof failures. Drainage with high mud or clay content would typically lead to plant failures.

The implementation of intensive green roofs in high-rise residential buildings became increasingly popular due to its numerous benefits to the environment, economy, and people. These intensive green roofs also mitigate urban heat islands, improve air and water quality, and reduce energy and water costs. An effective FM was needed to maximise the benefits, focussing on maintenance, installation, and sustainability. However, FM faced several challenges when managing intensive green roofs and a strategy was needed to overcome those challenges and ensure their functionality and longevity.

METHOD

In this research, the study employed qualitative data collection methods with a case study to achieve its objectives. The data were collected from semi-structured interviews with five selected facilities managers

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(FMs) responsible for managing intensive green roofs in different high-rise residential buildings in the Klang Valley area. According to Sargeant (2012), a five-sample size in a case study was valid because the researcher focused on specific contexts, such as FM managing intensive green roofs in high-rise residential buildings. The respondents provided diverse perspectives and experiences within the studied context, offering a comprehensive understanding of the topics. They provided sufficient information and data to address the research questions. After acquiring all relevant data for this study, the qualitative insights gathered through interviews were analysed using Atlas—ti software. Based on the study's findings, conclusions and recommendations were provided.

RESULTS AND DISCUSSION

FM faced several challenges in managing intensive green roofs in high-rise residential buildings. Based on semi-structured interviews with five FM in managing intensive green roofs in high-rise residential buildings, four challenges were identified such as (i) financial, (ii) maintenance issues, (iii) limited expertise, and (iv) lack of knowledge. These challenges highlight the difficulties and demand of effectively managing intensive green roofs to ensure their functionality and longevity.

Financial

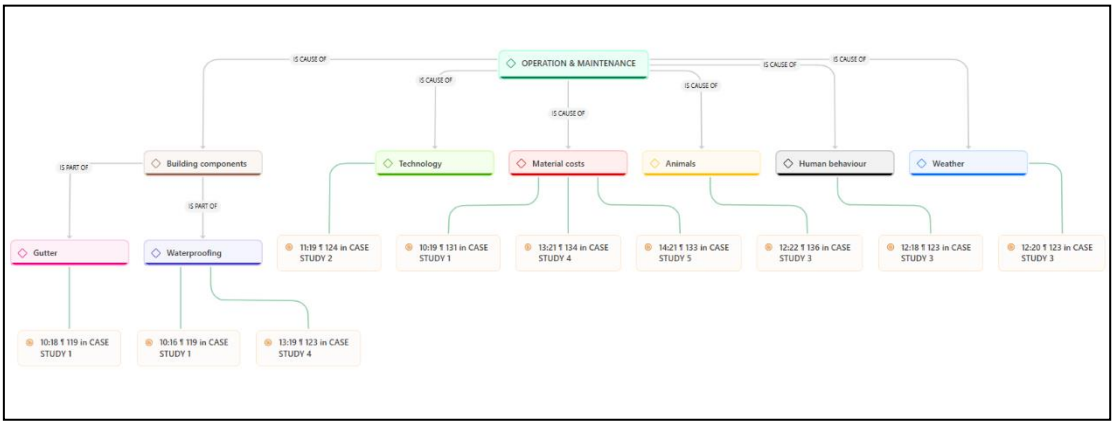

Fig. 6. Challenges on Financial in Managing Intensive Green Roofs

The main challenges faced by FM in managing intensive green roofs in high-rise residential buildings were financial, as shown in Figure 6. Financial considerations were crucial, particularly in managing intensive green roof areas. A robust financial system facilitated the smooth operation and maintenance of intensive green roof areas, including enhanced plants and trees, facilities, and amenities. However, the global impact of the coronavirus disease (COVID-19) led to economic instability in all countries involved. So, it was not easy to maintain the intensive green roofs because they contained a lot of facilities and amenities that required considerable maintenance work. So, it could prioritise maintenance tasks only. This statement was supported by respondents 1, 4, and 5 (as shown in Table 1), where these respondents mentioned that after COVID-19 impacted the country, all the material supplies for maintenance parts were highly increased due to the instability of the economy and inflation. When this happened, FM could only prioritise the maintenance tasks. This aligned with Shafique et al. (2018) research, where this author also stated financial challenges in maintaining the buildings.

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Moreover, all respondents said that due to financial constraints, FM was forced by the Joint Management Body (JMB) to prioritise necessary maintenance work and could not proactively handle every issue. Furthermore, when unexpected issues like flooding occurred, it required a considerable amount of money to hire professional landscapers to address this issue, as mentioned by respondent 2. Respondent 3 then pointed out that factors such as human behaviour (vandalism), unpredictable weather (extreme weather), and insects lead to unpredictability and higher costs, necessitating costly repairs, which is consistent with research Wang et al. (2023). The current economic situation limits the industry's ability to increase maintenance costs, making it difficult to obtain enough money for thorough maintenance and affecting the long-term viability and quality of intensive green roof facilities. Therefore, a strategy was necessary to overcome these challenges, including financial planning and income generation, to carry out maintenance tasks and enhance the functionality and longevity of intensive green roofs.

Table 2. Responses for Challenges on Maintenance Issues

Respondents	Quotations
R1	"…financial also part of challenges due to rising costs of materials and supplies especially after COVID-19, prompting community questions about the necessity of spending money on unnecessary expenses…"
R4	"…what can I say? Financial is part of challenges exacerbated by an unstable economy, high material costs, especially after COVID-19, and inability to increase maintenance fees, making it difficult to prioritise maintenance…"
R5	"… Financial is one of the challenges due to unstable economy presents financial challenges as material costs increase after the COVID-19 impacted the world, making it difficult to find similar or cheaper materials…"

Maintenance Issues

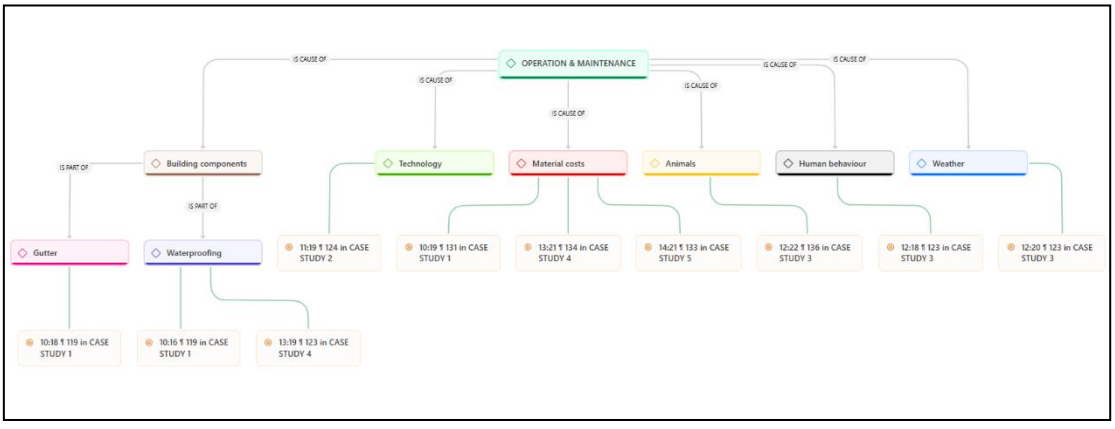

Fig. 7 Challenges on Maintenance Issues in Managing Intensive Green Roofs

Maintenance is also the main challenge FM has faced in managing intensive green roofs in high-rise residential buildings, as shown in Figure 7. Maintenance is essential to ensuring the functionality and longevity of intensive green roofs. Proper maintenance could mitigate financial resource limitations and promote increased performance, aesthetic values, user safety, etc. Therefore, to ensure the effectiveness and efficiency of intensive green roofs, FM must implement a proper maintenance strategy to prevent any issues from arising. Based on the findings, all respondents expressed a similar perspective regarding the challenges associated with maintenance aspects. All respondents emphasised that maintenance was essential to managing green roofs, as it required numerous actions to ensure the green roof areas remained

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in excellent condition and continued to function effectively. Respondent 4 (refer to Table 2) mentioned that problems with inadequate waterproofing thickness resulted in leaks that impacted the areas below. It was crucial because promptly addressing these issues required significant time and money. On the other hand, respondent one also emphasised the same opinion: it took a long time to discover waterproofing issues because much money was needed to fix them. Respondent 1 also said this issue came from the roots because they were already planted and would creep and crack, resulting in potential water damage. It was aligned with Cascone's (2019) research, where this author emphasised that this problem was difficult to manage once the plants had been planted, highlighting the importance of proper planning and root barriers at initial planting.

In addition, respondent 1 pointed out that a gutter presents a significant challenge in providing maintenance services. This is because of the gutter system's design, which allows leaves from trees to fall into gutters that are too high and closed off, making FM unreachable for cleaning and causing clogging and mosquito breeding. This design problem needs innovative solutions, such as automated gutter cleaning systems or gutter rebuilding, to improve accessibility. Respondent 3 further highlighted that the rooftop area, where the intensive green roofs were located, was directly exposed to the harsh and unpredictable conditions typical of Malaysia, such as strong winds and direct sunlight. Therefore, the FM had a crucial responsibility to maintain intensive green roofs whenever they faced extreme weather. It was aligned with Kadhim et al. (2023), where the authors said maintenance was the main challenge in maintaining intensive green roofs, and it would tend to fail if not maintained properly.

Meanwhile, respondent 2 pointed out that maintenance became a challenge in managing intensive green roofs because there are no devices to monitor the conditions of the trees and plants. Maintenance planning was essential to keep all facilities, amenities, and vegetation in good condition and enhance their functionality and longevity.

Table 2. Responses for Challenges on Maintenance Issues

Respondents	Quotations
R1	"…maintenance is the main challenge because of waterproofing issues where the trees can be monitored, but roots can cause cracks. Next, on gutter issues where high and closed gutter design prevents access when leaf fall on gutters makes cleaning difficult and cause clogging …"
R3	"…maintenance is main challenges faced in maintaining a green roof include humans, animals, and weather factors in Malaysia, which make it difficult to maintain the trees and plants…"
R4	"…maintenance is the main challenge because of waterproofing where the thickness of waterproofing does not follow the requirements, and it causes to leaking and affects parking areas…"

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Lack of Knowledge

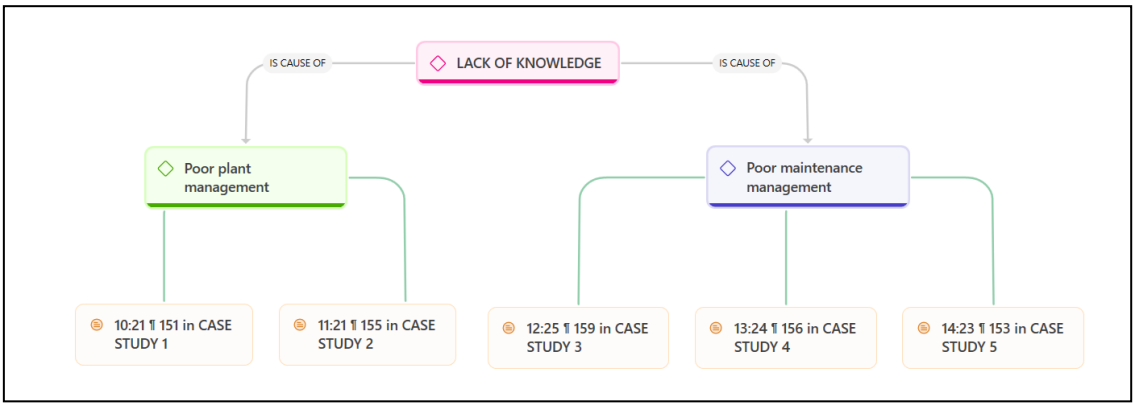

Fig. 8. Challenges on Lack of Knowledge in Managing Intensive Green Roofs

FM's third challenge in managing intensive green roofs in high-rise residential buildings is a lack of knowledge, as illustrated in Figure 8. Based on the findings, we can conclude that all respondents agreed that the challenges in managing intensive green roofs stemmed from a lack of knowledge. All respondents highlighted that the staff lack of knowledge on the types of trees and plants and maintenance methods could cause improper management of the intensive green roof areas (refer to Table 3). When the staff lacks knowledge, it could unintentionally make a faulty decision, resulting in the condition of intensive green roofs becoming worse and, for example, using incorrect fertiliser on vegetation or avoiding essential maintenance works. This assertion echoed the findings of Mayrand et al. (2018) research, where the authors concurred that the staff's lack of knowledge hindered their ability to execute tasks effectively, contributing to the substandard state of intensive green roofs.

In addition, Wang et al. (2023) emphasised the importance of having knowledgeable staff members, as those lacking the necessary training or experience may find it challenging to perform their duties, potentially leading to poor plant growth or even structural damage. Furthermore, respondents 4 and 5 stressed the importance of selecting vegetation carefully to prevent damage to building structures. These respondents also asserted that rational considerations, such as the potential for building structures to sustain damage from inappropriate vegetation, should guide the selection of vegetation instead of aesthetic values. Saharuddin et al. (2020) stated that intensive green roofs' successful management and longevity in high-rise residential buildings relied on appropriate training and instruction to overcome this lack of knowledge. By providing appropriate training, FM could provide the staff with the theoretical and practical skills required to manage the intensive green roofs effectively and efficiently. This approach can improve intensive green roofs' performance, increase user satisfaction by maintaining all facilities and amenities, and ensure optimal function.

Table 3. Responses for Challenges on Lack of Knowledge

Respondents	Quotations
R1	"…lack of knowledge in managing green roofs is a challenge, as it affects the person in charge, as they may not know the types of trees and the appropriate fertiliser to use, leading to poor tree maintenance…"
R2	"…lack of knowledge in managing trees and plants poses challenges as they may be misused, leading to poor tree and plant condition…"

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R3	"…lack of knowledge in managing green roofs presents challenges where it leads to improper handle maintenance, as those in charge need to have theoretical and experience to address unexpected maintenance issues effectively…"
R4	"…the challenge in managing green roofs is lack of knowledge among workers, as showed by the inexperience of gardeners in landscaping tasks and leads to incorrect practices of maintenance…"
R5	"…lack of knowledge in managing green roofs is a challenge, as it can lead to improper tasks like landscaping, requiring expertise to consider maintenance and long-term aspects…"

Limited Expertise

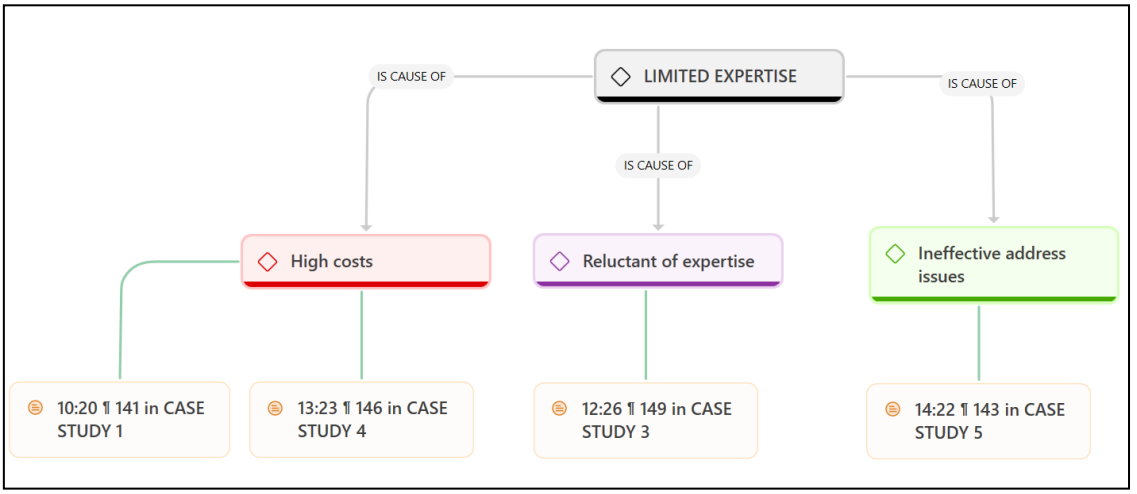

Fig. 9. Challenges with Limited Expertise in Managing Intensive Green Roofs

The fourth challenge faced by FM in managing intensive green roofs in high-rise residential buildings is limited expertise, as illustrated in Figure 9. Expertise is significant because it requires a better theoretical understanding and practical skills to perform tasks and provide a positive result. However, in today's world, finding expertise is crucial, particularly in managing intensive green roofs. In Malaysia, there was still a lack of expertise in this field, which led to improper practices when managing intensive green roofs. This statement was supported by respondents 1, 3, 4, and 5 (refer to Table 4), who emphasised that limited expertise was part of the challenges in managing intensive green roofs. This is because there is still a lack of expertise among landscapers and maintenance specialists, and if appointed, it would require a considerable amount of money to hire the experts. Rosasco et al. (2019) research provided support for this statement, and the author also concurred with it.

Moreover, employing inexperienced workers could lead to substandard maintenance methods, exacerbating current problems and reducing the longevity of intensive green roofs, a finding consistent with Ziaee et al. (2022) research. Respondent 3 mentioned that these challenges became more difficult because of the inadequate amount of expertise in Malaysia, as those who were accessible frequently refrained from practising their profession, making it challenging to recruit and retain qualified experts. Respondent 4 mentioned that companies often employ less skilled workers as a cost-cutting tactic. However, it led to long-term inefficiencies and increased costs for repairs. For example, inexperienced contractors could incorrectly handle problems like waterproofing, resulting in more severe defects and more expensive repairs. On the other hand, respondents 1 and 4 mentioned that JMB would question the necessity of

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spending money on expertise services despite the importance of such expertise in maintaining the condition and functionality of intensive green roofs. All parties must address these challenges to ensure effective and efficient maintenance of the intensive green roofs. Hiring experts could improve the quality of maintenance, increase income resources, and improve the performance and longevity of intensive green roofs.

Table 4. Responses for Challenges on Limited Expertise

Respondents	Quotations
R1	"…limited expertise in managing green roof part of challenges that can lead to complications and worsening conditions, as hiring expertise needs to spend high cost…"
R3	"…limited expertise, particularly in landscaper, poses challenges in maintaining and managing rooftop trees and plants due to the reluctance of Malaysian experts to engage in their field…"
R4	"…I can say it is part of the challenges because most companies avoid hiring experts in this field to cut costs, resulting in poor performance from their workers.…"
R5	"…limited expertise in certain fields makes it challenging to manage staff and address issues like waterproofing on swimming pools, emphasising the importance of expertise…"

Table 5: List of Challenges Faced by FM in Managing Intensive Green Roofs

Challenges	Case Study 1	Case Study 2	Case Study 3	Case Study 4	Case Study 5
Financial	√	√	√	√	√
Maintenance and operation	√	√	√	√	√
Lack of knowledge	√	√	√	√	√
Limited expertise	√		√	√	√
Inadequate of drainage					

To sum up, all the challenges that the five respondents mentioned have been summarised in Table 5. It could be seen that financial, maintenance, and operations were the main challenges agreed upon by the five respondents. Besides that, even though all respondents agreed that lack of knowledge it was not the main challenge mentioned by all respondents. However, the least challenge factor considered by the respondents was limited expertise, as respondents in Case Study 2 did not agree with these challenges, and inadequate drainage was not agreed upon by all respondents, where all respondents mentioned it was not a challenge faced by FM in managing intensive green roofs in high-rise residential buildings.

CONCLUSION

In conclusion, the research identified vital challenges FM faces in managing intensive green roofs in high-rise residential buildings: financial, maintenance issues, lack of knowledge, and limited expertise. Based on the findings, FM primarily faced financial and maintenance issues in managing intensive green roofs due to economic instability, structural design, human factors, and weather conditions. However, FM needed a strategy to address these challenges, which included generating solid financial support by supplementing the maintenance budget with other sources of income such as vending machines, car wash services, EV charges, event spaces, advertising spaces, and laundry services. Secondly, preventive maintenance prevents potential issues and prolongs the lifespan of intensive green roofs. This preventive maintenance could reduce the cost of significant repairs and provide environmental benefits. By implementing these strategies, the lifespan of intensive green roofs could be longer and more environmentally friendly. On the other hand, there was an opportunity for other researchers to continue this research and contribute to the sharing of

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ideas, opinions, and knowledge regarding these issues. Hence, the researcher provided recommendations for future research to explore these challenges in different buildings, such as comparing FM practices between residential and commercial buildings, which could help understand differences in practices and challenges. In addition, the research recommends further investigation into various buildings and the challenges encountered during the pandemic. So, conducting this research in different contexts could help comprehensively understand FM practices and challenges.

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CONFLICT OF INTEREST STATEMENT

The authors declare no financial, commercial, or personal conflicts of interest related to this research. The study was conducted without external funding, self-benefits, or commercial influences, and the authors have no competing interests to disclose.

AUTHORS' CONTRIBUTIONS

Nurul Amirah Khairuddin carried out the research and drafted the article. Wan Zuriea Wan Ismail supervised the research progress and reviewed and finalised the article. Hikmah Kamarudin and Ts. Mohd Shahir Mohamad Yusof supervised the case study's research methodology and data collection. Mohammad Zulfazdley Mohd Zulkifli Cheng participated in data collection. All authors approved the article submission.

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