

ANALYTICAL REVIEW OF MAINTENANCE CRITERIA FOR GREEN ROOF IN MALAYSIA

Shafikah Saharuddin¹, Natasha Khalil², Alia Abdullah Salleh³

¹Postgraduate Centre, Faculty of Architecture,
Planning and Surveying, Universiti Teknologi MARA, Perak Branch,
Seri Iskandar Campus, 32610 Seri Iskandar, Perak, Malaysia

²Department of Quantity Surveying, Faculty of Architecture,
Planning and Surveying, Universiti Teknologi MARA, Perak Branch,
Seri Iskandar Campus, 32610 Seri Iskandar, Perak, Malaysia

³Department of Building Surveying, Faculty of Architecture,
Planning and Surveying, Universiti Teknologi MARA, Perak Branch,
Seri Iskandar Campus, 32610 Seri Iskandar, Perak, Malaysia

¹natashakhalil29@gmail.com

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ABSTRACT

The implementation of green roof on top of buildings is becoming a trend in the urban cities and provides numerous benefits to the green development growth. Despite the benefit and enhancement on green roof installation, maintenance consideration is still largely unexplored as the main significant factor in the viability of green roof installation. This paper is aimed to identify the significant criteria of green roof maintenance practice in Malaysia. The literature findings revealed that there are generally twenty (20) criteria pointed as maintenance criteria. Out of 20, six maintenance criteria were identified as the most significant factors towards the best practice of green roof maintenance.

Keywords: Green roof, green roof maintenance, maintenance, maintenance criteria

INTRODUCTION AND BACKGROUND TO THE STUDY

Malaysia is one of the tropical countries that is located on the South China Sea, and lies at the latitude 3.12 °N and longitude 101.55 °E (Mirrahimi et al., 2016). The tropical region is an uncomfortable climate zone that accepts a large amount of solar radiation, high temperature, high level of relative humidity, and long periods of sunny days all the year (Al-obaidi et al., 2014). This is also supported by Khalil and Husin (2009) that described the location of Malaysia as under tropical climate region is naturally hot and a humid climate. Moreover, due to the rapid growth of the urban population, this region has experienced a rise in urbanization, especially in the developed countries such as Singapore, Malaysia, and Indonesia (Al-obaidi et al., 2014). The booming of urban population has produced mass development and has reduced the green areas. In 2012, a study by Yusof and Johari as cited in (Chow & Abu Bakar, 2016) stated that the green areas of Kuala Lumpur have been reduced from its original 24,222 hectare of city area to 59.4% or 14,386 hectare. This rapid development also has boosted the intensity of urban heat island (UHI) (Wong & Yuen, 2011). Nevertheless, the construction industry in Malaysia has been growing concurrently with sustainable development in order to cease the problems which have been occurring in the recent decades. One of the sustainable approaches to help minimizing this environmental problem is by using the means of vegetation or plant material on rooftops or also known as green roof.

Many buildings in developed countries such as Germany, Canada, Japan, America and Singapore have used green roof as one of the solution to reduce the environmental problems along with its benefits. As cited by Herman in (Zahir et al., 2014), about 14% of all flat roofs in Germany have adapted green roof and the supportive government policies make it becomes typical to have green roof in the cities. At the same time, over the past few decades, green roofs were well accepted and more popular across Europe (Kamarulzaman et al., 2014). Furthermore, Getter and Rowe (2006) also mentioned that, the roof area in most urban regions would usually constitute around 21% - 26% of the total areas. Thus, it will provide the possibility to add to the urban green area if green roofs were used. This technology also becomes common in USA for instance in Chicago, Portland, Atlanta and other cities (Ismail et al., 2016). Meanwhile in Canada, the Canadian government began incorporating green roofs in a continuum of sustainable

initiatives eligible for partial reimbursement and funding (McIntyre & Snodgrass, 2010). Moreover, Ministry of Federal Territories and Urban Wellbeing through the program of “The Greening of Greater KL” have targeted a total conventional roofs area of 150,000m² to be converted into green roofs by 2020 (Getter & Rowe, 2006). That was a very great initiative by the Government to help promote the implementation of green roof in the country even though the implementation of green roof in Malaysia is still at the preliminary stage.

Despite the application of green roofs in the country is still low, there are some successful green roofs applications applied in a few buildings in Malaysia as it has slowly becoming a trend in building industry. Regardless the green roof implementation on certain buildings are being imposed, challenges in terms of its maintenance should also be taken into account and should also be given attention. There have been cases where the main problems in green roof are on the technical issues such as damage on water proofing and leakage on floor structure for green roof level, blockage in the drainage system, increasing in the occurrence of water ponding as well as mosquito breeding (Ismail et al., 2010). Thus, lack of maintenance is seen as an observable fact that can result in the roof garden not functioning as intended (Ismail et al., 2010). The establishment of plant material on rooftops provide numerous benefits to the man and nature. When considering the viability of the installation of green roof, the maintenance process is a highly important factor. It is believed to be one of the major obstacles to their installation. According to Ismail et al., (2016) maintenance is essential in order to preserve the function of the green roof garden, where a thorough protection and maintenance is needed from the moment they are installed as to prevent from high capital cost as well as maintenance cost of the green roof.

Therefore, the aim of this paper is to identify the significant criteria of green roof maintenance practice in Malaysia. The objective of this research is to identify the current practices and vital criteria needed for green roof maintenance in Malaysia. Hence, the findings in this paper are presented to achieve the research’s objective. Apart from that, the findings can be an added value to the existing practice that are previously more concerns on the design and benefits consideration In order to achieve this aim, previous studies on the types of green roof, relation to the significant



of maintenance and maintenance criteria were explored in both local and international context.

TYPES OF GREEN ROOF

Basically, green roofs can be divided into two distinguished types which are either extensive or intensive green roofs (Abdul Rahman et al., 2015; Abdul Rahman et al., 2013; Hui, 2010; Jim, 2017; Silva et al., 2015). Extensive green roof is thinner, simple and a lighter kind of green roof where it is normally suitable for lightweight buildings. Usually, it only needs a shallow substrate of a depth about 15cm or less, and the selection of vegetations is rather limited than intensive green roof where the plants adopted are usually from the species of small plants, sedum, shrubs and bushes that only need low maintenance and can be self-generative. These make the extensive green roof to only require a low cost and easier to build and maintain than intensive green roof. Basically, this type of green roof is rarely accessible to the public as most of the time, it is only accessible for maintenance purposes (Abdul Rahman et al., 2013).

Meanwhile, the intensive green roofs or also known as roof gardens are heavier and strong enough to support an additional load, where it is suitable for underground garages and heavy buildings. Therefore, as it is generally heavy, the system requires specific support from the building (Rahman et al., 2013). On the contrary, it requires a deeper substrate of a minimum depth of 15 cm, and it offers varieties of vegetations which consist of trees, big shrubs and bushes and many species of ornamental plants as in the roof top garden. As described Hui (2006), it sometimes have additional features such as walkways, benches, playgrounds or even ponds can be set-up on the roof. Hence, it requires regular garden maintenance and needs proper irrigation system which makes it costly to build and maintain as intensive maintenance is needed periodically with skilled labours (Fauzi et al., 2013). The intensive green roof is usually accessible to the public as the green roof itself is being fully-facilitated with that of a park or normal garden; it is just that the garden is located on the building structure which makes it different from the normal one. Table 2.1 shows the difference between intensive and extensive green roof, as compiled from Bass et al.(2014) and Getter & Rowe (2006):

Table 2.1: Key Difference of Extensive and Intensive Green Roof
(Bass et al., 2014; Getter & Rowe, 2006)

| KEY DIFFERENCE | EXTENSIVE GREEN ROOF | INTENSIVE GREEN ROOF |
|---|---|---|
| Photo/Figure |  <p>(Getter & Rowe, 2006)</p> |  <p>(Getter & Rowe, 2006)</p> |
| Growing Media/ Structural Preparation (source: Bass et al., 2014) | Depth of growing media generally between 50 - 100 mm (2 – 4 inches) Minimal to no irrigation Light weight Structural engineering usually not required Suitable to cover large surface areas | Depth of growing media greater than 100 mm (4 inches) More likely to require irrigation Heavier in weight Requires structural engineering Used over smaller areas or in landscaped containers |
| Vegetation (source: Bass et al., 2014) | Stressful conditions for plants requires low growing drought resistant species Can support few plant species, generally monoculture | Deeper substrate can support wider range of native plant species Can be designed to simulate greater range of plant species and habitats |

By considering the types of green roofs, the maintenance criterion is therefore critical factors in the operation phase of a building. As mentioned by Saiz et al. (2006), building maintenance and operation is one of the critical factors in the stages of the building life cycle. To sustain the building life span with the green roof installation, ideally the criteria of green roof maintenance should be highlighted in reviewing the viability of its installation. Determining suitable criteria for maintenance helps to prolong the life-span of building, thus achieve sustainability. As supported by Khalil et al. (2015), proper building and maintenance assessment through suitable criteria and indicators can help organizations to reduce the building operation cost, including green roof maintenance.

The Criteria of Green Roof Maintenance

This section confers on the maintenance criteria derived from the previous researchers in examining the green roof systems. A lot of studies have been done, both locally and abroad, on matters concerning the green roof implementation issues and have been recorded and documented in various publications. But only a few studies were carried out in regards to the maintenance of green roof, particularly in Malaysia. This paper addressed an exploratory step and initial establishment in assessing the suitable maintenance criteria that can be used in this study. By exploring and understanding the viewpoints of past studies, the maintenance criterion of green roof is ascertained and leads to a better result.

Literatures studies on the maintenance of green roof in Malaysia were minimal. Nevertheless, there are few articles regarding this matter. These authors have also identified various literatures from overseas that create a more comprehensive research on the subject matter. Research by Kamarulzaman et al. (2014) points out on the vegetation, growing medium, filter mats, drainage layer, insulation, root barrier and waterproof membrane as the main criteria needed in the maintenance of green roof. Meanwhile, Ismail et al. (2016) highlights criteria such as roof slab, waterproofing membrane, drainage system, fertilization, pruning, weed control and irrigation system.

Tolderlund (2010) on the other hand, emphasizes the green roof maintenance criteria of waterproofing membrane, drainage inspection, rooftop structures, plants and growing medium including weeding, watering, pruning, fertilization, replacing plants and also irrigation. Other than that, Lucket (2009) stresses more to the vegetations involving watering, fertilizers, weed and pests. Harris (2014) analyses the criteria of irrigation, fertilization, plant management and clearance or removal. Coelho et al., (2015) divides the criteria into two which is layers and other elements, while Townshend (2006) underlines waterproofing inspection, drainage inspection, plant health inspections, replacing planting, irrigation, pruning, fertilizing, pests control and weeding as the important criteria in maintaining the green roof system. In the meantime, Gedge et al. (2013) discusses on the criteria of functional layers, roof deck, climate, thermal performance, stability, insulation, waterproofing, storm water management and also vegetation of the green roof.

Based on the above, the findings were further compiled and summarised as per Table 2.2, Table 2.3 and Table 2.4. Table 1 shows 20 criteria and the descriptions that were shortlisted in abbreviations. These criteria are revealed as the significant factors that should be considered in the maintenance management of green roof applications.

Table 2.2: Abbreviations and Description of the Maintenance Criteria

| ABBREVIATION | THE MAINTENANCE CRITERIA |
|---------------------|--|
| CL | Climate |
| DR | Debris Removal |
| DS | Drainage system |
| FT | Fertilization |
| FM | Filter mats |
| GM | Growing medium/ Soil substrate |
| INS | Insulation |
| ISW | Irrigation system/ Watering |
| OS | Occupancy & safety / Accident prevention |
| PC | Pest and disease control/ Plant Health Inspections |
| PR | Pruning |
| RA | Roof access |
| RS | Roof slab/ Structural deck |
| RB | Root Barrier |
| SS | Slope stability |
| TP | Thermal performance |
| VG | Vegetation |
| WR | Water retention/ Storm water management |
| WM | Waterproofing Membrane |
| WC | Weed control |

From the description of criteria and its abbreviations, Table 2.3 and Table 2.4 showed the summary of previous research that has pointed the maintenance criteria of green roof. Both compilations addressed the criteria of maintenance in both international and local context, respectively. The

compilation is highlighted as an initial establishment of the significant criteria for green roof maintenance in Malaysia.

Table 2.3: The Criteria of Maintenance in Green Roof (International Context)

| SOURCE(S) | THE CRITERIA OF MAINTENANCE | | | | | | | | | | | | | | | | | | | | |
|---------------------------|-----------------------------|----|----|----|----|----|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|---|
| | CL | DR | DS | FT | FM | GM | INS | ISW | OS | PC | PR | RA | RS | RB | SS | TP | VG | WR | WM | WC | |
| (Coelho, et al., 2015) | | | ✓ | | | ✓ | ✓ | ✓ | ✓ | | | ✓ | | ✓ | | | ✓ | | | | |
| (Harris, 2014) | | ✓ | | ✓ | | | | ✓ | | | | | | | | | ✓ | | | | |
| (Gedge et al., 2013) | ✓ | | | | | | ✓ | | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| (Tolderlund, 2010) | | ✓ | ✓ | ✓ | | ✓ | | ✓ | | | ✓ | | ✓ | | | | | | | ✓ | ✓ |
| (Luckett, 2009) | | | | ✓ | | | | ✓ | | ✓ | | | | | | | | | | | ✓ |
| (Townshend, 2006) | | ✓ | ✓ | ✓ | | | | ✓ | | ✓ | ✓ | | | | | | | | | ✓ | ✓ |
| ASTM International (2006) | | | | ✓ | | | | ✓ | | | | | | | | | | | | | |

Table 2.4: The Criteria of Maintenance in Green Roof (Malaysian Context)

| SOURCE(S) | THE CRITERIA OF MAINTENANCE | | | | | | | | | | | | | | | | | | | | |
|------------------------------|-----------------------------|----|----|----|----|----|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|---|
| | CL | DR | DS | FT | FM | GM | INS | ISW | OS | PC | PR | RA | RS | RB | SS | TP | VG | WR | WM | WC | |
| (Ismail, et al., 2016) | | | ✓ | ✓ | | | | ✓ | | | ✓ | | ✓ | | | | | | | ✓ | ✓ |
| (Kamarulzaman, et al., 2014) | | | ✓ | | ✓ | ✓ | ✓ | | | | | | | ✓ | | | ✓ | | | ✓ | |

METHODOLOGY

This study was done through an analysis of literature review on the tropical green roof and its maintenance criteria. The resources of the study are mostly from the secondary data which is journals and articles, conference proceedings, and also existing green roof guidelines. They are mainly drawn from between the years 2006 until 2017 in order to assure the most updated data on green roofs system are used. Based on the review on the current scenario and existing literatures, the maintenance criteria for green roofs are then analyzed.

DISCUSSIONS OF FINDINGS

Based on the review, the results had a number of similarities on the maintenance criteria of the green roof. It is also found that one criterion is very much related to other criteria. For instance, the criterion of weed control is much related to debris removal and fertilisation, while the criterion of drainage is related to water retention and irrigation system. The author decided to use the common criteria based on mode or frequent value retrieved in the previous study in identifying the suitable criteria of green roof maintenance in Malaysia. Based on the preliminary findings, six (6) maintenance criteria retrieved a higher mode or frequent value and they are; i) drainage, ii) fertilisation, iii) irrigation, iv) vegetation, v) waterproofing, vi) weed control. As an initial establishment of green roof maintenance criteria in Malaysia, these criteria were considered as the most significant factors to be included in the maintenance process. As compiled in Table 4.1, the justification on the appropriateness of the maintenance criteria is summarised as follows:

Table 4.1: Justifications of the Maintenance Criteria for Green Roof

| CRITERIA | JUSTIFICATION |
|------------------------------------|---|
| Drainage system | All drains must remain free of vegetation and foreign objects. Inspection of drainage flow paths is crucial because of the severe consequences of drainage back-ups. Every drain on a green roof must remain permanently accessible in order to allow for regular inspections and maintenance. Roof outlets, drains, interior gutters, and emergency overflows should be kept free from obstruction by either providing a drainage barrier or equipped with an inspection shaft (Tolderlund, 2010). |
| Fertilization | Fertilisation is the process by which additional nutrients can be supplied to the plants, enhancing germination, flowering and resistance to weather extremes. It may be used during establishment phase to promote plant health, where organic products are recommended (Tolderlund, 2010). Fertilization is not recommended for extensive green roof because they typically have low nutrient requirements and are therefore often fertilised on an annual basis, using a slow-release fertiliser. Meanwhile, the intensive greenroofs with a wider range of planting, using a more fertile growing medium, require a more regular fertilisation (Harris, 2014). Fertilizer application should be only be at minimum level (Ismail et al., 2016). Annual fertilization is necessary for the first 3 to 5 years (Lucket, 2009). Nonetheless, Periodic fertilization may be necessary to maintain lush growth (ASTM International, 2006). |
| Irrigation system/ Watering | Irrigation is a process where water is supplied by using artificial means for example by using pipes. Other than pipes, sprinkler or drip irrigation systems also can be used by installing their tanks, pipes and emitters during the design phase of the green roof. As the green roof can be accessed (intensive green roof), the more likely irrigation system is required (Ismail et al., 2016). Meanwhile, the extensive roofs should not require irrigation in general. However, it may be advisable to have an irrigation system in place just in case the site experiences an extended drought or other unusual weather patterns (ASTM International, 2006) |

| | |
|--------------------------------------|---|
| <p>Vegetation</p> | <p>The type of plants and vegetations used for the green roof depends on the type of green roof design, the depth of growing medium installed, and the climate zone. An Intensive green roofs may use any plant, including shrubs, perennials, trees, and so on. Meanwhile, Extensive green roof generally uses drought resistant plants with shallow roots such as Sedums and lawn (Kamarulzaman et al., 2014). The ability of plants to survive on a green roof is directly proportional to the amount of maintenance time and budget allocated to the project, particularly in the first two years when they are getting established (Ismail et al., 2016).</p> |
| <p>Waterproofing Membrane</p> | <p>This membrane either as a liquid or in sheets is applied to the building surface and keeps water from leaking into the building construction. In some cases, the membrane will also contain a root barrier either as a laminated surface or through chemical additives in the coating (Kamarulzaman et al., 2014). As leak is one of the main defects found at intensive green roofs, it can be detected by using a few methods such as Flood Testing, Flowing Testing, Electric Field Vector Mapping (EFVM), Capacitance, Infrared (IR) Thermal Imaging and Moisture Sensors (Hui, 2010). The roof membrane will have to be replaced after 30 – 50 years, according on the roof size, building height, type of planting and depth of the growing medium (Ismail et al., 2016). Meanwhile, regular inspections are advised at least three times per year (Tolderlund, 2010).</p> |
| <p>Weed control</p> | <p>Weeding is where the wild plants growing where it is not wanted especially among garden plants need to be taken out from the ground. Weeds can compete for water and food and choke out the intended green roof plants. It can also have much more aggressive roots that, when left unchecked, are capable of exploiting weaknesses in root barriers and damaging roofing membranes. Weed eradication is necessary throughout life of the roof where it usually involves hand weeding by using garden gloves and energetic weed pullers. The use of herbicides is strongly discouraged due to the same environmental concerns (Lucket, 2009)</p> |

CONCLUSION

The green movement has become a global trend in the construction industry nowadays, where the concept of a green roof is also being looked at and explored deeply. However, in Malaysia, the concerns on green roof maintenance are not prioritised in reviewing the viability of its application. The maintenance of the green roof system itself is often being neglected, but the maintenance holds an important role in sustaining the green roofs for their intended function. The outcome of this study has focused on the green roof concepts in assessing the appropriate maintenance criteria to be applied in Malaysia. Hence, the paper outlined six (6) maintenance criteria of green roof as an initial establishment. The criteria marked are appropriate and significant in the context of green roof maintenance in Malaysia. Further path of this study will outline the strategic ways and best practices in lieu of the current maintenance practice of green roof towards achieving sustainability and environmental enhancement.

REFERENCES

- Al-Obaidi, K. M., Ismail, M., & Rahman, A. M. A. (2014). Passive cooling techniques through reflective and radiative roofs in tropical houses in Southeast Asia : A literature review, *Frontiers of Architectural Research*. Vol. 3 (3), pp. 283-297.
- ASTM International. (2006). *Standard Guide for Selection , Installation , and Maintenance of Plants for Green Roof Systems*.
- Chow, M. F., & Abu Bakar, M. F. (2016). A Review on the Development and Challenges of Green Roof Systems in Malaysia. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*, Vol. 10(1), pp.16–20.
- Coelho, A., Silva, C. M., & Flores-Colen, I. (2015). Green roofs in Mediterranean areas e Survey and maintenance planning. *Building and Environment*. Vol. 94, pp. 131–143.

- Fauzi, M. A., Malek, N. A., & Othman, J. (2013). Evaluation of Green Roof System for Green Building Projects in Malaysia. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering*, Vol. 7 (2), pp. 75–81.
- Gedge, D., Grant, G., Kadas, G., & Dinham, C. (2013). *Creating Green Roofs for Invertebrates: A best practice guide*. Retrieved 14 August 2016 from [https://www.buglife.org.uk/sites/default/files/Creating Green Roofs for Invertebrates_Best practice guidance.pdf](https://www.buglife.org.uk/sites/default/files/Creating%20Green%20Roofs%20for%20Invertebrates_Best%20practice%20guidance.pdf)
- Getter, K. L., & Rowe, D. B. (2006). The role of extensive green roofs in sustainable development. *HortScience*, Vol.41 (5), pp. 1276–1285.
- Harris, M. (2014). *The GRO Green Roof Code. Final report of Green Roof Code of Best Practice for the UK 2014*.
- Hui, S. C. M. (2006). Benefits and potential applications of green roof systems in Hong Kong. *Proceedings of the 2nd Megacities International Conference 2006*, 12 December 2006, Guangzhou China, (December), 1–8. Retrieved from <http://hdl.handle.net/10722/100487>
- Hui, S. C. M. (2010). Development of technical guidelines for green roof systems in Hong Kong, *Proceedings of Joint Symposium 2010 on Low Carbon High Performance Buildings*. 23 November 2010, Hong Kong
- Ismail, W. Z. W., Ahmad, S. S., Hashim, A. E., Isnin, Z., & Ali, I. M. (2010). Perception Towards Green Roof In Malaysia. *Proceedings of Management in Construction Researchers Association 9th Annual Conference and Meeting (MiCRA 2010)*, Malaysia.
- Ismail, W. Z. W., Ariff, N. R. M., Ahmad, S. S., & Kamarudin, H. (2016). Green Roof Maintenance towards Sustaining Neighborhood Spaces of High-Rise Residential Developments in Malaysia, *Advanced Science Letters*. Vol. 22 (5-6) pp. 1502-1508.
- Kamarulzaman, N., Hashim, S. Z., Hashim, H., & Saleh, A. A. (2014). Green Roof Concepts as a Passive Cooling Approach in Tropical Climate- An Overview. *E3S Web of Conferences*, Vol. 3. pp. 01028-p.1 - 01028-p.7

- Khalil, N., & Husin, H. N. (2009). Post Occupancy Evaluation towards Indoor Environment Improvement in Malaysia's Office Buildings. *Journal of Sustainable Development*, Vol.2 (1), pp. 186–191.
- Khalil, N., Kamaruzzaman, S. N., & Baharum, M. R. (2015). A survey on the performance-risk rating index for building performance assessment in higher education buildings. *Jurnal Teknologi*, Vol. 75 (9), pp. 57-63.
- Lucket, K. (2009). *Green Roof Construction And Maintenance*. The McGraw-Hill Companies.
- McIntyre, L., & Snodgrass, E. (2010). *The green roof manual: a professional de to design, installation, and maintenance*. Timber Press, Inc.
- Mirrahimi, S., Mohamed, M. F., Haw, L. C., Ibrahim, N. L. N., Yusoff, W. F. M., & Aflaki, A. (2016). The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot – humid climate. *Renewable and Sustainable Energy Reviews*. Vol. 53, pp. 1508–1519.
- Rahman, S. R. A., Ahmad, H., & Rosley, M. S. F. (2013). Green Roof: Its Awareness Among Professionals and Potential in Malaysian Market. *Procedia - Social and Behavioral Sciences*, Vol. 85, pp. 443–453.
- Saiz, S., Kennedy, C., Bass, B., & Pressnail, K. (2006). Comparative life cycle assessment of standard and green roofs. *Environmental Science & Technology*, Vol. 40 (13), pp. 4312–4316.
- Tolderlund, L. (2010). *Design Guidelines and Maintenance Manual for Green Roofs in the Semi-Arid and Arid West*, Retrieved from <https://www.epa.gov/sites/production/files/documents/GreenRoofsSemiAridAridWest.pdf>.
- Townshend, D. (2006). *Study On Green Roof Application In Hong Kong*. Final Report for Urbis Limited, 16 February 2007.
- Office of Environment and Heritage (2015). *Urban green cover in NSW; Technical guidelines*. Sydney, Australia; the State of New South Wales, Office of Environment and Heritage.

Wong, T.-C., & Yuen, B. (2011). *Eco-city Planning: Policies, Practice and Design* - Google Books.

Zahir, M. H. M., Raman, S. N., Mohamed, M. F., Jamiland, M., & Nopiah, Z. M. (2014). The Perception of Malaysian Architects towards the Implementation of Green Roofs: A Review of Practices, Methodologies and Future Research. *E3S Web of Conferences*. Vol. 3, pp. 01022-p.2 –p.8