



Review article

Are green buildings more satisfactory? A review of global evidence

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ARTICLE INFO

Keywords:

Green building
Occupant satisfaction
Indoor environment quality
Building design
Facilities management
Global

ABSTRACT

Green buildings not just help to reduce energy and resource consumption, but also to improve user experience and satisfaction. The former relies on technical advancement, while the latter needs empirical evidence. In the past decades, numerous post-occupancy studies have been conducted to investigate green building occupant satisfaction in different regions; however, a systematic review of these studies is lacking. This study reviews the global evidence to examine whether green buildings are more satisfactory than non-green buildings. The performance of green buildings in terms of occupant satisfaction appeared to be inconsistent, varying from study to study. The evidence on green buildings outperforming non-green counterparts is inconclusive. Sample size, occupancy period and green features are discussed as the main bias accounting for the inconsistency of the global evidence. In spite of the inconsistency and inconclusiveness, this study identifies two global contexts: the Occident (mainly U.S. and U.K.), where no significant differences were found on occupant satisfaction between green and non-green buildings, and the Orient (mainly China and South Korea), where green building occupants showed significantly higher satisfaction compared to non-green building occupants. This paper contributes to the understanding of socio-economic factors underlying green building occupant satisfaction, and also provides evidence for commercial and institutional sectors, where green buildings are used to improve employee satisfaction.

1. Introduction

Green buildings refer to a practice in the building industry that prioritises environmental responsibility and resource efficiency in a whole building life cycle (U.S. Energy Information Administration, 2003). Many green building rating tools, such as U.S. LEED, U.K. BREEAM, Australia Green Star, South Korea G-SEED, and China's GBL have been initiated to accelerate the transformation of the building sector towards an environmentally friendly model. These green tools use credit rating systems to rank green building achievements and performance (Roderick, McEwan, Wheatley, & Alonso, 2009). These tools have shown their popularity in the real estate market; however, their role in improving occupant experience in green buildings remains uncertain (Altomonte, Saadouni, & Schiavon, 2016, Gou, Prasad, & Siu-Yu Lau, 2013). For commercial organisations and institutions, employee satisfaction and experience are as important as reducing the negative impact of buildings on the environment when investing in green buildings and green certifications. However, a contradictory body of knowledge regarding the impact of green buildings on occupant satisfaction has been discussed in earlier studies as a result of varying

research methods and measures (Thatcher & Milner, 2016).

Occupant experience and satisfaction are influenced by several environmental factors such as thermal, visual, acoustics and air quality, as well as workplace features such as privacy, furniture, needs, cleanliness, and environmental controls (Altomonte & Schiavon, 2013, Geng, Ji, Lin, & Zhu, 2017). Research has shown that satisfaction with working environments increases job satisfaction and thus, elevates employee work performance and productivity (Veitch, Charles, Farley, & Newsham, 2007). Occupant satisfaction has further been correlated with turnover intentions, and retaining talented and skilled workforces (Van Dick et al., 2004). Since employee related costs account for the largest operating costs among all business expenses, including energy bills and rental cost; occupant satisfaction, thus, is of great importance for many organisations particularly in commercial and institutional office environments, to enhance overall performance and profitability. This reinforces the importance of occupant perspectives in evaluating the overall performance of green buildings.

In the past decades, numerous post-occupancy studies have been conducted to investigate green building occupant satisfaction in different regions; however, a systematic review of these studies is still

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lacking. This study conducted a systematic quantitative literature review on green building occupant satisfaction. After the green building rating tools and programmes were initiated, thousands of buildings have been certified as green. Accordingly, a number of post-occupancy studies have been conducted to collect occupant satisfaction data to testify the hypothesis that green buildings can improve occupant satisfaction. All green building rating tools share a same concept on sustainable design, construction and operation to maximize energy and resources efficiency and to improve occupant health and well-being (Gou & Xie, 2017). However, green buildings are built and used in different socio-economic contexts. This review aims to collate global evidence to verify whether green buildings can improve occupant satisfaction. The review of the global evidence would help green building researchers better understand the socio-economic difference of green building occupant satisfaction; it would also help to inform the commercial and institutional sectors of investing in green buildings to improve their employee satisfaction.

2. Method

Using the method of the systematic quantitative literature review (Pickering & Byrne, 2014), scholarly electronic databases were searched to identify original research papers published on the topic “occupant satisfaction in green and non-green buildings”. A preliminary literature search showed that the literature which addresses the green building performance is bulky and extensive. However, a limited number of papers investigated green building performance with reference to non-green buildings. Since the main objective of the study is to aggregate and review the empirical arguments about the performance of green buildings in comparison to non-green counterparts, the literature search was limited to the publications that provided an empirical evidence of comparative studies using quantitative methods. The challenge of identifying literature sources that meet the selection criterion was reduced by the assumption that the terms “occupant satisfaction”, “benchmarks”, “Green certification”, “green buildings” and “green labels” are used in the title of papers, on keyword lists, or in abstracts. As a result, these terms were used as keywords in the literature search. The document type was limited to “article”, and date range “published all years to present”. The search engine databases included Scopus, Science Direct, ProQuest, Web of Knowledge, and Google Scholar. Additional papers were identified from the reference list of the papers found through the database search.

Finally, 25 papers, listed in Table 1, were selected for the literature review since they met selection criteria by directly analysing the connection between green rating tools and occupant satisfaction using quantitative research methods. The included papers used occupant satisfaction survey tools as a research methodology. The summary of selected papers in Table 1, thereby, lists some key research characteristics and methodology specifications.

The systematic literature review revealed that LEED buildings, the green building rating tool initiated in the U.S., constituted the most studied certification programme. In terms of geographical scattering, research was conducted in a limited number of countries; namely, the U.S., the U.K., Australia, China, New Zealand, Canada, Singapore, South Africa, South Korea, and Sri Lanka. A number of green and non-green case studies were also collected from the studied papers to determine the significance of findings and the validity of generalization. Many studies focused on individual occupant responses rather than overall average scores from each building. As a result, the number of responses was another criterion used to evaluate research significance.

3. Analysis

The majority of research papers (24 out of 25 papers) have studied the relationship between green certifications and indoor environmental quality (IEQ) by investigating occupant satisfaction with factors such as

thermal comfort, air quality, lighting, and noise. In total, 18 papers considered other parameters in relation to building design and facilities management (BD&FM) such as privacy, environmental control, cleanliness, operation and maintenance, design, aesthetics, image, needs, ease of interaction with co-workers, furniture, health, and productivity.

The available survey data from the Centre of the Built Environment (CBE) at the University of Berkeley in California have been used in several studies analysing LEED buildings (Abbaszadeh, Zagreus, Lehrer, Huizenga, 2006, Altomonte & Schiavon, 2013, Huizenga et al., 2005, Lee & Kim, 2008), resulting in a large amount of data being used in these papers. Other studies on LEED buildings had relatively smaller sample sizes. In terms of thermal comfort satisfaction, most studies detected a higher performance in LEED buildings compared to conventional buildings (Brown, Cole, Robinson, Dowlatabadi, 2010, Huizenga et al., 2005, Issa, Rankin, Attalla, Christian, 2011, Kim, Hwang, Lee, Corser, 2015, Lee & Kim, 2008, Newsham et al., 2013, Thatcher & Milner, 2016, Zhang & Altan, 2011). However, two studies indicated no significant difference in the thermal performance of LEED and non-LEED buildings (Altomonte & Schiavon, 2013). Indoor air quality (IAQ) was perceived higher in LEED buildings when compared with non-green buildings in most studies (Abbaszadeh et al., 2006, Huizenga et al., 2005, Issa et al., 2011, Kim et al., 2015, Lee & Kim, 2008). In another paper (Altomonte & Schiavon, 2013), LEED buildings delivered a less satisfactory performance by showing no significant differences when compared with non-LEED buildings. The lighting and noise performance of LEED buildings showed significant inconsistency in the literature. In terms of lighting performance in LEED buildings, most papers detected no significant differences in the performance of the green and non-green buildings (Abbaszadeh et al., 2006, Altomonte & Schiavon, 2013, Huizenga et al., 2005). However, two studies indicated a higher satisfaction score (Issa et al., 2011, Kim et al., 2015), and two studies reported a lower satisfaction score in LEED buildings (Brown et al., 2010, Lee & Kim, 2008). As reflected in the literature, LEED buildings were the least successful in terms of noise performance as the majority of papers either reported no significant differences (Abbaszadeh et al., 2006, Altomonte & Schiavon, 2013, Huizenga et al., 2005), or lower satisfaction scores in LEED buildings in comparison with non-LEED buildings (Brown et al., 2010, Issa et al., 2011, Lee & Kim, 2008). One paper (Newsham et al., 2013), however, reported a higher satisfaction score in overall noise performance of LEED buildings, and indicated that noise from HVAC was perceived to be more satisfactory in LEED buildings. Open-plan settings were the main reason for the noise and privacy dissatisfaction in both green and non-green buildings. Altomonte and Schiavon (2013) indicated that LEED buildings were more successful in delivering open-plan spaces in comparison with cellular offices, and smaller buildings in comparison with larger structures. Abbaszadeh et al., 2006 emphasized the necessity for improvements in lighting controls and sound privacy through the accommodation of innovative strategies in open-plan offices in both LEED and non-LEED buildings. In terms of BD&FM, most studies reflected a higher satisfactory performance in LEED buildings (Brown et al., 2010, Kim et al., 2015, Lee & Kim, 2008, Newsham et al., 2013).

Studies focused on BREEAM (the most common certification tool in the UK), reflected an inconsistent result in analysing various IEQ and BD&FM parameters. In terms of overall thermal performance, two studies (Baird, Leaman, Thompson, 2012, Zhang & Altan, 2011) reported lower satisfaction scores, while one paper (Altomonte, Saadouni, Schiavon, 2016) showed satisfaction scores were comparable in BREEAM and non-BREEAM buildings with no significant differences. All papers studying IAQ reported lower satisfactory results in BREEAM buildings compared to their conventional counterparts (Altomonte et al., 2016, Leaman & Bordass, 2007). Lighting performance in BREEAM buildings, however, was slightly better than other IEQ parameters, as two papers detected higher (Baird et al., 2012, Zhang & Altan, 2011) and two papers reported no significant differences (Altomonte et al., 2016, Leaman & Bordass, 2007) in satisfaction

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