Renewable and Sustainable Energy Reviews 67 (2017) 1360–1368

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Green retrofitting – A review of current status, implementations and challenges

Rehmaashini Jagarajan[a], Mat Naim Abdullah Mohd Asmoni[a,*], Abdul Hakim Mohammed[a], Mohd Nadzri Jaafar[a], Janice Lee Yim Mei[a], Maizan Baba[b]

[a] Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia, UTM Johor Bahru, 81310 Johor, Malaysia
[b] Centre of Real Estate Study, Department of Real Estate, Faculty of Geoinformation and Real Estate, Universiti Technologi Malaysia, UTM Johor Bahru, 81310 Johor, Malaysia

ARTICLE INFO

Keywords:
Green retrofitting
Existing building
Research trends
Challenges
Future research

ABSTRACT

One of the largest threats to future development is climate change. Apparently, the building sector has been the largest source of greenhouse gas production. One prospective solution to this is "green building" that aims to provide environmentally sustainable building in terms of design, construction and maintenance. However, green buildings symbolize the next stage of buildings, and the recent growth of new green building constructions is inadequate to overcome the negative impact of existing buildings. One logical solution to reduce the environmental impact of the existing buildings is through green retrofitting. Yet there is lack of systematic review on the existing body of knowledge on green retrofitting which is critical for future research. This paper aims to critically review the existing literature on green retrofitting and to identify contemporary research trends. Additionally, with the view to the current challenges, barriers, obstacles or problems to green retrofitting, this study highlights the needs to identify the Critical Success Factors (CSFs) for successful implementation of green retrofit projects.

1. Introduction

The development of facilities management in Malaysia began in the late 1990s [1]. Nevertheless, according to Kamaruzzaman and Zawawi, "countries such as Australia, New Zealand, Hong Kong, Japan and Singapore have successfully develop and establish facilities management" [2]. They also added that facilities management in these nations is perceived as "effective management of buildings, services and related workforce in support of the key goals of an organization". According to Lim "numerous companies still view the provision, operation and maintenance of facilities as a technical rather than strategic function with a blurred relationship to core business objectives although the evolution of the profession has been noteworthy" [3].

Facilities management (FM) is a term that incorporates an extensive variety of exercises to ensure functionality of the built assets [4]. Previously, facilities management was mainly viewed in terms of repairs and maintenance, and therefore has poor relationship within the professions involved in the built environment [2]. Nowadays, facilities management encompasses all support services with the aims to enhance the core business of an organization [2]. According to Becker, facilities management is in charge of planning all endeavors related to arranging, outlining, and overseeing structures and their frameworks, hardware and furniture to enhance the organization's ability to fight successfully in a quickly changing world [5]. Additionally, according to Loosemore and Hsin, "facilities management is the empowering function by which an organization passes on and supports a quality working environment for its human and physical resources with the objective that supervisors can meet core business objectives" [6]. Therefore, the purpose of facilities management is to improve running expenses of buildings, as well as to raise the proficiency and sustainability of the management of space and other related resources or individuals or procedures, all together that the mission and goals of the organization may be achieved at the best mix of viability, expense and quality [4]. Different researches have defined facilities management in different perspectives.

Generally, facilities management is the most important profession in ensuring organizational effectiveness [6]. However, Loosemore and Hsin stated that, property as an element of an organization's facility can increase the worth of an organization if appropriately managed, yet it is perceived as a deteriorating physical cost burden instead of as a benefit [6]. Therefore, as emphasized by Pong, sustainability being the latest value added services in the facilities management field may

* Corresponding author.
E-mail address: matnaim@utm.my (M.N. Abdullah Mohd Asmoni).

http://dx.doi.org/10.1016/j.rser.2016.09.091
Received 2 September 2015; Received in revised form 26 August 2016; Accepted 21 September 2016

ensure proper management of property for an organization in terms of physical, functional and financial performance [7].

The advantages of sustainability and green building practices in facilities management are well entrenched, for example, decrease in energy utilization, productivity improvement and waste reduction. Numerous other advantageous impacts of sustainability can be measured and presented to an organization's leadership with a specific end goal to defend sustainable practices and their constructive outcome on the bottom line [8]. Furthermore, with buildings evaluated to represent roughly 50% of all yearly energy and greenhouse gas emissions, ensuring environmentally sustainable building in terms of design, construction and maintenance is one of the possible solutions [9,10]. Undoubtedly, executing sustainability and green building approaches to facilities will benefit an organization through returns on investment, public image, enhanced efficiency and environmental friendly [8]. There has been critical global interest and support from public and private sectors and the overall population in encouraging a environmental-friendly and sustainable, “green” and carbon-reducing buildings [11].

Sustainable or green building is defined as “one that uses a careful integrated design strategy that minimizes energy use, maximizes daylight, has a high degree of indoor air quality and thermal comfort, conserves water, reuses materials and uses materials with recycled content, minimizes site disruptions and generally provides a high degree of occupant comfort” [12]. According to Robichaud and Anantatmula, there are four pillars of green buildings, which are minimizing impact on the environment, enhancing the wellbeing states of occupants, the return on investment to developers and local community, and the lifecycle consideration during the planning and development process [13]. Additionally, Frej and Browning defined green building as “an outcome of a design which focuses on increasing the efficiency of resource use such as energy, water and materials while reducing building impact on human health and environment during the building's lifecycle, through better sitting, design, construction, operation, maintenance and removal” [14]. To conclude, the definitions of green buildings revolve around lifecycle perspective, environmental sustainability, health issues and impact on the community [15].

Existing buildings are outperformed by green buildings in terms of environmental, economic and social indicators [11], hence represent the next phase of buildings. However, the ratio of existing buildings to new green buildings is large. As a consequence, Miller and Buys added that on the off chance that the test of climate change is to be effectively addressed, the limitless load of seasoned buildings should be retrofitted [11]. Generally, existing buildings especially non-residential have been the major single source of greenhouse gas emissions [16]. According to Gohardani and Bjork, calls for sustainability and the lowering of the environmental impact from existing building stock demands for retrofitting [17]. Therefore, to realistically attain decreased building energy utilization and greenhouse gas emanations, one of the major approaches is building retrofitting [18].

The literature review led a development of a model representing the chain link of study from facilities management to sustainability to green retrofits. This links have been carefully illustrated using Curry's Onion Model (1983) shown in Fig. 1 below..

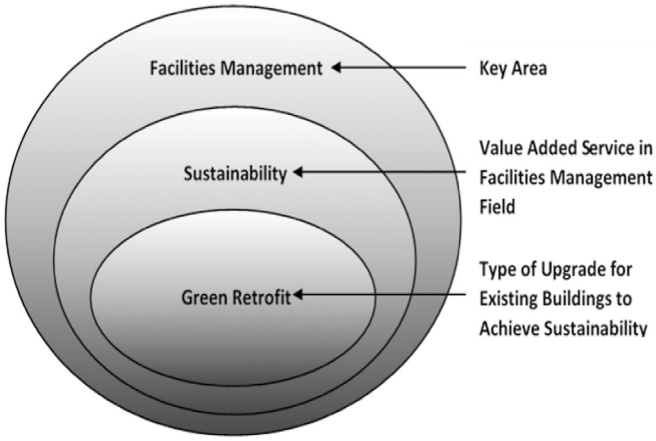

Fig. 1. Onion Model (Developed for this study).

2. Green retrofitting

Retrofitting is considered an effective strategy to enhance the sustainability of existing facilities [19]. Sanvido and Riggs have defined retrofit projects as “the modification or conversion (not a complete replacement) of an existing process, facility or structure [20]. Such modification may involve additions, deletions, rearrangements or replacements of one or more parts of the facility. Changes may alter the kind, quantity, cost or quality of the products or services being produced by the facility”. Latham viewed retrofitting as “a process that reaps the benefits of the embodied energy and quality of the original building in a dynamic and sustainable manner” [21]. According to Love and Bullen, the majority of existing buildings will still be in use for the next 50–100 years due to its long lifespan nature [19]. Therefore, Steemers points out that unless the rate of green retrofits is amplified, “building design and construction will have little responsibility in tackling global warming” [22]. The United State Green Building Council (USGBC) defined green retrofit as “any type of upgrade at an existing building that is wholly or partially occupied to improve energy and environmental performance, reduce water use, improve comfort and quality of space in terms of natural lighting, air quality and noise, all done in a way that it is financially beneficial to the owner” [23].

The past century has witnessed an ongoing argument regarding the feasibility of demolition as compared to retrofitting of existing buildings [24-27]. The method of demolition and rebuilding increases pressure on existing landfills, and therefore does not seem to make much sense [28]. Furthermore, if buildings are re-used, then less construction waste is generated and less material resources are required. According to Power, there are noteworthy environmental, social and economic benefits of retrofitting compared to demolition and rebuild [29]. The upgrading work on aged and deteriorated buildings is known as retrofitting [30]. Furthermore, Wilkinson stated that retrofit can occur to any parts of a building, for instance, to one or more levels of high rise buildings or to whole buildings [31].

According to Trusty and Meil [32], research was conducted on “comparing the environmental impacts of buildings resulting from complete demolition and subsequent construction of non-residential new buildings with existing office buildings which have undergone retrofitting process. The retrofit case was evaluated by calculating the environmental impacts that would be dodged by retaining the existing structural components and envelope systems. The comparison does not represent the effects significant from operating energy incurred over the life of the retrofitted building. The aftereffect of this correlation uncover that the measure of energy spared from retrofitting a building is near to the sum required to develop a similar size of new non-residential building and to operate it for a year” [32].

A vast extent of total energy utilized globally was contributed by the construction of buildings and their operations [33]. Existing buildings have noted to utilize more energy and yet, their replacement rate is only around 1.0–3.0% per annum [34]. In fact, the utmost potential to cut down the environmental impact within the following 20 years lies within the existing building stock [35]. Consequently, for timely reduction in worldwide energy use and for the advancement of environmental sustainability, it is crucial to rapidly improve energy effectiveness in existing buildings. An incomprehensible measure of exploration has been done to distinguish diverse energy proficiency chances to enhance energy performance of existing buildings [33]. Generally, proper retrofitting has been the major approach to reduce