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A review of interdependence of sustainable building

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ABSTRACT

Despite the worldwide promotion of the sustainable building (SB) approach, its associated interdependence has seldom been explored. This knowledge gap is significant given the paradigm shift of regarding SBs as complex socio-technical systems embedded with multifaceted interdependence. The aim of this paper is to examine the interdependence of SB through a literature review. The literature review was guided by a framework comprising three dimensions of SB systems, i.e., building performance, methodology and stakeholders, on their theoretical grounds ranged from reductionism to holism. In order to articulate the integration of the three dimensions, this paper examined zero carbon building as a specific case of SB. The findings contribute an innovative approach to examining the interdependence of SB, and should guide the development of strategies for managing the trade-offs in delivering SBs.

Contents

1. Introduction

According to the United Nations Environment Programme (UNEP, 2012), the building and construction sector directly employs over 111 million people worldwide, and contributes to global environmental issues such as 20% of water use, 25–40% of energy use, 30–40% of solid waste generation and 30–40% of global greenhouse gas emissions. Sustainable building (SB) has been promoted worldwide as an effective approach to reducing the impact of building and construction on human health and the environment. However, there exists no common definition of sustainable building, and this approach has been adopted in

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many cases without explicit explanation. Some researchers (e.g. Häkkinen and Belloni, 2011) acknowledged the description provided by ISO (2008:7) that "sustainable development of buildings and other construction works brings about the required performance and functionality with minimum adverse environmental impact, while encouraging improvements in economic and social (and cultural) aspects at local, regional and global levels". This description implies the systems consideration of environmental, social and economic (ESE) aspects of SB.

However, this systems thinking, especially the interdependence of SB, has seldom been explored in the assessment exercise (Morrison-Saunders and Pope, 2013). This knowledge gap is critical, as SBs are being increasingly understood as complex systems (see Li and Yao, 2012; Summerfield and Lowe, 2012). The present paper argues for a systems approach to examining the interdependence of sustainable building. Guided by a framework which synthesizes three dimensions, namely, SB performance, methodology and stakeholder, this paper examines the interdependence that exists in each dimension through a literature review.

2. A conceptual framework of examining interdependence of sustainable building

The literature review of this paper was guided by a framework presented by Pan and Ning (2014, 2015) (see Fig. 1). The interdependence presented in this framework exists in three dimensions, namely the building performance, methodology and stakeholder on their theoretical grounds ranged from reductionism to holism. Interdependence may exist in any single dimension and/or sub-aspect, and/or in the integration of them.

- In relation to the area 'building performance', the reductionism approach examines one aspect of ESE or one element of a single aspect, e.g. carbon or energy, whereas the holism approach focuses on the interdependence among the ESE aspects as a whole.
- The methodological perspective comprises the temporal and spatial dimensions of the building. There are two trajectories describing the temporal dimension: 1) material flow that ranges from material extraction to the end of product life-cycle; and 2) work flow that starts from concept study and ends at demolition. The spatial dimension describes the location of physical subjects, from technology, building component through the building as a system to the broad context, e.g. community and city levels (Pan and Ning, 2015).
- The area 'stakeholder' is concerned with the stakeholders involved in SB and their interfaces with the project delivery (Pan and Ning, 2015).

In addition to the interdependence existing with each of the dimensions, the interdependence of SB also depends on an integrated interpretation of the three dimensions (illustrated using 'Point A' in Fig. 1). For example, an examination of energy performance per se in the performance dimension underpinned by the reductionism approach may imply an ignorance of the interdependence between the ESE aspects. However, the methodological perspective would triangulate the interdependence from the temporal and spatial aspects. From the performance perspective, the focus on the energy performance indicates a reductionism approach, whereas this specialization could be a holistic attempt from the methodological perspective if the lifecycle energy associated with the building is taken into account. In order to articulate the integration of the three dimensions, this paper also examined zero carbon building as a specific case of SB.

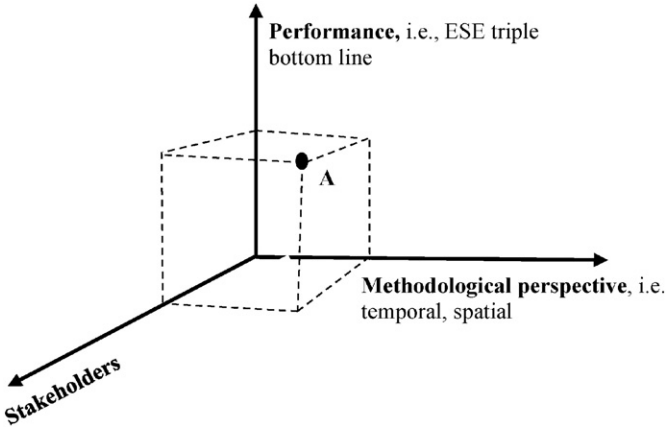

Fig. 1. A conceptual framework of examining interdependence of sustainable buildings. Source: Pan and Ning (2015)

3. Interdependence of sustainable building

3.1. Performance framework of sustainable building

Berardi (2011) argued that "the definitions of sustainable building often prove to be useless because they are unclear (p. 277)". Defining SB is difficult because of its dependence on time, scale, domain and social uncertainties (Berardi, 2013a). Nevertheless, three types of sustainability impacts, namely environmental, economic and social impacts, are widely accepted in the current assessment exercise (e.g., Häkkinen and Belloni, 2011; ISO, 2011).

The typology presented by Chwieduk (2003) is adopted here, which consists of 1) energy-efficient buildings; 2) environmentally-friendly buildings; and 3) sustainable buildings. Energy-efficient buildings have the smallest performance scope, only dealing with energy performance of environmentally-friendly buildings. Furthermore, the main differences between green and sustainable buildings consist of the economic and social requirements of the sustainability (Berardi, 2013a).

3.2. Interdependence in relation to sustainable building performance

The ESE framework of SB has been widely adopted by prior studies (Calderón, 2000). In some specific cases other aspects such as technological performance are also added (Alwaer and Clements-Croome, 2010). From the reductionism approach, research focuses on a single aspect or elements of one aspect, whereas the holism approach emphasizes interdependence between multiple aspects or multiple elements of one aspect.

3.2.1. Single aspect, single element of one aspect of ESE

In the literature of SB, there are a huge number of studies examining a single aspect of the ESE or a single element of one aspect. This pattern is particularly evident when studying energy consumption or carbon emissions (e.g., Jiang and Tovey, 2009; Jack and Swaffield, 2009; Lomas, 2010; Summerfield and Lowe, 2012; Zuo et al., 2011). The terms in use also abound, e.g. nearly-zero energy, zero energy, zero net energy, energy plus, fossil fuel free, zero carbon, carbon neutral, climate neutral, climate positive, and positive development (Riedy et al., 2011). There exist some other terms, e.g. emergy analysis (Srinivasan et al., 2012) and exergy (El shenawy and Zmeureanu, 2013; Meggers et al., 2012, 2013) that complement or substitute energy analysis.

The specialization of previous research on energy consumption or carbon emissions may be attributed to three reasons. First, the global warming potentials constitute most of the environmental impacts resulted from building's heating energy consumption, compared to human toxicity, acidification, eutrophication and photochemical oxidation potentials (Cetiner and Edis, 2013). Second, achieving high energy performance is the most challenging. By analyzing 490 LEED certificated buildings, Berardi (2012) found that energy performance, albeit the most important, is less achieved than water efficiency and indoor air quality. Third, reducing carbon emissions of buildings is considered worldwide as a key part of government policy (Pan and Garmston,