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Factors Hindering Green Building Performance: A Review

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Abstract

The demand for green buildings in the property market is substantially increasing. The motivation for the investment on green buildings ranges from environmental concerns and social benefits to financial savings during the operational stage. However, these perceived benefits have been argued to be mostly theoretical and yet to be empirically proven. There is often a performance gap between the expected and the actual measured performance of green buildings once operational. Green buildings simply fail to perform as to what it was intended despite the thorough design and technological considerations put at the initial stage of their development. Hence, by reviewing various literatures, this paper targets to indicate and discuss the factors that hinder green buildings from achieving their fullest performance potential. Six theoretical factors namely miscommunication, technologies used, modeling tools, construction process and handover, occupant behavior and management and control were identified from various literatures. The findings in this paper will be a commencement for further studies pertaining to non-performance of green buildings.

Keywords: Green building, performance

1.0 INTRODUCTION

There has been a drastic rise in the demand for green buildings in the past several years. Global challenges that manifest in the form of environmental crisis, life quality degradation and spiking cost of living due to increased cost of energy have led to the introduction of green buildings. Green buildings are perceived as a built environment that provide a better place for people to live and work, garner higher value and pose a lesser impact on the environment. This has encouraged architects and engineers to integrate green features in buildings to make them green. However, despite the echoing claims on the benefits and improved performance achieved in green building efforts, there have been numerous issues that pertain to the performance of green buildings. In another words, green buildings are not performing as to what they intended (De Wilde, 2014).

2.0 GREEN BUILDING

Green buildings emphasis to improve the efficacy of resources use and mitigate the negative impact on human well-being and the atmosphere through the whole life-cycle of building (GBI, 2016). The main outcomes of green structure are to minimise site disruption, reduce consumption of fossil fuel, decrease water consumption, and lessen the emission of pollutants and building wastes (Mohanty, 2011).

Green buildings help to reduce the devastation of land, habitat and space and the urban sprawl which will lead to inefficient low density development. This helps to preserve land by evaluating the design of each site and the construction process to minimise site disturbance (FEMP, 2003). Green features in green buildings such as natural water is recycled by using storm water, on-site penetration and ground water. This is to minimise unnecessary wastage of water in green buildings (GBI, 2016).

Energy efficiency is one of the main aims of green buildings to achieve sustainability (GBI, 2016). By optimising the building design, material selection and use of energy can reduce the adverse impacts on the environment. Solar photovoltaic, external shading devices, building orientation, shape, design and interior colors and finishes, lighting controls, air ventilation and air conditioning (HVAC) are integrated in green structures to maximise energy conservation. Green buildings also emphasis on occupants health, comfort and productivity in indoor environment (GBI, 2016). This is to create a pleasant environment which offers the best condition in terms of indoor air quality, air ventilation, thermal comfort, natural ventilation, day lighting, and acoustical environment.

3.0 THE NEED FOR GREEN BUILDINGS

Green buildings can reduce energy use in buildings. According to previous studies, buildings average use up to forty percent of energy (Schneider Electric & O' Mara, 2012). With the high demand for energy, there is a compelling reason to invest in green buildings. The

energy demand is growing tremendously and the amount of carbon gas emissions is increasing causing severe climate change that will affect everyone.

Green buildings assure business to success because buildings become more practical and profitable (FEMP, 2003; UGBC, 2013). The occupier of green buildings foresee palpable economic advantages such as better rental value stock prices and property value and reduce operating cost. This could increase competitive edge, return on investment and increase the net operating income of the building.

A good working environment in green buildings has great influence to occupants' productivity because it provides a better environment to the occupants (FEMP, 2003; UGBC, 2013). These help to attract and retain occupants in green buildings and resulted low level of sickness, absence and employee turnover. Green buildings also reduce fungus and health issues (FEMP, 2003) by controlling the moisture, apply pollution and contamination rejection strategies and improve ventilation.

4.0 GREEN BUILDING PERFORMANCE ISSUES

Green buildings are expected to perform better compared to non-green buildings. However, this is not happening in real life. Green buildings are not performed as intended (Bordass *et al.*, 2004; Bordass *et al.*, 2011; Demanuele *et al.*, 2010; PROBE, 2011).

The discrepancy between expected and actual performance of green buildings have been very common nowadays and caused a major concern within the building industry. The enormous challenges of environmental issues, the rising energy prices, human health and ecosystems preservation has increased the pressure in building industry to realize the importance to address this so called 'the performance gap' faced by designers and builders to meet clients' expectation on the stringent green building efficiency targets (De Wilde, 2014). It is reasonable for small variation for both predicted and actual performance due to uncertainties and data scatter, but this discrepancy seems evident to be too wide to accept.

A major source of contention within the construction industry is whether green buildings are actually outperforming non-green buildings (De Wilde, 2014). According to green buildings council, green buildings perform better than non-green buildings in a number of areas. These areas are energy, water, waste and occupant health. It is claimed that green buildings can save more energy compare to non-green buildings (FEMP, 2003; UGBC, 2013). Most of the green buildings are awarded energy points based on the predicted performance but not actual performance. This is first calculating the energy use of the green buildings during design stage. Then, the calculation will rerun using various energy saving strategies and points are awarded based on the degree of improvement.

It is also claimed that green buildings can save more of water compare to non-green buildings (FEMP, 2003; UGBC, 2013). However, assumptions are made for calculation purposes. These assumptions include the number of times per day that a toilet or a urinal will be flushed, the number of times a faucet will be used and etc (De Wilde, 2014).Then, the water use data will be inputted into the calculator and the total assumption of water consumption quantity is estimated (De Wilde, 2014).Similarly, it is claimed that green buildings help in saving waste cost. This is unreliable because the assumption is made based on the quantity of waste that would result from non-green buildings. Client will not be able to assess the value because the number is not known beforehand.

Factors to Performance Gap in Green Buildings

Despite the various considerations given by the architects and engineers during the design and construction phase, there are various factors that have been linked to the non-performance of green buildings. Identifying the factors can provide a great input to deliver high performance green buildings. This also helps to develop a solution to the problem of underperformance. There are three stages of factors which cause to non-performance of green buildings accordingly. The stages are shown in table 1 below. This paper only presents the factors to performance gap in green building which identify from literature review. However, the identified factors are merely theoretical factors. It will be worthwhile for the better quality of green building development if the factors undergo a survey and analysis to determine the validity of factors as well as identify the significant of each of the factors in the short coming of green building development.

Table 1 Factors to non-performance green building

Stages	Factors to non-performance green building
First stage: Design stage	(a) Miscommunication (b) Technologies used (c) Modeling tools
Second stage: Construction stage	(a) Construction process and handover
Third stage: Operational stage	(a) Occupant Behaviour (b) Management and controls

Table 1 shows that there are three stages involve in building construction which are design stage (De Wilde, 2014; Demanuele *et al.*, 2010), construction stage (Dasgupta *et al.*, 2012; De Wilde, 2014) and operational stage (De Wilde, 2014; UGBC, 2013). In these stages, design stage is the initial phases that cause to non-performance of green buildings because the construction of building always starts with design stage.

In design stage, miscommunication between clients and designers on the future performance targets is the first factor of non-performance of green buildings (Carbon Trust, 2011; De Wilde, 2014; Morant. 2012). The designers often fail to predict the future functions and the operational requirements of green buildings. This tends to cause the performance of green buildings subject to change (Dasgupta *et al.*, 2012; Korjenic & Bednar, 2012; Menezes *et al.*, 2012; Morant. 2012; Newsham *et al.*, 2009). The data input in green building model is based on

assumption. This assumption is typically executed during design stage. Sometime, many aspects of the green buildings functions and uses are unknown or uncertain. The designers may have to rely on their experience, guidelines taken from design standards to make considerable assumptions and approximations. This can lead to oversimplified or impractical inputs in green buildings model (De Wilde, 2014).

The second factors in design stage that cause to non-performance green buildings is technologies used (De Wilde, 2014). High technologies buildings that aim to be more efficient 'green' tend to have issues as well. The equipment simply not perform as well as specified by manufacturer (Turner & Frankel, 2008; Newsham *et al.,* 2009). Advanced and novel system might be a problem for users to use because energy saving system appears to be complicated and difficult to control (Zero Carbon Hub, 2010). For instance, many of energy saving equipment in green buildings are complex and difficult to control. Most of this equipment is dependent on software to keep pace with changes to the environment, thus adding to more complex.

The third factor for the performance gap in the design stage is modeling and simulation (De Wilde, 2014). Modeling is important to help the architects and engineers to predict the actual outcome for green buildings. By using these models, the architects and engineers will know to make more informed decision. This will be a guideline for them to design a green building.

Unreliable predictions and gaps for green buildings occur when the use of tools and component models are incorrectly used (Carbon Trust, 2011; Menezes *et al.,* 2012; Morant. 2012). Green buildings modeling software can contain error, causing the predictions are not accurate. This can be evaded by selecting appropriate verified modeling tools. The choice of software should be considered based on the type of building, usage and operation so that the model is representing the reality. Using the correct tools alone is not enough, the modelers need to have the right knowledge, skills and ability to apply in a right manner (Dwyer, 2013). This includes a clear understanding on models and methods, as well as the right input of data.

In the second stage, construction stage is one of the causes to non-performance green buildings. The first factor for the performance gap during the construction stage is the green buildings construction process and the handover to the client. Overall, the industry of culture in construction is hard to change. The traditional processes are tough to change where there are often issues with quality, integrity, and responsibility (Tofield, 2012; National Measurement Network, 2012; Zero Carbon Hub, 2010).Various scholars point out that the quality of green buildings are vary from specification especially on insulation and air tightness (Menezes *et al.,* 2012; Newsham *et al.,* 2009; Morant, 2012). Details for contractors are less specified, increasing the potential risks to create high thermal green building or leading to unexpected additional material used in green building walls can alter the performance.

In the third stage, building operational stage is one of the causes to non-performance green buildings. In third stage, occupant behavior is the main factor that cause to non-performance green buildings. Occupants have a main impact on green buildings performance because occupants have direct control over green buildings such as equipment and electric appliances. The assumption on occupant behavior is always difficult and results dissimilar during the design stage of green buildings (Korjenic & Bednar, 2012; Menezes *et al.,* 2012; Haldi & Robinson, 2008; Carbon Buzz, 2013; Newsham *et al.,* 2009). The assumption on occupant behavior is often lead to disparity between input for calculations or simulations, actual values for internal gain (Molin *et al.,* 2011; Haldi & Robinson, 2008) and plug loads (Morant, 2012). High technological can also cause a discrepancy due to high loads usage for IT related equipment (Dasgupta *et al.,* 2012). The actual operation of green buildings are usually different compare to the assumption during the design stage due to the actual control settings on building as well as the facilities management on building (Carbon Trust, 2011; Menezes *et al.,* 2012; Demanuele *et al.,* 2010; Newsham *et al.,* 2009; Thompson *et al.,* 2012)

The second factors cause to non-performance of green buildings in building operational stage is the management and control of a building. Good management and control on green buildings result good operation and building services and this can reduce unnecessary wastage (i.e. energy, water) (Menezes *et al.,* 2012). Facility managers are responsible to control the overall performance of green buildings. However, the lack of performance measurement and management routine result poor building performance. This helps to improve the efficacy of green building facilities and evading redundant wastage (Bunn & Way, 2010; Menezes *et al.,* 2012). Figure 1 shows the factors hindering green building performance in relation to the three stages of construction.

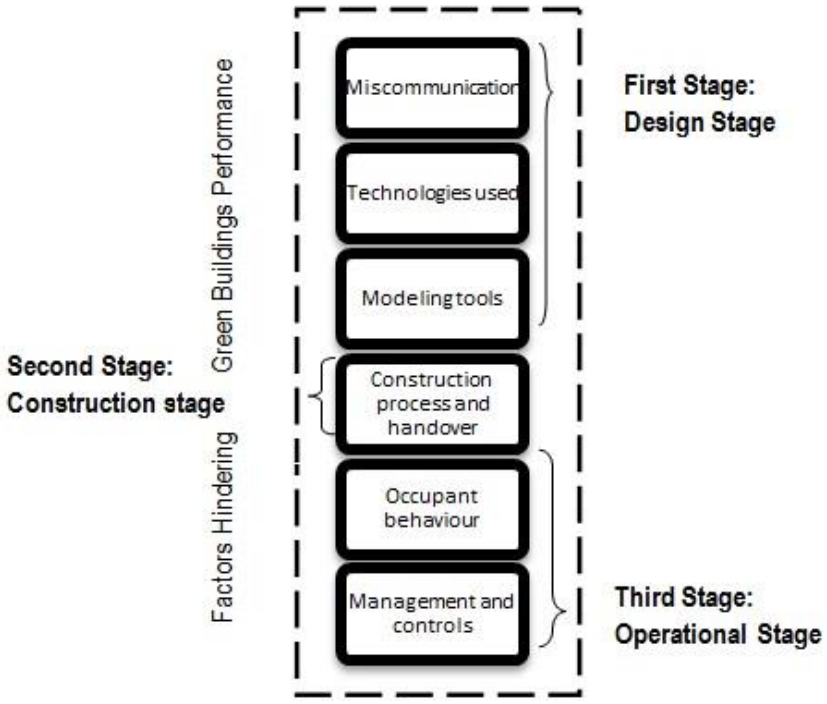

Figure 1 Factors hindering green building performance

5.0 CONCLUSION

This paper has discussed the factors that hinder green buildings from achieving its fullest performance potential based on literature review. Six factors namely miscommunication, technologies used, modeling tools, construction process and handover, occupant behavior and management and control were identified from various literatures. Bridging the performance gap in green buildings is very important. In order to improve the performance, more outreach program such as seminar or workshop should be reached out to the developers to improve their understanding and knowledge on green building. The lack of knowledge could lead the consultants fail to design a good and performing green building. Green building should also do with legislation action as well. The government should produce a policy or a guided principle on green buildings operation and maintenance. The current policy on green buildings has been brought forward by green building rating tools. Green buildings that adhere to the requirements of green design and green construction are recognized and certified by green building rating tools as green buildings. This however is insufficient and the requirements for future green buildings will inevitably include green operations and maintenance. As most of a building's life encompasses its operation and maintenance phase, there is an indeed an urgency for green policies to cover the operation and maintenance phase of green buildings.

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