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An empirical study of the variables affecting site planning and design in green buildings

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ABSTRACT

Site planning and design (SPD) is a key issue for site sustainability in green building development. This research study explores participants' perception of SPD in green buildings. A questionnaire survey was conducted to investigate how the participants rated the importance and difficulty of SPD-related variables and items. The Kendall concordance test and Mann–Whitney *U* test were used to analyse and compare the responses of participants involved directly and indirectly in SPD, where the participants were divided into Group 1 and Group 2 respectively. The results showed a good consensus between the rankings provided by the two groups. The Relative Importance Index was used to calculate the scores and rankings. The top 5 most important variables and the most difficult ones to realize, and the top 5 most important items and the most difficult ones to realize, were identified and analysed respectively. Environmental protection was regarded as the most important variable, and open space was considered as the most difficult one to achieve. The most important item was water pollution reduction, and the most difficult one was rational underground space utilisation. When considering the correlation between the importance and difficulty of the items and variables, the participants show different concerns on the most important and most difficult items while hold similar opinions on the most important and most difficult variables. The findings deepen the understanding of variables which are most important and which are most difficult to achieve in the SPD of green buildings, which helps the practitioners to implement effective SPD in green buildings.

1. Introduction

Sustainable development is commonly defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland, 1987). Green construction is regarded as the implementation of sustainable design (Montoya, 2010). The design and construction of green buildings are based on the principles of sustainable development to conserve resources and energy, recycle materials and minimise emissions from the buildings throughout their life cycle. The location of a project is the foundation of its sustainability. Therefore, site planners must consider how to minimise the disturbance to the construction site. Site planning and design (SPD), i.e. the process of bringing a vision to implementation, is a key issue in the initial stage of construction projects. SPD is a multi-phase activity conducted by qualified professionals to ensure that the site is used in ways that are functionally efficient, aesthetically pleasing and environmentally sustainable (LaGro, 2011).

A number of green building rating tools have been developed to assist green development. BREEAM (Building Research Establishment's Environmental Assessment Method), launched in 1990, was the world's first green building rating system. LEED (Leadership in Energy and Environmental Design), issued in 1998 by the U.S. Green Building Council, is currently considered among the most comprehensive and influential green building rating systems. China, which now has the largest construction market in the world, established ESGB (Evaluation Standard for Green Building) in 2006. In the context of SPD, various relevant issues are considered in these green building rating tools. According to Huo et al. (2017), the average percentage of SPD-related items in major green building rating tools around the world is about 20%. Relevant items are distributed among various sections, including 'land use', 'location and transportation', 'environmental protection', and 'energy saving

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and energy utilisation', which indicates the importance of SPD in green building development.

In previous studies, researchers have explored SPD from different perspectives and at different stages, including site selection, site analysis and site layout planning. Researchers have also investigated several green strategies on site in construction projects such as brownfield redevelopment, storm water management and urban heat island reduction, in addition to a number of studies focusing on site layout planning and optimisation (Wedding and Crawford-Brown, 2007; Cook, 2007; Guillette, 2010; Hammad et al., 2015). However, few studies have investigated the behaviours of participants in green building projects and their perception of the variables of SPD. To fill this research gap, this study identifies a comprehensive list of variables and items in SPD of green buildings based on five well-known green building rating tools, including BREEAM, LEED, Building Environmental Assessment Method (BEAM), Green Mark (GM) and the Assessment Standard for Green Building (ASGB), and investigates how participants understand these variables and items. The findings of this study not only make contribution to the existing research on green buildings by deepening the understanding on the most important and most difficult variables and items in SPD of green buildings, but also encourage practitioners in construction industry to conduct more effective SPD in green building development and shape a sustainable built environment.

2. Literature review

The SPD stage is a key process for planners and designers to reorganize the site layout, to re-locate facilities, materials warehouses, car parking space, and offices in the project site. In sustainable site design, on-site information is gathered, investigated, and composited in a creative and analytical way, leading to the connection of natural environment and building systems in a mutually beneficial way. (Venhaus, 2012). Ozdemir (2008) illustrated that in the early stages of on-site development, sustainable site design is helpful in dealing with natural disaster risks for planners, designers and policy makers. That study identified a number of principles and approaches in sustainable site design: assessing site resources in site selection, blending with the existing topography, defining the existing vegetation use, designing planting for site protection and engineering, understanding the topographic conditions of the site, minimising disruption to landforms and drainage patterns and minimising the paved area. Calkins (2011) argued that sustainable sites in cities play important roles in providing ecosystem services and habitat, forming productive workplaces and sustaining cultural connections with nature.

A site exists as part of a larger landscape and ecosystem, and sustainable site design must include broad considerations of the environmental role of the site as well as the programme or intention of the project. To form a sustainable site requires comprehensive and ecologically based strategies which help to reserve and repair existing site systems instead of altering and damage them (Ozdemir, 2008; Russ, 2009). Sustainable and context-sensitive site planning requires a thorough understanding of the site's suitability for the proposed programme. This analytical and creative process often begins with site selection and programming (LaGro, 2011). Wang et al. (2014) developed a framework of variables affecting the decision-making process for sustainable land use planning in urban renewal projects. They compared variables that were abstracted from a literature review with those found in practical case studies. The results showed that a number of variables relevant to sustainable site planning had not yet been put into practice, including environmental indicators (such as air and water quality), social and cultural concerns (such as community identity, accessibility of service facilities and landscape uniqueness) and physical constraints (such as slope gradient and relative elevation).

To create an environmentally friendly worksite and protect the habitat and environment around buildings, some researchers have focused on site-related green construction. To reduce the generation of waste on site, Jaques (2000) concluded that 'attention at design stage' can be effective, as well as 'fully complete drawings' and 'modular construction'. 'Smart design' and 'total design involvement' are the most favoured methods to reduce material waste. Gwaze and Woolliams (2001) proposed a number of planning, design and construction strategies in green buildings, including green strategies for site design. Important priorities of green site design strategies include biodiversity, water use reduction, urban heat island reduction and provision of multiple transport modes. According to Montoya (2010), in site layout and land use, green construction should aim to minimise on-site disturbance, heat island effects and construction waste from buildings and sites. Sillah (2011) pointed out that important considerations in the selection of new construction sites include the provision of adequate and renewable water resource, and the access to renewable energy such as solar energy, wind energy, and geothermal energy. Gonzales and Romero (2014) found that good site planning was an important component of a building's relationship with the community, and that desirable aspects included socio-cultural variables such as a sense of community and the need for and access to open spaces and outdoor activities. Wedding and Crawford-Brown, 2007 assessed the performance of brownfield redevelopment at the site level with respect to sustainable development and green buildings. Cook (2007) proposed various strategies for storm water management in green site design, including 'green roof', 'green parking', permeable paving and alternative paving systems. Low impact development (LID) is a sustainable storm water management strategy to prevent degradation of groundwater quality, manage storm water more efficiently and protect drinking water supplies. LID has proven to be a dynamic and adaptable strategy to minimise operational and maintenance costs and improve the marketability of projects. The current challenge for LID is how to implement the underlying technologies in novel configurations (Guillette, 2010).

Construction site layout planning is a decision-making process that involves the identification of problems and opportunities, development of solutions, and selection and implementation of optimal options (Ning et al., 2011). To optimise the construction site layout requires balancing conflicting objectives, i.e., maximising construction safety while minimising the cost of material transport, and satisfying all practical layout constraints (Mawdesley et al., 2002). Considering the importance of construction safety, El-Rayes and Khalafallah (2005) developed a robust site layout planning model to provide optimal trade-offs between construction safety and the cost of resource transport on site, while meeting all practical constraints on the construction issues. Hammad et al. (2015) presented an estimation framework in which the travel frequency parameter can be estimated based on the information provided by building information models and project schedules. The estimated frequencies can be used as parameters in optimisation models for site layout planning.

This section summarises the existing literature relevant to SPD in green buildings. The importance of SPD is emphasised, and several SPD issues relevant to green buildings explored, such as brownfield redevelopment, low-impact development and storm water management. In addition, it is shown that increasing attention has been paid to site layout planning and optimisation. However, previous analyses of SPD issues in this context remain incomplete. Therefore, in the present study, a comprehensive and