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Green hospital design: integrating quality function deployment and end-user demands

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ABSTRACT

There is a rapidly growing awareness amongst the public of facilities where the design incorporates green construction principles. This paper aims to study the quality function deployment (QFD) concept and technique when implemented in the construction industry with a particular focus on supporting green hospital design by identifying the end-user factors (concerns) that affect the design. This research develops QFD tools for green hospital designs known as the House of Quality Green Design (HOQGD). Data were collected using a questionnaire survey distributed to public and private hospital end-users in Klang Valley, Malaysia. Findings revealed that end-users perceived "safety mechanisms during emergency" as being of the utmost importance and also the feature they were most satisfied with. The other demanded qualities were at an average degree of satisfaction; however, the end-users considered that green hospital design must make efforts to maximize the use of natural light and ventilation while considering the building orientation; materials should be free from toxicity and be environmentally friendly; the landscape should be strategically designed and the facilities should increase the sense of a healing environment, and water efficient equipment should be installed. Accordingly, these were prioritized and incorporated in the developed HOQGD to inform green hospital design for both public and private facilities.

1. Introduction

Among the many studies on green design and construction, little attention has been paid to the systemic incorporation of end-user demands. It is recognized that sustainability and green building commitment improves financial performance, competitive positioning, and market differentiation and is therefore emerging as an important competitive tool for construction companies (Han and Shin, 2014). However, little research has been conducted on how hospitals' end-users – both the staff that work there and the visiting public – perceive green hospital designs. While financial and competitive positioning for construction firms is important, care must also be taken to ensure the long-term success of such projects by ensuring that other, less tangible, success factors are also considered; this can be accomplished by examining and incorporating user perceptions into the final design. Green building principles are redefining and revolutionizing building practices and are emerging as a response to growing societal concern over pollution and environmental damage, increasing awareness and acceptance of climate change, decreasing natural resources, increasing energy cost, and increasing demand for sustainability in building design and construction (Aliagha et al., 2013).

Green rating tools for evaluating and measuring the environmental performance of a building have been gaining global popularity. Consequently, a plethora of green rating systems with different rating criteria have emerged with the commonly applied systems including the US Leadership in Energy and Environmental Design (LEED), the UK Building Research Establishment Environmental Assessment Method (BREEAM), Singapore's BCA Green Mark, and Australia's NABERS rating system. The Malaysian rating system, the Green Building Index (GBI), was developed jointly by the Association of Consulting Engineers Malaysia (ACEM) and the

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Malaysian Institute of Architects. The objective of GBI is to save energy and resources, recycle materials, and adapt buildings to the Malaysia climate, culture, and environment. Such contemporary approaches encourage environmentally responsible and resource-efficient decisions by accounting for requirements throughout a building's life-cycle; i.e., considering the entire cycle from design through to construction, operation, maintenance, renovation, and demolition (Liu and London, 2013). In recent years, there has been an emerging subset of green design that has been revolutionizing hospital design by employing sustainable technologies, energy saving systems, and recyclable or renewable resources and materials (Gudiene et al., 2013). Green hospital design aspires to provide users with energy savings and a comfortable environment through innovative designs and green techniques. With many green design elements already specified during the design phase and coming from external sources (e.g., funding agencies), the overall perception of the facility's users must also be accounted for; the impact of green design on the users of the facilities has been under-researched.

This research is important, as while many building design elements might contribute to the reduced operating expenses of the facility (McGraw-Hill Construction, 2008), we have less awareness of the relative importance of each to facilities end-users. The application of life-cycle analysis (LCA) or life-cycle costing has enabled evaluation of costs (Woodward, 1997; Wübbenhorst, 1986), energy use (Ramesh et al., 2010), or other environmental impact factors (an overview is provided by Ortiz et al. (2009)). In contrast to LCA, our focus is not on the analysis of costs or environmental impact, but rather the perceptions of the end-users regarding the sustainability initiatives embodied in the project, so that these can inform the technical specifications of future projects to meet user requirements. Within hospitals and healthcare facilities, the impact of the environment on users is more important than in offices or other commercial environments, because of the intention to create a place of healing and recovery (Gross et al., 1998). Therefore, we require a greater understanding of end-user concerns relating to design elements in green hospitals as this provides an important input into future green hospital design processes.

This paper aims to identify the factors that can affect the end-users' perception of quality of green hospital design, rather than a life-cycle analysis of the environmental impact. We address the need for, and inclusion of, the end-user preferences into the design principles through the use of quality function deployment (QFD). In doing this, the contribution of this paper is an analysis of the end-user preferences in green hospital design and how these are prioritized and incorporated into the existing green-design based literature. Given that QFD is a well-applied technique in product design (Zaim et al., 2014; Moldovan, 2014), this study uses QFD to identify the factors (customer concerns) that affect the quality of green hospital design and to develop a QFD tool that will inform future green hospital designs (HOQGD). This paper determines the suitability and practicability the concept and application of QFD in green construction and also connects this with factors that may help broaden the application of the model into different settings. By identifying relevant criteria and characteristics of green hospital design, the HOQGD model is developed to emphasize and support green design and provide integration of customer preferences, knowledge, and information. Using the HOQGD platform, design experts can design and construct green buildings based on the green design-related information that is integrated and analyzed in the HOQGD.

The next section provides an overview of the green design principles and key considerations, followed by an overview of QFD. This provides background on crucial elements that will need to be considered and how the research instruments were derived from the literature. Section three addresses the methodology and the research sample. Section four presents the results in relation to both public and private hospitals. Section five discusses application of the QFD design principles in hospital design. The final section summarizes the article and discusses the implications of these results.

2. Quality function deployment (QFD) and green building design

As green design becomes increasingly important in the marketplace it will become embedded in design processes. While there is a long history in product design of including a range of different preferences during the design process, less has been done to include green design preferences in construction. QFD is a key tool that may support this inclusion of green principles in construction.

2.1. Green building design

While there are many green design principles, the core concepts often focus on the production and use of energy, water resources, the use of solar energy to improve electricity generation and reduce use of electricity, improved aeration, climatic features, and the long-term impact building materials the consideration of the life-cycle of the facility. Green building techniques were developed during the world's energy crisis in 1970's and have been used since (Mao et al., 2011). There is wide recognition that green design can bring financial benefits during both the construction and operational phases. Green building strategies reduce buildings' operating costs by 8–9 percent, increase building value by 7.5 percent, realize a 6.6 percent return on investment, increase occupancy ratio by 3.5 percent, and increase rent ratios by 3 percent (McGraw-Hill Construction, 2008).

The Construction Industry Development Board of Malaysia (CIDB), which monitors national construction activities, found that environmental and other sustainability issues were among the top issues facing the construction industry (Construction Industry Development Board, 2000). While it is vital for green buildings to provide a satisfying environment, they must also achieve economic efficiency by minimizing redesign and rework. Economic efficiency can be ensured through evaluation of inputs into the construction industry, including labor (Abdul-Rahman et al., 2012), and by managing the design process carefully. In addition to receiving greater support from stakeholders, the ongoing impact of green design should be reflected through reduced operating expenses; e.g., the Malaysian Health Minister noted that public hospitals would turn to green technology to reduce their electricity bills (Morden, 2011).

Integration of green design into healthcare buildings must meet rigidly defined quality levels to ensure that patients are comfortable and are treated with appropriate care. Green design emphasizes a number of features (Fik, 2005; Huff, 2009): reducing energy use; improving aeration; using passive solar heating and cooling; considering the life-cycle impact of building materials; improving water-use, -capture, and -recycling; and the integration of climatic- and site-features (Ismail, 2013).

Reducing energy use is a key focus for green designers, especially when considering ventilation and lighting. Maximizing the use of natural lighting during the day can reduce energy costs and improve the atmosphere for buildings' users. The importance of access to natural light and the impact this has on buildings' users has been established, including the way it can significantly change behaviors; e.g., use of natural lighting improves sales volume at retail outlets versus artificial light (Heschong et al., 2002). Green design facilitates

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