APPLICABILITY OF GREEN ROOFS IN SRI LANKAN HIGH-RISE BUILDINGS: DRIVERS AND BARRIERS

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ABSTRACT

Sri Lanka is experiencing a construction boom and there are many high-rise building constructions coming up. Thus, many adverse effects are associated with high rise buildings. Greenery provides several benefits to the environment and reduces these effects. However due to limited space in urban areas it is impossible to plant new plants, trees and vegetation around the buildings. As a solution green roofs can be adopted as they provide many environmental and sustainable benefits from rooftops. Though this concept is more popular across many countries over the past few decades, still implementation of this technology in Sri Lanka is new and scant. Due to the lack of past researches, awareness on green roofs is very low for professionals, developers, government authorities, building owners and general public.

The aim of this research is to identify and analyse the potential of green roofs in high rise buildings in Sri Lanka. A comprehensive literature review was carried out on popularity of green roof in global context, types of green roofs, components of green roofs, barriers and drivers in implementing green roofs. The data collection was conducted through expert interviews and questionnaire survey. Expert interviews were carried out to validate the barriers and drivers identified through literature review in Sri Lankan context and questionnaire survey was used to identify the most significant barriers and drivers. Purposive sampling techniques was used for selection of the respondents. The data collected from expert interviews were analysed through manual content analysis and the data collected by questionnaire were analysed using RII method. The final outcome of this study finds that green roof is an applicable concept for Sri Lankan high rise buildings.

Keywords: *Barriers; Drivers; Green Roofs; High Rise Buildings.*

1. INTRODUCTION

Globally buildings are responsible for 40% of the total world annual energy consumption (Kamarulzaman, et al., 2014) and increasing of energy consumption due to global warming issues have attracted the awareness of researchers, architects, engineers, property developers, facilities managers and authorities to the crucial of green construction or sustainable development concepts (Sheweka and Mohamed, 2012). Sri Lanka is currently experiencing a construction boom due to increased interest of investors after the end of a three decade-long conflict and restoration of peace (Karunasena, Rathnayake & Senarathne, 2016) However, major adverse effects can be identified associated with high rise building construction activities on environment such as greenhouse gas emissions into air, waste generation, soil pollution, water spills, high consumption of resources, impacts associated with transportation and effects on biodiversity (Gangolells, et al., 2009).

There are different strategies to mitigate the negative impacts of urbanization (Moghbel & Erfanian, 2017). One of the most effective strategies is conversion of impervious surfaces in urban areas into a multifunctional land cover such as vegetated roofs or green roofs (Carter & Butler, 2008). There are many descriptors for green roofs, including intensive/extensive, living roofs, garden roofs, eco roofs, vegetated roof tops and high-maintenance/low-maintenance roofs (Barreiro, 2012). This technology is more popular across Europe over the past few decades in countries like Switzerland, France (Zhang, et al., 2012), United Kingdom (Oberndorfer, et al., 2007) and Portland (Townshend & Duggie 2007) and as well as other many countries such as USA (United

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States of America), Canada, Australia, Singapore, Japan (Vijayaraghavan, 2016) and Hong Kong (Zhang, et al., 2012). In contrast, implementation of this technology in other developing countries is still new and scant (Blank, et al., 2013).

2. LITERATURE REVIEW

2.1. INTRODUCTION TO GREEN ROOFS

Green (vegetated) roofs are globally accepted technology which has the potential to help mitigate the complex environmental problems of urban centres (Clark, Adriaens & Talbot, 2008). As mentioned by Dunnett and Kingsbury (2004) green roof is a planted roof or a roof that consists of vegetation and growing medium. It uses plants ranging from grass, trees, moss, flowers lichen, sedum, shrubs, and bushes. In addition to their ecological characteristics, green roofs can improve the life of the roof and provides a fully functioning roof (Kamarulzaman, et al., 2014). Although green roofs are initially more expensive to construct than conventional roofs, they can be more economical over the life span of the roof for the reason that energy saved and long life of roof membranes (Porsche & Kohler, 2003). Moreover, they act positively upon the global warming and climate of the city and its region as well upon the interior climate of the buildings beneath them. According to Velazquez (2005), combining plants with architecture is not a new idea, and neither are green roofs. Planting vegetation at the building rooftop is an old technique (Vijayaraghavan, 2016). The earliest documented roof gardens were the hanging gardens of Semiramis in what is now Syria, considered one of the seven wonders of the ancient world (Oberndorfer, et al., 2007). Green roof can be divided into two distinguished types such as extensive green roofs and intensive green roofs.

2.2. COMPONENTS OF GREEN ROOFS

A green roof comprises of a waterproofing membrane, a root barrier, drainage layer, filter layer, substrate and plants. A waterproofing membrane sits immediately on top of the structural roof deck as an insulation to prevent moisture from entering the building (Vijayaraghavan, 2016). Typically, a root barrier layer is designed to prevent roots from penetrating the waterproofing membrane and the structural roof (Bianchini & Hewage, 2012). The drainage layer is the next and it protects water proof membrane too and improves thermal properties of green roof (Townshend & Duggie 2007). Filter layer separates the growth substrate from the drainage layer and prevents small media particles from entering and clogging the drainage layer below. The next components are substrate and plants. Green roof substrates need to be lightweight, physically and chemically stable, hold adequate amounts of water and nutrients for plant survival (Rowe, Monterusso & Rugh, 2006). A green roof uses plants ranging from grasses, mosses, lichens, sedums, trees, shrubs, flowers and bushes (Weiler & Scholz-Barth, 2009).

2.3. DRIVERS FOR GREEN ROOF SYSTEM

Several authors explained that green roofs provide many economic and environmental benefits which act as drivers for adopting green roof retrofit.

Table 1: Drivers Identified from Previous Studies

Drivers	Sources																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Reduce Urban Heat Island effects									√				√				
Thermal benefits and energy savings				√		√								√		√	
Storm water management					√					√	√			√			
Better run-off water quality	√		√														
Reduce air polution							√	√						√	√		
Noise reduction		√															√
Green rating system												√			√		
Aesthetical appearance												√			√		

1 - Barreiro (2012), 2 - Connelly & Hodgson (2013), 3 - Getter & Rowe (2006), 4 - Hashemi, Mahmud & Ashraf (2015), 5 - Mentens, Raes & Hermy (2006), 6 - Niachou et al. (2001), 7 - Pandit & Laband (2010), 8 - Rowe (2011), 9 - Santamouris (2014), 10 - Speak et al. (2012), 11 - Stovin, Vesuviano & Kasmin (2013), 12 - Velazquez (2005), 13 - Vijayaraghavan & Raja (2015), 14 - Vijayaraghavan (2016), 15 - Wilkinson & Reed (2009), 16 - Wong et al. (2003), 17 - Yang, Kang & Choi (2012).

2.4. BARRIERS FOR GREEN ROOF SYSTEM

There is a lot of discussion in research literature on different benefits and challenges of green roof systems (Williams, Rayner & Raynor, 2010). Even though research reports and environmentalists attempt to highlight positive aspects of the green roofs, several factors hinder the growth of green roofs as well (Vijayaraghavan, 2016). To improve comparative benefits and bring about advocated green change, researchers need to answer and find solutions regarding the barriers and challenges related to usage and acceptance of green roofs (Williams, Rayner & Raynor, 2010).

Table 2: Barriers Identified from Previous Studies

Main Factors	References	Main Factors	References
1. Cost	Vijayaraghavan (2016), Bianchini & Hewage (2012), Carter & Keeler (2008), Jim (2011), Duda (2009), Peri, et al. (2012)	2. Lack of awareness and research	Blank et al. (2013), Wong & Lau (2013), Vijayaraghavan (2016), Kibert (2016)
3. High amount of maintenance	Nagase, Dunnett & Choi (2013), Vijayaraghavan (2016)	4. Lack of support from government	Williams Rayner & Raynor (2010), Steven & Ireen (2003), Zhang, et al. (2012)
5. Lack of support from building owners	Vijayaraghavan (2016), Hwang & Tan (2012)	6. Lack of technical competence	Zhang, et al. (2012), Thwala & Mvubu (2008)
7. Space allocation on roof tops	Duda (2009), Zhang, et al. (2012)	8. Concern on disposal of green roof components	Vijayaraghavan (2016), Peri et al. (2012)
9. Lack of green roof, materials and suppliers	Williams, Rayner & Raynor (2010), Vijayaraghavan (2016)	10. Lack of human resources	Zhang, et al. (2012), Hwang, Zhu, L & Tan (2017)
11. Uncertainty and risks	Duda (2009), Sailor (2008), Dunnett & Kingsbury (2004)	12. Lack of plants	Williams, Rayner & Raynor (2010), Snodgrass & Snodgrass (2006), Monterusso et al. (2002)

3. RESEARCH METHODOLOGY

Research approaches are classified mainly in to two as quantitative and qualitative (Fellows & Lui, 2015). This study uses both quantitative and qualitative approaches. Expert interviews and questionnaire survey method have been identified as the most appropriate approach for this research. Expert interviews were carried out to identify the main factors which act as drivers and barriers in implementing green roof technology in Sri Lankan context. Then a questionnaire survey was conducted to identify the most significant drivers and barriers out of the drivers and barriers identified through literature review and experts interviews. Each identified barrier and driver is assigned a score based on a one to five point Likert's scale. The respondents were invited to give their opinion on the relative significance of each barrier which hinder and drivers which motivate the implementation of green roof systems. The respondents were invited to judge the significance degree of each listed barrier, with grading "1" as strongly disagree, "2" being disagree, "3" being neutral, "4" being agree and "5" as strongly agree. After that again expert interviews were carried out to identify the ways to overcome the most significant barriers. The sampling technique used in this study is purposive sampling. The reason for the purposive sampling method is that there are only few expertise in green roofs in Sri Lanka. Data collected from

expert interviews was analysed through manual content analysis and questionnaire survey was analysed through relative important index.

4. DATA ANALYSIS AND FINDINGS

4.1. FINDINGS OF THE EXPERT INTERVIEWS

Table 3: Profile of the Respondents of Expert Interviews

Code	Designation	Experience
R1	Architect	15-20 years
R2	Architect	10-15 years
R3	Engineer	15-20 years
R4	Engineer	5-10 years
R5	Green Cosultant	5-10 years
R6	Facility Manager	10-15 years
R7	Facility Manager	15-20 years

All experts agreed that green roofs can be applicable in Sri Lanka and R1-R6 agreed that green roofs can be applicable in Sri Lankan high rise buildings. R7 stated that green roofs cannot be applicable in high rise buildings due to the space constraint. He explained his point by stating that the roof top area in many high rise buildings are mostly occupied for building services such as chiller plants, cooling towers, telecommunication antennas and swimming pools. Therefore, there is no much space left for green roofs in high rise buildings. He accepted that green roofs can be applicable in Sri Lanka for low rise wider buildings. Experts who agreed on applicable of green roofs in high rise buildings gave their opinions on drivers and barriers for green roofs in Sri Lankan context. The factors which are accepted by 4 or more than 4 respondents are included in the questionnaire survey.

From the literature review eight factors were identified as drivers. Through the expert interviews additionally three factors were identified which are “bio diversity”, “increased roof life and property value” and “better Indoor Environmental Quality and well-being of people”. When it comes to barriers, twelve barriers were identified through literature review. Experts identified eleven factors as significant barriers in Sri Lankan context and rejected “lack of plants” as a barrier. From the point of experts, there are variety of plants available in Sri Lanka and only the problem is lack of professional experts to advise on the selection of suitable plants according to the type of green roof, location and climate conditions.

From the discussion, points and explanation of the experts, out of the final eleven factors six factors were divided into sixteen sub factors. Two factors which are technical competence and lack of human resources were merged and divided into three sub factors. Three factors were not divided into sub factors. All together 22 sub factors were identified and included in the questionnaire.

Table 4: Categorization of Main Factors and Sub Factors

No	Main Factor	No	Sub Factors
1	Cost	1	High construction cost
		2	High maintenance cost
		3	Opportunity cost
2	Lack of awareness and research	4	Lack of research on environmental and economic benefits of green roof
		5	Lack of awareness
3	High amount of maintenance	6	High amount of maintenance
4	Lack of support from government	7	Lack of government policies and regulations
		8	Lack of government incentives and promotions
5	Lack of support from building owners	9	Lack of support from building owners

6	Lack of technical competence	10	Lack of experienced professionals
7	Lack of human resources	11	Lack of experienced installers
		12	Lack of experienced maintenance staff
8	Space allocation on roof tops	13	Space allocation on roof tops
9	Concern on disposal of green roof components	14	Environmental considerations on disposal of the components
		15	Cost and man power needed for disposal of the components
10	Lack of green roof, materials and suppliers	16	Lack of green roof components suppliers
		17	Lack of green roof plants and growing media suppliers
11	Uncertainty and risks	18	Fire risk
		19	Financial risk
		20	Climate and PESTs
		21	Weed spread
		22	Risk of failure

4.2. FINDINGS OF THE QUESTIONNAIRE SURVEY

After identifying the drivers and barriers in Sri Lankan context through expert interviews, a questionnaire survey was conducted to identify the most significant drivers and barriers and at the same time respondents were asked the applicability of green roofs in Sri Lanka and in Sri Lankan high-rise buildings. Out of the 54 professionals who received the questionnaire, 38 professionals responded representing 70.4 % responding rate. All the professionals were well experienced in green concepts and familiar with green roofs. Above 70% of the respondents had more than 5 years post qualification experience, indicating that those surveyed were well experienced built environment practitioners.

Table 5: Profile of the Respondents of Questionnaire Survey

Categorisation	Details	No.	Percentage
Profession	Architects	16	42%
	Engineers	11	29%
	Quantity surveyors	4	11%
	Facility Managers	7	18%
Experience	0-5 years	10	26%
	6-10 years	14	37%
	11-15 years	6	16%
	More than 15 years	8	21%
Sector	Private	22	58%
	Public	10	26%
	Academic	6	16%
Familiarity with green roofs	Very familiar	24	63%
	Familiar	8	21%
	Slightly familiar	6	16%

When it comes to the applicability of the green roofs in Sri Lanka, all the 38 respondents agreed (100%) that green roofs can be applicable in Sri Lanka while when it comes to the applicability in high-rise buildings 34 (89%) out of the 38 respondents agreed. Out of the 34 respondents 32 respondents have experience of more than 5 years. The respondents who agreed that green roofs are applicable in Sri Lankan high-rise buildings (34 respondents) were invited to judge the significance of each listed driver and barriers according to Likert scale.

Table 6: Final Ranking of the Drivers Through Questionnaire Survey

Drivers for successful implementation of green roofs	No of respondents and their points					RII	Ranking
	1	2	3	4	5		
Reduction of air pollution	0	0	0	13	21	0.826	1
Aesthetical appearance	0	0	0	19	15	0.795	2
Thermal benefits and energy savings	0	3	2	14	15	0.753	3
Reduce Urban Heat Island effect	0	2	4	15	13	0.742	4
Points in green rating system	0	0	1	28	5	0.737	5
Better IEQ and well-being of people	0	0	13	18	3	0.663	6
Biodiversity	0	0	21	13	0	0.605	7
Noise reduction	0	1	20	13	0	0.6	8
Increased roof life and value of property	0	7	16	11	0	0.558	9
Storm water management	0	6	14	13	0	0.558	9
Better run-off water quality	1	9	16	4	0	0.437	11

Reduction of air pollution is ranked as first driver of green roofs in Sri Lanka with RII value of 0.826. There is limited space in Sri Lankan urban areas and green roofs make it possible to plant plants and vegetation in roof tops. Green roofs provide opportunity to reduce the negative impact of carbon dioxide and produces oxygen and filters the air. Airborne particulates are caught within the vegetation and the pollutants are filtered naturally through the planting systems. Aesthetical appearance is the second most significant driver as green roofs offer people to spend their leisure time with relaxing and eye-catching view at their roof top and this reduces stress. The third significant factor is thermal benefits and energy savings as green roofs reduce the heat transferred from the sun to the buildings. This creates a cooler environment and the need of air conditioning is reduced. Green roofs have more contribution towards reducing UHI effects as they are on the roof top. The heat transferred to the lower part of the building is low. As a reason reducing UHI effects has been ranked as fourth driver. The least significant factors are storm water management and better run-off water quality as they are not suitable for high rise buildings in Sri Lanka. In low rise buildings green roofs can offer better storm water management and better run-off water quality.

Table 7: Final Ranking of the Barriers through Questionnaire Survey

Barriers for successful implementation of green roofs	No of respondents and their points					RII	Ranking
	1	2	3	4	5		
Lack of awareness	0	0	0	11	22	0.811	1
Lack of space on roof tops	0	1	2	9	22	0.810	2
Lack of experienced professionals	0	0	1	16	17	0.8	3
Lack of experienced installers	0	0	0	25	9	0.763	4
High construction cost	0	1	2	22	9	0.742	5
Opportunity cost	0	0	12	21	1	0.737	6
Lack of research on environmental and economic benefits of green roof	0	0	1	28	5	0.737	6
Lack of support from building owners	0	0	9	16	9	0.716	8
High amount of maintenance activities	0	0	2	32	0	0.705	9
Lack of government policies and regulations	0	0	10	19	4	0.663	10
Fire risk	0	0	11	23	0	0.658	11
Climate and PESTs	0	0	12	22	0	0.658	11
Financial risk	0	0	13	21	0	0.647	13
High maintenance cost	0	1	12	21	0	0.642	14
Weed spread	0	0	16	18	0	0.632	15

Barriers for successful implementation of green roofs	No of respondents and their points					RII	Ranking
	1	2	3	4	5		
Risk of failure	0	0	17	17	0	0.626	16
Lack of government incentives and promotions	0	2	12	19	0	0.611	17
Lack of experienced maintenance staff	0	0	23	11	0	0.595	18
Lack of green roof components suppliers	0	9	14	11	0	0.547	19
Environmental considerations on disposal of the components	0	8	26	0	0	0.495	20
Lack of green roof plants and growing media suppliers	0	22	10	2	0	0.432	21
Cost and man power needed for disposal of the components	0	26	8	0	0	0.4	22

Lack of awareness is the main barrier identified through questionnaire survey with a RII value of 0.811. In Sri Lanka, green roof is a new concept and general public, building owners and developers do not know about green roofs or the benefits they can provide. The second most significant barrier is the lack of space on roof tops with RII value of 0.810. High-rise buildings usually have more problems in promoting green roof as roof space has competing uses including electricity generation (solar/wind/tri-generation), communications towers, helipad, swimming pool and building plants in Sri Lanka and as a result there is no much of a space left to implement green roofs. The third significant barrier is the lack of experienced professionals in Sri Lanka. The compliance with employing green roof system in the existing or new buildings is very low due to the lack of professional experts who can address the complex construction process and technical difficulties within the green roof technologies. Involvement of various professionals is needed for designing, constructing and maintaining the green roofs such as architects or landscape architects, structural engineers, maintenance managers and horticulturalists. Lack of experienced installers is the fourth significant barrier in Sri Lanka for adopting green roof as there are not many green roofing contractors and installers in Sri Lanka. The fifth significant barrier in Sri Lanka for adopting green roof is high construction cost. The initial cost of green roof is higher than a conventional roof due to the professional fees for designing and planning, contractor fees, planning and building permits, demolition or relocation of existing infrastructure on the roof, importing materials and components and addition of specific hard infrastructure elements.

The ways to overcome the barriers were discussed through expert interviews and those ways can be solutions for all the barriers including the most significant barriers. The ways to overcome the barriers were identified as increasing the awareness through encouraging research and development on green roofs, educating and training of professionals on green roof construction and establishing proper government regulation, policies, incentives and promotion. There is a need to increase the level of awareness, knowledge and understanding of green roofs to construction professionals, professionals who are involved in the maintenance and refurbishment of buildings, building owners, developers, stake holders and public. Research on green roofs in Sri Lankan context should be done to give knowledge about green roofs to Sri Lankans. Education programs on green roofs can be organized in order to increase the knowledge and raise the public awareness. Universities and industries should run programs through seminars, presentations, and study tours for high-rise buildings / buildings which have green roofs to raise awareness, support research and trainings.Sri Lankan government should provide tax benefits or an exemption from certain service fees for adopting green technologies including green roofs. Also government can give provision on clean development mechanism and Kyoto protocol. The government can promote green roof technology by giving awards to the buildings or building owners or facilities managers/ chief engineer who have implemented proper green roofs and achieving better energy savings.

5. CONCLUSIONS

There are several negative impacts associated with the urbanization and construction of high rise buildings. Greenery provides several benefits to the environment and reduces the impact of the urbanization. Green roofs are one of the effective strategic to reduce these adverse effects of high rise buildings. In Sri Lanka there are few factors motivating the implementation of green roofs and several factors hindering the adoption of green roofs. This research clearly identified that green roofs are one of the technology which can be applicable in Sri

Lanka and in Sri Lankan high rise buildings. Furthermore the drivers and barriers of green roofs in Sri Lankan context were identified and the ways to overcome those barriers were analysed.

The first five benefits most positively affect the adoption of green roofs in Sri Lankan high rise buildings were found to be: reduction of air pollution, aesthetical appearance, thermal benefits and energy savings, reduction of Urban Heat Island (UHI) effect and points on green rating systems. The first ten barriers that most negatively affect the adoption of green roofs in Sri Lankan high rise buildings were found to be: lack of awareness, lack of space on roof tops, lack of experienced professionals, lack of experienced installers, high construction cost, lack of research on environmental and economic benefits in Sri Lanka, opportunity cost, lack of support from building owners, high amount of maintenance activities and last being lack of government support on policies and regulations. The solutions which were identified are increasing the awareness through encouraging research and development on green roofs, educating and training of professionals on green roof construction and establishing proper government regulation, policies, incentives and promotion, should be established and the green roofs should be included in the upcoming projects for better Sri Lanka.

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