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Building performance modelling for sustainable building design

Olufolahan Oduyemi [a], Michael Okoroh [b,*]

[a] College of Engineering and Technology, University of Derby, DE22 3AW, United Kingdom
[b] Al Imam Mohammad Ibn Saud Islamic University, Riyadh, Saudi Arabia

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Abstract

Sustainability has become a significant aspect of real estate and has been integrated into the design, construction and operation of buildings. Now, emerging from the various initiatives around the world, the building information modelling (BIM) approach has been seen as a method that might deliver substantial gains in terms of designing and assessing the environmental cost of buildings.

Various research methodologies have been adopted, including a literature review exploring the benefits and challenges of BIM and of using a building performance modelling software (BPM) called Ecotect for sustainable building design. Finally, it introduces a design tool analysis of a case study using Ecotect to evaluate various what if scenarios on a proposed multi-use building.

The output revealed that BPM delivers information needed for enhanced design and building performance. Recommendations such as the establishment of proper mechanisms to monitor the performance of BPM related construction are suggested to allow for its continuous implementation. This research consolidates collective movements towards wider implementation of BPM and forms a base for developing a sound BIM strategy and guidance.

Keywords: Building information modelling; Building performance modelling; Construction; Ecotect; Sustainability

1. Introduction

Recently, there has been a drive to discover how climate change and greenhouse gas emissions can be reduced (United Nations, 2007). Hence, the need for sustainable buildings as it is believed that buildings account for more than half of energy consumption and emissions (Berardi, 2013). Luckily, recent research has also supported the existence of a robust business case for sustainable buildings (Walker, 2015; Davies, 2005).

Existing methods such as the life cycle assessment (LCA) and life cycle costing (LCC) have been used to determine the environmental and economic costs of these buildings throughout its entire service life including the disposal cost (Dhillon, 2013; El-Haram et al., 2002). However, where LCA and LCC are performed and used together, by the same persons, using the same software, with the same databases, and in an integrated way, inconsistencies between the two underlying tools will provide a barrier in terms of efficiency, reproducibility and transparency.

Hence the need has arisen to embrace the building information modelling (BIM) method as it covers the architecture, information technology and construction. BIM is a set of interrelating strategies, procedures and skills that cre-

* Corresponding author. Tel.: +966 502382833.
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ates a framework to monitor the vital building design and display data in digital layout throughout the building's lifecycle (Penttilä, 2006).

Thus, it's relevance among all built environment professionals as it has turned out to be a dynamic research area of sustainable building design. Similarly, building simulation is gaining extensive use as a cost-effective technique of supporting energy efficient design and the subsequent operation and maintenance of buildings (Wang et al., 2015; Bryde et al., 2013). These simulations include the assessment of the performance of energy-saving methods and architectural concepts (Monteiro and Martins, 2013).

While there has been significant progress on the application of BIM in sustainable building design as seen in Smith (2007), most research work has also emphasised on the analysis of energy usage as seen in Niewoehner (2010). Similar work showed how BIM could be used to promote sustainable building design with particular emphasis on the mechanical and electrical sections of buildings (Middlebrooks, 2008) and also the contribution of solar analysis to energy saving (Wong and Fan, 2013).

Further research work considered the thermal analysis of a building block containing phase change material (Alawadhi, 2008), the finite-volume thermal analysis of building roofs under two dimensional periodic conditions (Al-Sanea, 2003) and thermal analysis and design of passive solar buildings (Athienitis and Santamouris, 2013).

However, no research work has introduced BPM enabled sustainable design with emphasis on thermal analysis of a simulated conference hall which incorporates various indices of sustainability by exploring several what if scenarios to determine which design parameters/configurations can be combined to achieve a low energy and self-sustaining building.

This paper discusses BIM and Ecotect's benefits and challenges and provides recommendations on how to apply BPM to sustainable building design. This would allow researchers to be more confident in demonstrating the relevance of sustainable design analysis tools in meriting sustainable design criteria.

2. Research methodology

This research begins with a review of the literature on BIM and sustainable design. It also investigates the challenges of BIM and the limitations of Ecotect in sustainable design and then proceeds to conduct a design tool analysis of a simulated case study.

Building performance modelling (BPM) is the use of software to predict the energy use of a building (Volk et al., 2014). It is the attempt to model the various energy and mass flows within a building in order to forecast one or several performance aspects of a building using computer simulations (Arup, 2013; Tao and Tam, 2013).

The models provide a simplified illustration of the features of our environment in order to use performance to inform design. The initial sketch of the model applied was experimented using sensitivity analysis in order to achieve a sustainable design alternative at the design sketch stage when the cost of change to project is at the least.

3. BIM in sustainable design

BIM has deservedly received so much attention in recent years and is very useful in performing sustainable building designs (Wang et al., 2015). BIM provides important data and information for design projects and also encompasses several important functions for building performance analysis. Consequently, studies around sustainable building design have become more methodical in nature (Liu et al., 2015).

With the help of BIM, designers can foresee and envisage the likely errors in design and subsequently adjust the designs early in order to reduce the possibility of project failure. Consequently, BIM has become a common tool used for sustainable building design. It simulates building projects in the virtually visible environment and incorporates all associated information include geometry, spatial relationships, geographic information, and quantities and properties of building elements (Hoes et al., 2009). It provides an ability to do the simulation for validating the performance of design projects and enables designers to improve their designs and select the optimal one.

4. Challenges of BIM application in sustainable design

The use of BIM in sustainable design requires significant training and as with many software programmes, there are huge costs associated with purchasing, licensing and training (Bynum et al., 2012). A contractor may need to upgrade its computer system to effectively use the BIM software. Adequate training is needed in different areas, and levels of expertise can vary (Wang et al., 2015).

Furthermore, BIM requires more effort at the outset of a sustainable design project (McAdam, 2010). When BIM is used, it is insufficient for a contractor to simply submit plans for its own work and then begin construction. The contractor must first sit down with the designer and other contractors associated with the project to create a collaborative model (Sawhney and Singhal, 2013).

Although one of the advantages of using a BIM model is that changes can be made quickly, BIM can disrupt the general procurement and construction process when ordering items that require a long lead time (Manning and Messner, 2008).

5. Design tool analysis

The following steps are used in this paper to develop a BIM enabled sustainable design conceptual framework with emphasis on thermal analysis.

(i) Site description.
(ii) The building.

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