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Original article

Probabilistic private cost-benefit analysis for green roof installation: A Monte Carlo simulation approach

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ABSTRACT

Green roofs are known as one of the environmentally-friendly applications and also as a sustainable approach in developing countries. Although many researchers have proven the environmental benefits of installing green roofs all around the world, they have not been used widely in many countries due to the lack of knowledge about cost-benefit issues. This paper places an emphasis on all the private factors affecting cost-benefit analysis. Installation, operation and maintenance costs are compared with the benefits such as energy saving, the increase in property value, and the acoustic effect in order to determine two indicators namely "net present value" and "pay-back period," using the Monte Carlo simulation. Two scenarios are considered in the analyses: using the property, and selling the property after construction. Moreover, correlation and regression sensitivity analyses are also conducted. The capital of Malaysia, Kuala Lumpur, is selected for the case study due to the lack of cost-benefit analysis in developing countries. The results show that there is low probability of loss in the installation of both types of green roofs during their lifespans. Moreover, net present value for intensive green roofs is found to be higher than extensive ones, whereas the payback period for installing extensive green roofs is lower than intensive green roofs. It is concluded that the probability of loss for the owner is higher than that of benefit in the scenario of selling the property after construction resulting from the installation of both types of green roofs.

1. Introduction

Sustainable approaches in construction industry are known to make a significant contribution to the purpose of reusing and recycling materials, energy saving, and reducing emissions in order to alleviate the resultant adverse impacts on the environment created by the construction industry (Akadiri et al., 2013; Alyami et al., 2013; Lundholm and Peck, 2008). Green roofs have been introduced as the environmentally friendly approach to inspire sustainable construction (Bianchini and Hewage, 2012a), and carry a large number of environmental benefits (Berardi et al., 2014; Ondono et al., 2016; Simmons et al., 2008). However, there are still some barriers in many countries like Australia, Hong Kong, and Malaysia in installing green roofs (Rahman et al., 2013; Williams et al., 2010; Zhang et al., 2012). Additional initial costs and the maintenance-related costs are stated as the major barriers for green roof installation (Wong, Tay et al., 2003).

There are two different classifications for green roofs: a) intensive and extensive green roof, and b) built-in-place versus modular (Morgan et al., 2013). Intensive green roofs show remarkable similarities to roof gardens; they need adequate and reasonable depth of soil and also require a constant maintenance during their entire lifespans. However, extensive green roofs consist of a relatively thin layer of soil in comparison to the other types (Czemiel Berndtsson, 2010). Furthermore, they are designed in such a way to be virtually self-sustaining for which high maintenance is not required (Dvorak, 2009). Private benefits and costs for the installation of green roofs vary along with the types; however, all these types provide positive environmental benefits (Mahdiyar et al., 2015). Storm water retention (Dunnett et al., 2008), mitigation of urban heat island (Susca et al., 2011), increasing the property value (Jim and Peng, 2012), and providing recreational spaces (Ascione et al., 2013) are some of the benefits of green roof installation.

Green roofs have been implemented in many countries with different economic and climatic circumstances (La Roche and Berardi, 2014), and a number of studies have been investigated into economic impacts of installing green roofs. Clark et al. (2008)

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demonstrated that Net Present Value (NPV) for a conventional roof is between 20% and 25% more than the extensive green roof during its lifespan (over 40 years). Carter and Keeler (2008) collected data during an experimental study for green roof in order to conduct a cost-benefit analysis. The NPV of extensive green roofs in their study indicates that this type of green roof is more expensive than the conventional one ranging from 10% to 14%. Consequently, they concluded that a 20% reduction in initial cost is necessary to consider this type of green roof as an economic-feasible construction practice. Bianchini and Hewage (2012b) assessed the costs and benefits involved in personal and social sectors in installing green roofs. The results from their study indicate that by installing any type of green roof, both private and social sectors are at a lower-risk investment, and green roofs are a personal investment. They also found that the social benefits of green roofs play an important role in obtaining the results. Indeed, considering social costs and benefits directly affects the decision making related to this investment. Niu et al. (2010) aimed investigating into the scale of environmental benefits of green roof installation, from the range of private buildings to the city scale using the financial NPV model. Sproul et al. (2014) conducted an economic comparison between white roof and green roofs, and they found that white roofs provide more net savings for the owner; however, green roof might be preferable due to its environmental benefits. Blackhurst et al. (2010) focused on the beneficial aspects of green roofs such as reduction in building cooling load, storm water runoff, carbon dioxide, air pollutants and mitigation of UHI. They found that green roofs are not cost-effective in private sectors; nevertheless, adding the social sector makes it more cost-efficient.

Although many studies have focused on green roofs for developed countries, there is a lack of cost-oriented study as regards the green roof installation for the private sector in developing countries. Regarding the differences in economic factors between developed and developing countries (Di Vita, 2008), remarkable differences are expected to be embedded in the results of cost-benefit analysis for installing green roofs for these types of countries. Additionally, the economic benefit of sound isolation of green roof installation is not being affected in previous cost-benefit studies of installing green roofs. The aim of this paper is to bring out the probabilistic cost-benefit analysis of installing green roofs focusing on the private sector. In this paper, analyses are conducted to calculate NPV and the payback period for installing green roofs in Kuala Lumpur considering two scenarios. The conclusions are based on the assessments of the probability of reaping benefits or incurring losses during the lifespan of each type of green roof.

2. Factors affecting cost-benefit analysis of installing green roof for private sector

There are many effective factors in cost-benefit analysis of green roof installation; however, the effectiveness of each factor depends on many criteria such as climate, economic circumstances, government policies and so on (Berardi et al., 2014). Malaysia as a developing country with a high potential of implementing green roof (Rahman et al., 2013), has an equatorial climate with uniformly high temperatures, high humidity, relatively light winds, and abundant rainfall throughout the year (Makaremi et al., 2012). These environmental specifications and governmental policies cause some economic benefits or drawbacks in terms of installing green roofs. For instance, extensive and intensive green roofs are capable of stormwater retention from 30% to 60% (Ayub et al., 2015), and 17% to 48% (Musa et al., 2008), respectively. This could be regarded as a significant benefit of the rainy weather prolonged in Kuala Lumpur, capital of Malaysia. However, it is a social benefit, and there is an apparent lack of reference to the private benefit of storm water management in Kuala Lumpur. Moreover, green roof installation is considered as an effective application to gain recognition and certification through Green Building Index (GBI) (Fauzi et al., 2013; Zahir et al., 2014). It is worth mentioning that 100% costs of green roofs are claimable, if the building obtain GBI certificate ("Green Building Index," 2016). However, there are myriad of criteria that should be met to obtain GBI certificate. Finally, all the influential factors in cost-benefit analysis of green roof installation in Kuala Lumpur are discussed in detail in the following sections. Moreover, in order to make it globally understandable, all the cost-related values are converted from Malaysian ringgit (RM) to US Dollar ($), as 1$ ≈ 4RM.

2.1. Initial cost

Installation of each type of green roof needs much more capital than the conventional roof (Carter and Keeler, 2008). Wong, Tay et al. (2003) demonstrated that additional structural support is not required for installing extensive green roofs, and as far as installing intensive green roofs are concerned, required additional costs depend on the type of vegetation and additional roof deck structural support. In a study, Sproul et al. (2014) considered $172/m^2$ incurred on installing extensive green roofs as the median installation cost of the green roof projects surveyed in their report. In another study, Berardi (2016) distributed a survey to green roof companies in Canada, and stated that the cost of extensive green roof installation is between around $107/m^2$ and $122/m^2$ for individual plug plants compared to pre-planted sedum mats for which a bit more amount is required. Moreover, Castleton et al. (2010) reviewed the costs of retrofitting the buildings with green roofs in UK. According to the references that have been reviewed in their study, the costs of green roof installation is between $56/m^2$ and $202/m^2$. They also concluded that the reasonable estimate to retrofit a building with an extensive green roof is around $168/m^2$. Additionally, in retrofitting the buildings with green roofs, the variations of cost of green roof installation highly depend on whether the roof is needed to be re-waterproofed or the waterproofing layer of the old roof is in a good condition (Castleton et al., 2010).

On the other hand, the differences between the initial costs of green roof installation incurred by the owners in different countries could be due to the differences in labor cost, the production and manufacturing location of the materials, and the economic incentives. As reported by previous researchers (e.g. Berardi, 2016; Bianchini and Hewage, 2012b), in some cities, economic incentives (tax reduction) reduce the initial costs of green roof installation for the owners. These incentives differ from a city to another one. For instance, in Toronto the incentive is $75/m^2$, while in New York is $48/m^2$.

In terms of Asian countries, according to Peng and Jim (2015), the cost of extensive green roof installation in Hong Kong is around $64/m^2$; however, for China, Manila, and Singapore it is around $28/m^2$, $37/m^2$, and $80/m^2$, respectively (Rahman et al., 2013). In Kuala Lumpur, Rahman et al. (2013) demonstrated that the minimum and maximum costs during the installation of extensive green roofs are between $75/m^2$ and $100/m^2$. Additionally, in terms of intensive green roof, it is more than $100/m^2$. It is worth mentioning that incentive to install green roofs has not yet provided by the government of Malaysia. Moreover, a survey among green roof companies in Kuala Lumpur allowed the authors to establish that the maximum amount for installing an intensive green roof could be up to $240/m^2$. Consequently, as owing to the fact that the minimum cost of intensive green roof installation is $100/m^2$, this paper considers the cost of intensive green roof installation between $100/m^2$ and $240/m^2$.