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Life cycle cost analysis of rooftop gardens in Singapore

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Abstract

Since the 1960's green movement, green roofs have 're-emerged' as a viable solution to address pressing environmental issues like increased storm water runoff, the urban heat island effect, deterioration of air and water quality, and loss of habitat and biodiversity facing urban centres. Increasingly becoming popular worldwide, green roofs are still not an area local builders are keen to take on. Despite the availability of materials and suitability of climate here, they are held back partly by concerns pertaining to costs. The objectives of this study are to highlight the economic benefits of green roofs that can offset the initial costs; to examine the initial cost implications of having a green roof as compared to a conventional flat roof; to compute and compare the *life cycle costs* of roof gardens and average flat roofs; and to incorporate economic benefits by incorporating energy costs into life cycle costs. It is observed that life cycle costs of extensive green roofs with or without consideration for energy costs, are lower than that of exposed flat roofs, despite its higher initial costs. However, for accessible rooftops, even life cycle (energy) costs of intensive system are not less than the normal build-up flat roof.

Keywords: Life cycle cost; Energy simulations; Extensive rooftop gardens; Intensive rooftop gardens

1. Introduction

1.1. Background

The New Concept Plan 2001's vision calls for an even greener Singapore city. This blueprint is designed to turn Singapore into a thriving world class and very green city in the next 50 years [1]. One key aspect of this greening process is the use of more aesthetically pleasing plantings with trees, shrubs and grass in our urban environment.

With a current population of 4 million and a projected population of 5.5 million in 40–50 years time, all within a tiny island state of 682.7 km^2, the trend would inevitably move towards higher density housing exploiting almost every inch of land available. However, to maintain a pleasant living environment, the balance between vegetation and concrete built-up areas cannot be overlooked. With the fundamental layout of cities unlikely to change for some years to come, planners face the challenge of finding other means of increasing and enhancing the amount of greenery in urban areas.

One promising option for dense urban settings is the greening of buildings [2]. Roof gardens, though not a new concept, increase the percentage of greenery in urban built-up area and bring back the vanishing urban green space. Sprucing up the originally under-utilized portion of the buildings, they can 'create a new network of vegetation linking roofs' and increase the ratio of greenery to population. To a certain extent, roof gardens do contribute to the National Parks Board (NParks) target to develop 0.75 ha of parkland per 1000 population.

Roof gardens, more commonly known as green roofs in European countries, are gaining foothold in North America while widely popular and established in European countries especially Germany, France, Austria, Norway, and Switzerland. A large amount of research has also been undertaken in an attempt to improve the performance of green roofs.

By comparison, the acquisition of green roofs technology into current design and construction practice through research and application to local context in Singapore is still in its infancy phase, with a considerable gap compared to our European counterparts. Nevertheless, the extensive research conducted in Europe, do provide us with significant insights of green roof technology commonly adopted there.

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Many designs of plantings on rooftops are tried and tested in Germany but this does not mean that they can be totally adopted and adapted to the local context. One obvious reason is the difference in climatic conditions. Interestingly, German professor Manfred Koehler who has studied urban ecology for 20 years, commented that Singapore, unlike Germany, is not subject to seasonal changes, the weather conditions are ideal for plant growth and not much re-planting is required [3].

One key economic benefit as highlighted by German professor Manfred Koehler is that 'green surfaces are less expensive than tiled roofs in the long run because they last longer'. Other than this attractive economic benefit, NParks is aware of the many other benefits (environmental, social, aesthetic and economic aspects) roof gardens have brought and thus, hopes to motivate the developers and builders to landscape Singapore's skyline [3]. Many initiatives have been undertaken to bring roof gardens to the awareness of developers and builders. The Garden City Awards, for instance, is one of NParks' effort to recognize the hard work put in by developers, landscape architects and property-managing agents in making Singapore a garden city. These awards also try to encourage developers in greening the building development.

Despite the growing interest in green roofing and the fact that Singapore does have all the materials required for green roofs, many developers are often held back from including rooftop gardens in the design brief mainly by concerns like high initial costs and structural loading capacity [3].

The objectives of this study are as follows:

- to examine the initial cost implications of having a green roof as compared to a conventional flat roof,
- to compute and compare the *life cycle costs* of roof gardens and average flat roofs,
- to incorporate economic benefits by incorporating energy costs into life cycle costs.

1.2. Costs of rooftop gardens

In Germany, an entire service industry has been formed around green roof installation, significantly reducing the first costs of a green roof. However, in local context, the same economy of scale is not enjoyed. Despite improved manufacturing and installation methods, increased first costs still limit the use of green roofs. Generally, there is a lack of understanding about direct, tangible and long-term economic benefits. The costs of green roofs therefore appear to be much higher than they actually are [4]. In considering a green roof, the cost savings it provides should be scrutinized. Also, the challenge is to look beyond the first cost comparison between conventional waterproofing and green roofs [5].

Patterson [6] mentioned that even though first costs of green roof range from three to six times the cost of a typical roofing system, in the long term, green roofs may be less expensive and outperform conventional roofing.

Babara et al. [7] also observed that a short-lived, low first-cost product is often not the cost-effective alternative. A higher first cost may be justified many times over for a durable product with minimal maintenance.

1.2.1. Economic benefits of green roofs

Green roofs provide a large range of benefits from amenity to ecological, technical advantages to financial aspects [2]. The potential benefits for the community at large are many. Roof gardens act as filters to particles, alleviating the problems of poor air quality, the quality of storm water can be improved and volumes reduced. Roof gardens also provide habitat for native plants and birds and opportunities for urban food production [8].

The most significant benefits of green roofs, such as stormwater retention and a cooler microclimate in urban areas, are hard to quantify or to put a dollar value. However, these benefits, combined with the improved roof longevity and thermal insulation of a green roof, can easily outweigh the increased first costs for most installations [5].

Patterson [6] noted that green roofs modify building behaviour as the structure is not subjected to temperature extremes. The insulation value of the soil on the structure lowers cooling costs. Heat transmitted through a barren roof would be more than a rooftop with plantings due to the additional layers of drainage, substrates and vegetation that act as insulation [9]. The California-based study by Simpson and Macpherson [10] shows that tree shades have potential to reduce annual energy use for cooling 10–50% (200–600 kWh) and peak electrical use up to 23% (0.7 kW). The results of another US-based estimate also suggest that strategic planting of lawns and other landscape plants could reduce total air conditioning energy requirements by 25% [11]. These studies clearly emphasize the important role the tree shades play in reducing the energy consumption of the building when located at close proximity.

By constructing green roofs, solar radiation, external temperature, relative humidity and winds are slowed down and reduced as they pass through the foliage that covers the roof. Furthermore, the plants can absorb large quantities of solar energy through biological functions. The remaining solar radiation that would affect the internal temperature of the building is much less than that of a bare roof. Of the total solar radiation absorbed by the planted roofs, 27% is reflected, 60% is absorbed by the plants and the soil, and 13% is transmitted into soils [12]. With a green roof, the insulation value is in *both* the plants and the layer of substrates. Even without considering the increased thickness of soil due to additional layers of soil and drainage, the plants layer can shield off as much as 87% of solar radiation while a bare roof receives 100% direct exposure. As research studies have shown, under a green roof, indoor temperatures (without cooling) were found to be at least 3–4°C lower