

## **Study of Green Roof System Implementation in Green Building Construction**

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**Abstract:** The green roof system is an extension of the existing roof, which involves a minimum, high-quality waterproofing, root repellent system, drainage system, filter cloth, a lightweight growing medium, and plants. The major issue that affecting the implementation of the green roof system is achieve a cost disadvantage since it includes a huge cost of implementation. In Malaysia, the green roof system is still considered a new concept that can offer many benefits. Therefore, the purpose of this study is to identify the types, benefits and problems of the green roof system implementation. The G7 level contractor in Malaysia will be the target respondent in this research and the qualitative method will be using which is conducting a virtual interview. The data have been obtaining from the interview section and the thematic analysis method has been using to analyze the collected data. By conducting this research, it can be identified the types, benefits and problems of the green roof system implementation in green building construction. In conclusion, it will have a clear understanding about the types of the green roof system, which is a semi-intensive green roof system, intensive green roof system, and extensive green roof system. Furthermore, the benefits of the implementation of the green roof system, which is stormwater management, enhance biodiversity, and reduces greenhouse gases. Finally, the implementation of the green roof system requires a huge cost, complicated design, inexperienced contractor and maintenance and operation work.

**Keywords:** Construction, Green building, Green roof system

### **1. Introduction**

The construction industry has an obligation and a responsibility to ensure that development of the construction work taking place today and pursuit of wealth today of the quality of life in the future. The green building refers to the act of developing, constructing, and constructing buildings and

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utilizing procedures that are environmental and resource-efficient in various construction activities (Kamarudin, *et al.*, 2011). The green building also serves as the basis of sustainable construction development (Samari, 2013). The green buildings increase the productivity of employees by providing a more comfortable and healthier working environment for them to work. The green roof system is an extension of the existing roof which involves, at a minimum, high-quality waterproofing, root repellent system, drainage system, filter cloth, a lightweight growing medium and plants. The green roof system contains a growing medium and vegetation which use to plant a layer of soil on the top of the building roof. The green roof system also contains a water membrane system to transport the access water and has a filter system to ensure that the plant has enough water supply on drier days (Long, 2006). The implementation of the green roof system also creates an attractive space for occupants of neighboring buildings. The green roof system plays an important tool to increase sustainability and biodiversity and has a positive impact in decrease the consumption of energy, urban heat island and greenhouse gas generation (Charlie & Stuart, 2011). The construction industry plays an important role in the development of the construction work taking place today and the pursuit of wealth today of the quality of life in the future. It is significant to understand the stakeholder play an important role in the construction industry. The institution of construction also develops a strategy in the construction of infrastructure, especially for contractors who carry out the construction work in Malaysia. (Dwikojuliardi, 2015). The construction industry can create more working opportunities for the country. When the start of a construction project, it will give out many job opportunities to the people in the country. The construction work is inherently dangerous which makes insurance and workers compensation costly expenditure (Clavero, 2018). Many of the workers may experience an incident or injury when they carry out the construction work. Green building construction is also is the practice of designing, constructing and operating the building to minimize resource use, reduce waste and giving negative impacts to the environment, maximize occupant health and decrease life cycle costs.

In green building construction, green technology means the application and development of products, systems, and equipment used to conserve the natural environment and resources, which minimize and reduces the negative impact of human activities (Kettha, 2010). The construction of a green building can give advance to the environment by efficient use of the land, materials, energy and water, minimal waste, provide a healthy indoor environment for its occupants and restores, improves or enhance the natural environment (Linda, 2013). A green building which can reduce the impact through the environment and human health, it has a high-performance property that involves maintenance technique, complicated design and construction method (Yudelson, 2008). The construction of the green building includes ensuring the indoor air quality, thermal quality air conditioning and lighting elements and make people feeling more comfortable when staying inside the green building. The construction of the green roof can gain many benefits towards the green building. The green roof system is the parts of green building which contain the amenity and aesthetic benefits, environmental benefits, and economic benefit. The implementation of a green roof system can provide a new habitat for plants and animals in urban areas and in order to increase the local biodiversity (Lovejoy & Schneider, 2005). Other than that, the implementation of the green roof system also creates an attractive space for occupants of neighboring buildings. These systems have provided a comfortable and relax place to reduce their stress and improve worker productivity (Kuo, 2010). By constructing the green roof, it offers job opportunities for both skilled and unskilled workers (Chang & Chou, 2010). It has provided a green job generation through the product installation and maintenance of green roofs. Besides offer job opportunities, the green roofs also enable people to do investment in the building and provide marketing opportunities to the building. Therefore, the study is focusing on the implementation of the green roof system in green building construction.

In construction work, there has a different problem usually faced by the contractor or other parties who involve in the construction project when carrying the construction work, there may be left many

construction wastes. When the country carries out the rapid development of the construction industry, it will cause excessive construction waste in the country. For the green building construction, the problems faced by the developers is it includes a higher investment (Rustom, 2014). The higher initial cost was often the biggest obstacle because the financial risk is high and the construction of the green building is more expensive than conventional buildings (Hwang & Tan, 2012). Before the implementation of the green roof system, that has some disadvantages that needed to consider before installing it. The factor that affects the installation of a green roof system is it will achieve a cost disadvantage. Although it will save a budget on the heat and cooling bills, while it will spend a lot when installed the green roof system (Salter, 2018). Besides, when the green roof system is installed by an inexperienced green roofing contractor, it will cause a budget overrun and improperly installed green roofs. An inexperienced green roofing contractor likely delays the construction process because they do not have enough experience to install the green roof system (Charlie & Stuart 2011). Other than that, green roofs require proper operation and maintenance to prevent the failure of the green roof system (Shams *et al.*, 2018). Lastly, it is significant to know the types of green roof systems, the problems face when the implementation of the green roof system and determine the benefits of the green roof system in green building construction. Therefore, the objectives of this study are to study the types, identify the problems and determine the benefits of green roof system implementation in green building construction.

## 2. Literature Review

The green building refers to the act of developing, constructing, and constructing buildings and utilizing procedures that are environmental and resource-efficient in various construction activities (Kamarudin, *et al.*, 2011). The green building also serves as the basis of sustainable construction development (Samari, 2013). Green buildings have concepts in reducing the environmental impact of the building by improving factors such as energy efficiency and waste management (Zein, 2018). It minimizes the negative effects on occupants' health and wellbeing. The construction of the green building has brought various to the people and environment. It enhances human life by improving the quality of humans and maintain the balance of the ecosystem at local and global levels at the same time (Green Building Index, 2013). The green building also provides thermal comfort for the occupant in the green building and achieves energy efficiency by enables the public to receive and save more energy usage. The green buildings also achieve financial benefits by reducing energy use, water cost, waste disposal, maintenance and operation costs (Yaman, 2011). Besides that, green building improves the efficiency of the resource's usage, operational savings and workplace productivity (Green Building Index, 2013).

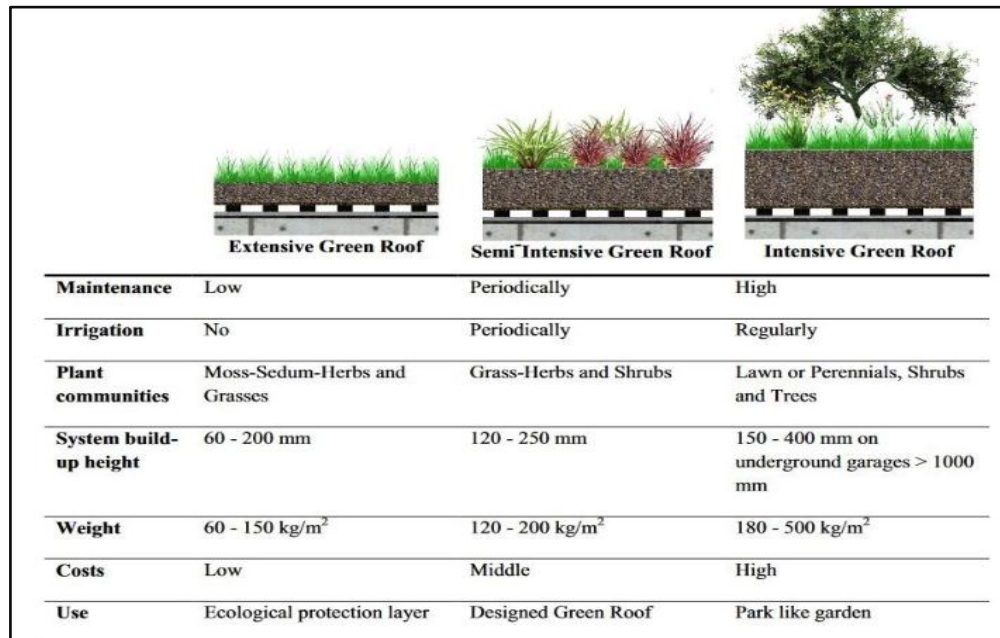
There will be some problems face when the implementation of the green building which is a lack of professionals who value all the components that needed to be installed in the green building like temperature management, ventilation management and lighting management (Nichols, 2016). Other than that, the buyers and contractors face the problem when there has insufficient information about green products of green buildings (Griffin, 2010). The higher investment cost is always a critical problem because it includes a huge cost when the implementation of the green building (Kamaruzzaman & Pitt, 2014). Other than that, the unavailability of the supplier also affects the adoption of green buildings because the demand for green buildings is still considered less in many countries (Chan *et al.*, 2018). This problem was closely related to the unavailability of green building technology in the local market if the supplier of the green building material is unavailable.

### 2.1 Green Roof System

The green roof system is an extension of the existing roof which involves, at a minimum, high-quality waterproofing, root repellent system, drainage system, filter cloth, a lightweight growing

medium and plants. The implementation of a green roof system has aesthetic benefits, environmental benefits and economic benefits (Long, 2006).

There are three types of green roofs system, which is extensive green roof systems, intensive green roof systems, and semi-intensive roof systems. Figure 1 below shows the classification of green roofs according to the type of usage, construction factors and maintenance requirements.



**Figure 1: Classification of green roof (BabakRaji, Martin, Andyvan & Dobbelsteen, 2015)**

The extensive roofs are thin lightweight roof systems that typically have a planting media measuring 6 to 20 cm deep and its weights about 60 to 150 kg/m<sup>2</sup> (Raji, 2015). The extensive roof system was usually designed as environmental solutions and this system has a thin substrate layer with low-level planting, typically sedum or lawn and can be very lightweight in structure (Castleton, 2010). It requires little or no additional structural support from the building, needs low maintenance and is designed for limited human access. The extensive green roof system is relatively inexpensive to install and is used mainly for environmental benefit.

The intensive green roof system has a growing media range in thickness from 20 cm to 100 cm and the roof weights were more than 180 kg/m<sup>2</sup> and up to 500 kg/m<sup>2</sup>. It was quite similar to the conventional ground-level garden and it usually constructs with the building which requires a substantial investment in plant care (Oberndorfer, 2007). The intensive roof system is often designed as public places and generally requires substrate depths between 150 and 1200mm. Therefore, there may comprise of trees and shrubs like landscaping found at ground level (Snodgrass & McIntyre, 2010). It allows a greater variety and size of plants such as shrubs and small trees. This type of roof system typically installs within the business and public buildings unless the roofs are intended primarily as occupied garden amenity space.

The semi-intensive green roof system falls in between extensive and intensive green roof systems. The semi-intensive green roof system has a thinner planting media than an intensive roof but thicker than an extensive roof. The roof system ranges from 120 to 250 mm and the roof weights from 120 to 200 kg/m<sup>2</sup> and it was heavier amongst the other green roof system. This type of green roof system requires more maintenance, higher costs and more weight on the roof (Hui, 2006). A deeper substrate-level allows more possibilities for the design in various grasses, herbaceous perennials and shrubs such as lavender can be planted while tall-growing bushes and trees are still missing.

## 2.2 Benefits of Green Roof System Implementation in Green Building Construction

The installation of the green roof system has benefits range from stormwater management, which is the best way to address wet weather flows in urban areas with high-density development (Cantor, 2008). Green roofs system can provide new habitats for flora and fauna in urban areas to increase the local biodiversity to help support wildlife and create a healthy habitat (Chrisman, 2005). The green roof system also provided an attractive space for tenants and occupants of neighboring buildings. It provides a place of refuge and relaxation for people who access the building, thus reducing stress and improving worker productivity (Charlie & Stuart, 2011). It also provides an aesthetic design to the building owner (Dunnett, 2010). The implementation of the green roof system also enhanced the reduction of air pollution and protect the environment (Bianchini & Hewage, 2012). The green roof system has reduced air pollution and greenhouse gases by improving building energy consumption with decrease the use of mechanical ventilation systems such as air-conditioners (Charlie & Stuart, 2011). Table 1 shows the benefits of the green roof system.

**Table 1: Summary of the benefits of the green roof system**

Authors	Benefits	Findings
Charlie & Stuart (2011)	Reduce the air pollution and greenhouse gases	The Benefits and Challenges of Green Roofs on Public and Commercial Buildings
Cantor (2008)	Stormwater management	Green Roofs in Sustainable Landscape Design
Bianchi & Hewage (2012)	Reduce air pollution	Lifecycle analysis of green roof materials, Building and Environment
Dunett (2010)	Aesthetic Designed	Integrating aesthetics and ecology on the accessible green roof
Chrisman (2005)	Enhance biodiversity	Green Roofs: Ecological Design and Construction

### 2.3 Problems of Green Roof System Implementation in Green Building Construction

The problem that faces when the implementation of a green roof system is the lack of technical awareness who monitor the construction work of the green roof system (Shams *et al.*, 2018). Another problem that may occur when the implementation of the green roof system is the contractor who was inexperienced that may cause budget overruns and improperly installed of the green roof system (Ismail *et al.*, 2012). The maintenance and operation also a big problem towards the green roof system because it was costly when carrying out the work because the maintenance work needs to spend time in maintaining the design aesthetic (Charlie & Stuart, 2011). It is significant to consider the variation in a dead load of a green roof system before the construction work started (Charlie & Stuart, 2011). A dead load of a green roof system is influenced by several factors which include contractor skill, medium components, and potential water retention (Velazquez, 2010). The other problem that occurs in the construction of the green roof system was it always includes a huge cost when installing it in the green building (Shams *et al.*, 2018). The cost of constructing the green roof system is estimated to be an additional 40% to 50% when construct in the new building. Table 2 shows the problems with the green roof system implementation.

**Table 2: Summary of the problems with the green roof system**

Authors	Problems	Findings
Shams <i>et al.</i> (2018)	Lack of technical awareness Including a huge cost	Challenges and opportunities of green roof in building design
Ismail <i>et al.</i> (2012)	Overrun of the project time and cost	Obstacles to adopting green roof in Malaysia
Charlie & Stuart (2011)	Higher maintenance cost	The benefits and challenges of green

Velazquez (2010)	A dead load of a green roof should be determined Consider the variation in dead load	roofs on public and commercial buildings Green roof construction-structural considerations
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### 3. Research Methodology

#### 3.1 Research Design

This research will be using a qualitative method to collect data. The findings of the research can be analyzed analytically based on data and the approach implemented in the research. In this study, the interview will act as an information collection and the result obtained from the interviewee, together with the literature review will be analyzed and studied to achieve the objective of this study. In this study, the interview will act as an information collection and the result obtained from the interviewee, together with the literature review will be analyzed and studied to achieve the objective in this study.

#### 3.2 Research Process

The research process flow chart can refer to Figure 2 in Appendix A. This research was consisting of 5 phases which describe the whole procedure and activities from the start of the research until the end of the research. Phase 1 is the study and discusses the title from the problem statement which includes the research background, problem statement, research questions, research objectives, the scope of research, the significance of research and research methodology. In phase 2, it explains the process of literature review. It obtained information from literature review through various resources. Phase 3 is explained about data collection which is primary data and secondary data will use in this research. The primary data will be collected through the interview with the selected contractor in Malaysia. However, the secondary data will collect the data via books, journals and internet articles. Phase 4 was to express and analyze the data collected through the qualitative method. It explains the data analysis technique and the results in the previous data collected from the interviewee. The final phase of this research is phase 5 which is the conclusion and recommendation. In this phase, the results from the data analysis will be summarized and concluded.

#### 3.3 Data Collection

The data collected in this research includes the collection of primary data and secondary data. The primary data is will be collected by using a qualitative method via an interview with the specific respondents who participate in this research are the G7 contractor who carries out the construction work of the green building in Malaysia. The secondary data, it collected by gathered the existing sources via books, journals, internet articles and newspaper articles and is presented in the form of a literature review in this research. It provides the initial framework for the research by analyzing the earlier works in the research topic. The population in this research involved the G7 contractor who has the relevant knowledge and experience in constructing the green roof system. The green roof contractor was selected because it was suitable and can achieve the objective in this study.

#### 3.3 Data Analysis

The main strategy in this research will be using the survey method. The survey method can be carried out in three different methods which are the questionnaire, interview and observation. The interview method will be chosen among the three methods as stated above to collect the data in this research. All the primary data collected through the specific respondent will be collected and doing analysis on the data. The data will be collected from the specific respondent in Malaysia and for further analysis. The thematic analysis will be selected to use as a data analysis method to analyze the data collected in this research. It is a good approach to find out about people's views, opinions, knowledge and experiences from a set of qualitative data.

#### 4. Results and Discussion

##### 4.1 Respondent Background

The respondent in this research was the G7 contractor who has been carrying out the construction of the green roof system in green building construction. The respondent’s background was important in the qualitative method because it needs to ensure all the data that have been collected from the respondent are valid and answering the questions based on their working experience and their relevant knowledge in the green roof system. Table 3 have shown the respondent’s background in this research.

**Table 3: Respondent Background**

Respondent	Organization	Position	Working Experience	Experience in Green Building Construction Project	Job Scope
Respondent 1 (R1)	Company A	Design Engineer	3 years	A small garden was built on the flat roof of and rooftop of some bungalow.	Senior engineer in structural design
Respondent 2 (R2)	Company B	Urban Greenery	8 years	Develop the green building in the bungalow	Advise, give solutions suited to project requirements, offer technical support.
Respondent 3 (R3)	Company C	Project Manager	6 years	Develop the green building in the shophouse.	Give technical support to the project.
Respondent 4 (R4)	Company D	Managing Director	9 years	Promote the construction of the green building	As project management and ensure the project runs fluently.

Based on Table 3 above shows that there have 4 respondents involved in this research through the method of study that has been conducted. Respondent 1 is a design engineer who works in Company A with 3 years of working experience in the construction industry who has responsibility for handling the structural design in the construction project and has experience in developing the small garden on the rooftop. For the second respondent (R2), who was urban greenery in Company B with 8 years of working experience in handling the construction project in term of advice, recommend solutions offer product specifications and technical support which suited to the project requirement and have experience in developing the green building in the bungalow. Meanwhile, respondent 3 is a project manager in Company C who has 6 years of working experience in the construction industry in giving technical support in the construction project and have the relevant experience in developing the green building in the shophouse. Respondent 4 was working in Company D as a managing director with 9 years of working experience in the construction industry in managing the project to ensure the project run fluently and have the experience in promoting the construction of the green building. Therefore, the respondent of this study has the relevant knowledge and experience about the construction of green building especially for the green roof system implementation.

##### 4.2 Types of Green Roof System Implementation in Green Building Construction

The summary of the types of green roof system implementation in green building construction is as shown in Table 4 (refer to Appendix B). There consists of three types of green roof systems which

is semi-intensive green roof system, intensive green roof system and extensive green roof system. The semi-intensive green roof system only requires minimal maintenance work, a medium-range of the cost implication of the roof system and functions as a small garden to the building. The specific height and the specific weight for semi-intensive green roof system is about 120-250mm and 120- 300kg/m<sup>2</sup> which is having a medium range of height and weight to the intensive green roof system and the extensive green roof system. Other than that, the intensive green roof system was needed to regularly carry out the irrigation work and maintenance work. The specific height and the specific weight for these types of the green roof system is about 150-400mm and 180-500kg/m<sup>2</sup> which is more height and more weight to other types of the green roof system. It required a higher implication cost when compared to other green roof systems and it also serves as a park-like garden on the business and public buildings. Lastly, the extensive green roof system has a lower implementation cost and lower maintenance work needed when compared to other green roof systems. It also does not require more irrigation work unless having a specific condition such as during a heatwave. The specific height and the specific weight for these types of the green roof system is about 60-200mm and 60-190kg/m<sup>2</sup> which is less height and less weight when compared to other types of the green roof system. It functions is act as an ecological protection layer and implemented on the small construction project which required instant greening.

#### 4.3 Problems of Green Roof System Implementation in Green Building Construction

The summary of the problems of green roof system implementation in green building construction is as shown in Table 5 (refer to Appendix C). Firstly, the problems are a lack of technical awareness who was expert in the construction of the green roof system. The lack of technical awareness in the installation of the green roof system may cause the worst case which is causing the roof to have a leaking problem in the future. Since it is not easy to build, it needs a specialist technical to install to prevent the structural issues, waterproofing issues and future maintenance problems. Besides, the lack of experience contractors may also lead to a problem in the implementation of the green roof system. The experienced contractor was needed in the construction project to prevent overrun of the time and budget, improper installation of the green roof system, failure of the green roof system function and some of the unsolved problems that may occur. Furthermore, the maintenance and operation work was another problem with the installation of the green roof system. It needs an expert or professional who has a proper understanding of the green roof system to reduce any unnecessary trouble that occurs in the maintenance and operation work. The design of the green roof system was difficult and complicated to maintain and difficult to carry out the maintenance and operation work. Other than that, the higher maintenance cost of the green roof system will lead to a problem with the implementation of the green roof system. It includes higher maintenance costs because it is still considered not common practice in Malaysia which caused the cost of services from landscapers will be higher than usual. It is an additional cost to the building owner since there contain an additional landscape to maintain.

In addition, the construction of the green roof system requires a huge cost, which will cause a problem to the people. The huge cost of the installation work is due to the limitation of the green roof suppliers, green materials and expertise in our country have caused the higher implementation cost of the green roof system. Besides that, the variation of the dead load was one of the problems in the implementation of the green roof system. It needs to consider the self-weight of the layered soil, plant, and hardware like drainage system which will directly be applied to the designed roof and contribute additional weight to the roof. Dead loads pertain to the weight of the roofing structure with the permanent components and the weight of the construction materials and need to be considered before developing the green roof system. Moreover, the complicated design of the green roof system may also cause a problem to the construction work. The complicated design needs continuous communication and instruction between the landscape, civil and structural consultant to ensure the green roof system can be implemented and functioned well. The design of the green roof system requires to accommodate the water retention, suitable drainage, structural loading and the depth of green roof growing substrate. Lastly, the green roof system implementation was more expensive than the conventional roof because the green roof system is still not common practice in Malaysia which caused the cost of implementing the green roof system to become higher. It needs a complicated



design, expensive green material, limited local expertise, which reason the implementation cost of the green roof system higher than a conventional roof.

#### 4.4 Benefits of Green Roof System Implementation in Green Building Construction

The summary of the benefits of green roof system implementation in green building construction is as shown in Table 6 (refer to Appendix D). Firstly, the benefit of the implementation of the green roof system is it enhances indoor thermal comfort. The roof system has the features of absorbing the heat from the sun and directly transmitted it to the roof and the layers of soil which can maintain the low temperature of the roof. It also shades the building and absorbs less heat from the sun and reducing the temperature of the roof which can cool the surrounding air through evapotranspiration. Besides, the implementation of the green roof system also has benefits in stormwater management which can retain rainwater and reduce the flow of runoff into the drainage system to prevent overflows of rainwater. It also consists of the layer of plant material, which can absorb water, capture water when raining and slowly releasing it through evaporation and plant use.

Furthermore, the green roof system also enhances biodiversity on the rooftop by providing a substitute habitat. It also incorporates different vegetation layers and landscaping features to increase opportunities for wildlife to feed and shelter. Other than that, the green roof system has enhanced providing an attractive space for tenants and occupants by providing extra space on top of the roof for their rest area and recreation. It offers a space for peace and relaxation in bustling cities and environments and becomes an aesthetic feature of the building. Besides that, the green roof system implementation has enhanced in reducing the air pollution and greenhouse gases within natural plants planting in the rooftop which can create a stable ecosystem for the surrounding development. It also acts as a filter that removes contaminants in the air as well as greenhouse gases, improving the air quality which can protect the environment. In addition, the implementation of the green roof system also enhances human health by reducing pollution and greenhouse gases. The green plant on the rooftop also beneficial to human health. Lastly, the green roof system has provided a new habitat for plants and animals by facilitating habitat restoration and provide a new habitat to them. Urban green roofs provide a habitat for migrating and breeding birds and their arthropod prey.

## 5. Conclusion

In this study, the research objective was achieved which is to identify the type of green roof system implementation in green building construction. These consist of three types of green roof systems which are semi-intensive green roof system, intensive green roof system and extensive green roof system. The second objective that has been achieved is to identify the problems of green roof system implementation in green building construction. The problems in the implementation of the green roof system are the lack of technical awareness and experience contractor, require a huge cost of implication, maintenance and operation work, complicated design, a variation of dead load, higher maintenance cost and the implementation of the green roof system is more expensive than the conventional roof are the problems associated with the implication of the green roof system. The third objective that has been achieved is to determine the benefits of green roof system implementation in green building construction. The benefits in the construction of green roof system are providing indoor thermal comfort, stormwater management, biodiversity, provide an attractive space for occupants and tenants, reduce air pollution and greenhouse gases, enhance human health and provide a new habitat for plants and animals were the benefits with the installation of the green roof system.

The limitation in this research that the researcher has been identified when conducting the research. The first limitation is a respondent corporation. The data collection was done through distribute the interview question to the selected respondent through email. However, the response rate from the company did not reach the expectation because most of the email was ignored by the respondents. Besides, one of the limitations that occur to the researcher is the limit of reference sources to write a literature review in this research. This is because there was a lack of reference material that relates to the research topic which is the implementation of the green roof system in

green building construction. Lastly, another limitation in this research was the limitation of time when carrying out the research work. Researchers have spent more time finding the relevant research material about the research topic.

The recommendation for the construction industry is to improve the construction of green roof systems in the future. The green roof system construction usually faces the problems of lack of technical awareness and lack of experience contractor in run out the construction of the green roof system. Due to that, the green construction industry can import the profession from overseas to resolve the problem. The construction industry also can promote the construction of the green roof system to increase more of the technical and the contractor. For the problem of maintenance and operation work, it usually needs a technical who have a proper understanding to reduce any unnecessary trouble in maintenance and operation work. In order to resolve these problems, the company can provide more practices and courses to their work to increase their knowledge and expertise about the green roof system. Other than that, the recommendation for future research which regards the implementation of the green roof system, these are some of the recommendations that are suggested by the research are this research study can be continued by studying because the green roof system implementation still rarely in our country and it requires more related research to improve and enhance the implementation of the green roof system.

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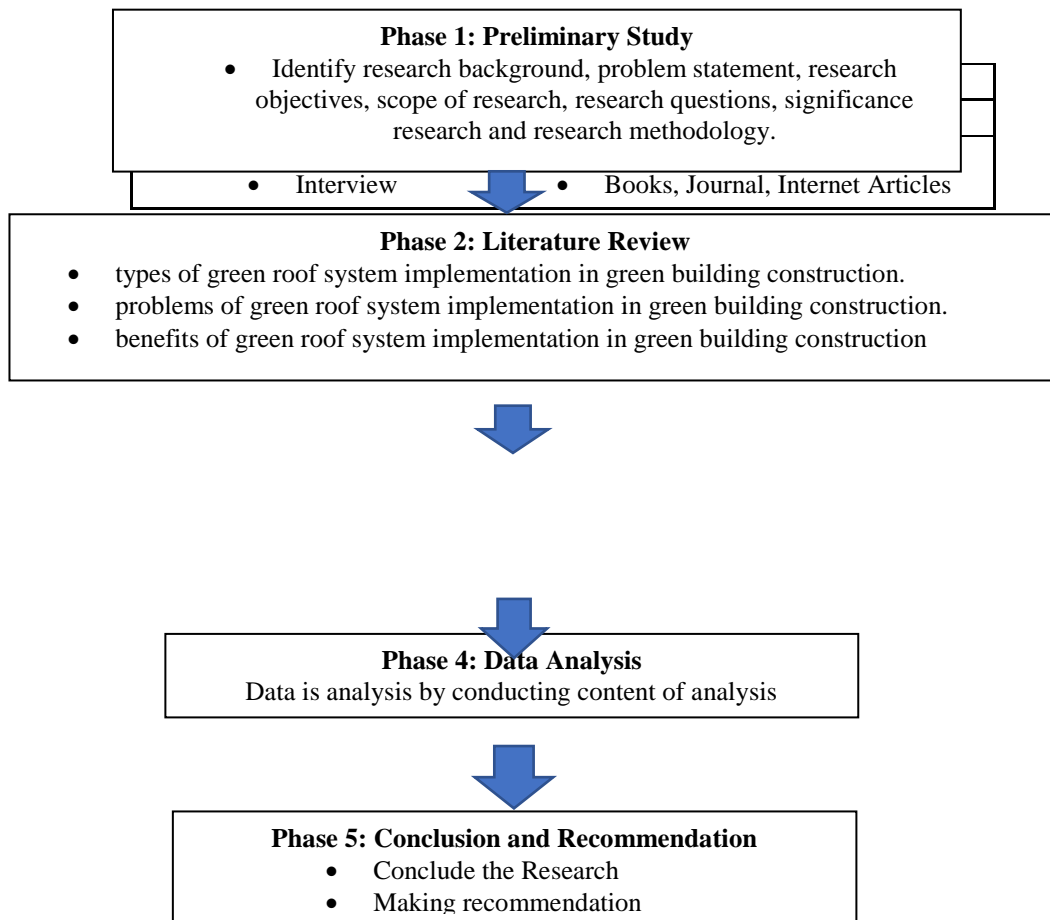
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## Appendix A



**Figure 2: Flow chart of research methodology**

## **Appendix B**

**Table 4: Types of green roof system implementation in green building construction**

Questions	R1	R2	R3	R4
Types of green roof system	Semi-intensive green roof system	Intensive green roof system	Extensive green roof system	Extensive green roof system
Carry out the irrigation work	The large building will install a mechanical sprinkler system for watering the plant while small roof garden usually waters the plant manually	Regularly carry out the irrigation work and auto irrigation for the plant community	Use dripline irrigation system and least to carry out irrigation work.	No need to carry out irrigation work, unless specified example, during a heat wave
Types of plant community	<ul style="list-style-type: none"> <li>• Grass-Herbs</li> <li>• Shrubs</li> <li>• Lawns</li> </ul>	<ul style="list-style-type: none"> <li>• Trees</li> <li>• Lawn</li> <li>• Shrubs</li> </ul>	<ul style="list-style-type: none"> <li>• Moss</li> <li>• Grass</li> </ul>	<ul style="list-style-type: none"> <li>• Grass</li> <li>• Herb</li> </ul>
Carry out the maintenance work	Maintenance work was minimal and annual maintenance for checking the soil condition.	Regularly carry out the maintenance work	Monthly visits to weed and check irrigation system for first-year and low maintenance work needed	once per 2 months visitation for subsequent years and least compare to another roof system
Specific height	120-250 mm	150-400 mm	60-200 mm	80-200 mm
Specific weight	120-300 kg/m <sup>2</sup>	180-500 kg/m <sup>2</sup>	60-150 kg/m <sup>2</sup>	80-190 kg/m <sup>2</sup>
Cost Implication	Lower range of implication cost when compared to intensive green roof system but slightly higher than extensive green roof	Higher range of prices when compared to intensive green roof system and extensive green roof and high range of implication cost	Low range when compare with another green roof system	Low range when compare to another green roof system
Usage	Functioned as recreation area, reduce slightly temperature in a confined building	Install within the business and public buildings As garden amenity space	As an ecological protection layer	Smaller projects requiring 'Instant greening'

## Appendix C

**Table 5: Problems of green roof system implementation in green building construction**

Problems	R1	R2	R3	R4
Lack of Technical Awareness	Inconsistence in the installation cause the roof system to have a leaking problem in the future.	May cause the roof face problem in the future for example leakage problem	Structural issues, waterproofing issues, and future maintenance problems.	Need a specialist contractor to give advice and install.to prevent problems occur.
Lack of Experience Contractor	Cause the budget and time overrun of the project and improper installation of the roof system	Unsuccessful installation of the green roof system and function failure	Failure of the green roof function and increase the project budget and cost	Improper of the installation of green roof system and some unsolved problems may occur.
Maintenance and Operation Work	Needs proper understanding to reduce trouble in maintenance and operation work.	Difficult maintain and complicated to carry out maintenance and operation work	Minimal maintenance required and needs an expert to carry out maintenance work	Costly to carry out the work and need to spend more to maintain its aesthetic.
Higher Maintenance Cost	not common in Malaysia and the cost of services from the landscaper will be higher than usual.	It is an additional cost since there is an additional landscape to maintain.	Depends on the type of green roof installed.	The green roof will need only minimal maintenance.
Huge Cost of Construction	It is because of the limitation of green roof suppliers and causes the higher cost.	Lack of expertise in constructing the green roof.	The limitation of green materials supply in our country.	The green material and expertise were limited and cause the construction cost of the green roof system high.
Variation of Dead Load	The self-weight of layer soil itself and the self-weight of the plant is directly applied to the designed roof	Planting media and hardware contribute additional weight to the roof	It depends on what kind of green roofing system. A dead load of the extensive green roof system was minimal.	Dead loads pertain to the weight of the roofing structure with the permanent components.
Complicated Design	The complicated design needs continuous communication and instruction between the landscape and civil and structural consultant.	The complicated design to ensure the green roof system can function well to prevent structural failure.	It needs a complicated design to ensure the roof system can be implemented well	The green roof design needs to accommodate adequate water retention, suitable drainage, structural loading substrate.

Implementation of Green Roof System More Expensive than Conventional Roof	The green roof system is still not common practice in Malaysia which caused the cost of implementation higher.	It requires a more complicated design and expensive material for constructing the green roof system.	The imported materials and limited local expertise cause the implementation cost of the green roof system high.	Material use for constructing the green roof system is higher than a conventional roof.
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## Appendix D

**Table 6: Benefits of green roof system implementation in green building construction**



Benefits	R1	R2	R3	R4
Indoor Thermal Comfort	It absorbing heat from the sun and directly transmitted to the roof and the layers of soil and maintaining the low temperature of the roof	Shade buildings and absorb less heat from the sun and reducing the temperature of the roof and cools the surrounding air through evapotranspiration.	It cools the surface temperature by moisture content, the gap between green roof and roof slab as air gap to regulate temperature change.	The green roof system has the possibility to cool the ambient air to provide thermal comfort to the users.
Stormwater Management	It can catch the rainwater from directly using pipe discharge into the drainage.	Green roofs retain rainwater and reduce the flow of runoff into the drainage to prevent overflows of rainwater	It reduces and delays rainwater from flowing into the drainage system	Green roofs have a layer of plant material that absorbs and capture water, slowly releasing it through evaporation.
Biodiversity	Increase the biodiversity on the rooftop More plants and animals in the roof system	Providing substitute habitats for flora and fauna	Incorporate different vegetation layers and increase opportunities for wildlife to feed and shelter	Green areas on the rooftop can provide replacement habitats for flora and fauna
Attractive Space for tenants and occupants	Provide extra space on top of the roof for their rest area For accessible roofs, the green space serves as an attractive gathering point.	Green roofs offer a space for peace and relaxation in bustling cities and environments Contain an aesthetic feature of the building.	Provide a greener view and the living around spaces with biophilic design generally reduces stress for occupants.	Environmental-friendly Natural Insulation & comfort.
Reduce Air Pollution and Greenhouse Gases	The more natural plants are planted, it helps in reducing the air pollution creating a stable ecosystem for the surrounding development.	Green roofs act as a filter that removes contaminants in the air as well as greenhouse gases Improving the air quality.	Plants are absorbed air particles including pollutants. green roofs, act as carbon sinks, absorbing more CO <sub>2</sub> to reduce the effects of climate change.	The plantation of the green roof system has improved the overall air quality which can protect the environment.
Human Health	Reduced pollution and increased water quality	Serve as community hubs, increasing social cohesion, sense of community, and public safety	Green plants on the rooftop also beneficial for human health	The green roof system can reduce pollution and enhance human health

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New Habitat for Plants and Animals	Potential new habitat for plants and animals in urban areas	Green roofs facilitating habitat restoration and provide a new habitat to them	Urban green roofs provide habitat for migrating and breeding birds and their arthropod prey	The green roof system help supports wildlife and creates a healthy habitat on the rooftop
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