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What leads to low-carbon buildings? A China study

Qian Shi [a], Tao Yu [a], Jian Zuo [b,*]

[a] Department of Construction Management and Real Estate, School of Economics and Management, Tongji University, Siping Road 1239, Shanghai 200092, China
[b] School of Natural and Built Environments, University of South Australia, Adelaide 5001, Australia

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ABSTRACT

There has been a growing public concern on global warming and associated implications, which is arguably due to greenhouse gas emissions (carbon emission). Building stock is one of biggest emitters. As a result, a number of studies have been undertaken to investigate the effective ways of carbon emission reduction in buildings. However, there is lack of a systematic investigation of the interactive relationship between various factors related to low carbon building. Vast majority of existing studies place focus on one aspect of low carbon building, e.g. policy, technology, awareness, etc. An integrated Interpretative Structural Modeling (ISM) and Matrice d'Impacts croises-multipication appliqué a classment (MICMAC) approach is adopted in this study to explore the interactions amongst various factors related to low carbon buildings. Outcome of the integrated ISM and MICMAC modeling exercise provides a visualized tool for facilitating the low carbon building developments. This study not only identified the critical success factors for the implementation of low carbon buildings, but also explored how they interacted. Results showed that higher priority should be assigned to international cooperation, macro-level management, the development of low-carbon theories and technologies due to their strong driving power to low carbon buildings. As a result, other factors such as low-carbon facilities, the structure of building energy consumption, and low carbon building project practice will be developed rapidly because of their strong dependent power. This in turn helps to promote the low carbon building developments. Therefore, these factors need to be taken into consideration during policy making process.

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* Corresponding author. Tel.: +61 8 8302 1914; fax: +61 8 8302 2252.
E-mail address: jian.zuo@unisa.edu.au (J. Zuo).

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1. Introduction

It is well recognized that the greenhouse gas emission has significant impacts on human being's survival and development. In the Stern Review on Economics of Climate Change, Nicholas Stern, the former World Bank chief economist suggested that the growing effects of greenhouse gas emission is detrimental to the global economy while the level of effect is more significant than that of world war or economic recession [1]. The Fifth Assessment Report recently released by the Intergovernmental Panel on Climate Change revealed that certain amount of terrestrial plant and animal species will be vulnerable to extinction due to the global warming [2]. CO_2 is one of main types of greenhouse gas emission [3,4]. According to the U.S. Energy Information Administration, the global amount of CO_2 emission in 2035 will be 42.7% higher than that in 2007, which exaggerates the effect of greenhouse gas emission [5]. Indeed, the climate change has motivated the behavior of human beings toward low carbon [6–10].

Building stock is amongst biggest emitters of greenhouse gases [11–14]. The extent of the effects of building stock to the environment is exaggerated due to the rapid urbanization and associated development activities particularly in Asian Pacific regions [15–17]. In many countries, the building stock contributes to more than 40% of the total amount of greenhouse gas emissions [18]. Therefore, it is imperative to implement low carbon buildings [19–21]. There are numerous benefits associate with the implementation of low carbon buildings. These benefits are multi-facet. Apart from environmental benefits such as pollution reduction, low carbon buildings have social and economic implications [22–25]. For instance, tenants of low carbon building experience higher level of satisfaction, wellbeing, and productivity [26,27]. Similarly, office buildings achieved green building rating have higher premium compared to those without rating [28–30]. However, the challenges remain mainly due to the comparatively higher up-front cost associated with the sustainable features [31–33].

There is no lack of studies on investigating factors that are critical for the implementation of low carbon buildings. However, there is lack of systematic approach as vast majority of these studies place focus on a single aspect, such as technical, legislative or managerial practice. The nature of low carbon building is complex. There are inherent limitations associated with these studies due to overlooking the interactions amongst various aspects of low carbon buildings. An overwhelming focus on one factor may not become an effective approach as it may be affected by other factors. Therefore, it is necessary to explore the interactive relationship between numerous aspects of low carbon building in order to facilitate its sustainable development. This study aims to fill this gap by employing an integrated ISM (Interpretative Structural Modeling) and Matrice d'Impacts croises-multipication appliqué an classment (MICMAC) approach.

2. Critical success factors for low carbon building

2.1. Macro-level management

The macro-level management is one of the most influential factors for carbon emission reduction of buildings [34]. Indeed, the decarburization presents significant challenges to governments on related policies and regulations [35–40]. Indeed, laws and regulations are essential for building energy efficiency [41–43]. This is supported by Newton and Tucker which suggested that the adjustment of management mechanisms helps to promote the low carbon building developments [44].

As a result, efforts have been made to improve the macro-level management globally. These include the green building assessment tools such as Building Research Establishment's Environmental Assessment Method (BREEAM) in UK, Leadership in Energy and Environmental Design (LEED) in USA, and GBCA Green Star in Australia. China also released the Evaluation Standard for Green Construction of Buildings (GB/T50640-2010) to regulate low carbon building development [45]. Similarly, the international Organization for Standardization (ISO) developed the ISO14004 to standardize the calculation of carbon emissions [46]. The UK Parliament even set a target of 80% reduction of total UK carbon emissions at 1990 level by 2050 in the Climate Change Act [47]. Low-carbon building is not only a technical problem but also a management issue [48].

2.2. Development of low-carbon theories and technologies

According to Dimoudi and Tompa, the advances in materials, technologies and developers' knowledge on carbon emissions reduction in this phase are critical to mitigate emissions of building stock [49]. There are numerous aspects of the effects on related technologies and theories on low carbon building developments [50].

Zuo et al. argued that there was lack of universe definition of low carbon building which presented a significant barrier to the promotion of low carbon buildings [11]. An accurate assessment of the carbon emissions of construction materials will facilitate its selection process via dioxide carbon labeling [34]. Similarly, Conejos et al. highlighted the importance of theories of building adaptive reuse in mitigating carbon emissions and climate change [51]. They subsequently developed the AdaptSTAR model to assist the sustainable building design with a consideration of building adaptation. By studying alternate hybrid building configurations, Newton and Tucker revealed that carbon footprints could be reduced significantly by means of a reasonable design [44]. Bendewald and Zhai proposed a sustainable building assessment model which was based on carrying capacity [52]. They suggested that the design technological innovation can be facilitated by means of effective sustainability assessment, which in turn achieve low carbon building development. It is not unusual that ICT is used to monitor the energy consumption, water consumption and carbon emissions of buildings [53,54].

2.3. Awareness and attitude

Reluctance in using low carbon dioxide materials and the lack of environmental awareness hinder the dioxide carbon labeling of materials and consequently the development of low-carbon buildings [34]. Therefore, it is essential to strengthen the education on environmental sustainability and low carbon building [55]. This will enhance the awareness of public on environmental issues as well as training professionals [13,56]. This is particularly the case as students are the future leaders and practitioners in various sectors [55].

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