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DEVELOPING A CONCEPTUAL FRAMEWORK OF CARBON REDUCTION RESEARCH IN CONSTRUCTION

PETER S. P. WONG, FRANCESCO IMPERATORI, CHRISTIAN KAKAVOULES, STEFAN POLASTRI and ALESSIO ACQUARO

School of Property, Construction and Project Management, RMIT University, Melbourne

The construction industry has been proven to be increasingly detrimental to the environment in the past few decades. As environmental awareness expands, efforts to reduce the carbon intensive sector into a sustainable and environmentally friendly industry increase. It is indisputable that the efforts put in place to transform such a sector. Subsequently, the studies associated with carbon reduction development have also funneled into three streams: technology advancement, mechanism establishment and organizational behavior. However, research until now has focused on these streams independently. This paper presents a study that aims to take a holistic approach in analyzing the strengths and weaknesses of previous studies on carbon reduction in construction. A systematic review was conducted and the results came to expose five prevalent and determining factors that catalyze the success and failures of carbon reduction research. The discussion of these factors with their association to technology advancement, mechanism establishment and organizational behavior have uncovered suggestions, that researchers in future can focus on in order to foster carbon reduction within the construction industry. A conceptual framework of carbon reduction research in construction was then developed.

Keywords: Carbon reduction, Success factors, Construction, Systematic review.

1 INTRODUCTION

Carbon emissions allegedly cause global warming (EIA 2013). Researchers have warned that if the global carbon emissions are not going to be reduced, the associated negative effects including the extreme weather may drastically damage the ecosystems to a point that human beings may not be able to cope with (EIA 2013). The building sector notoriously accounts for more than one-fifth of the total worldwide carbon emissions (EIA 2013). In this connection, it is not surprising to see the growing number of research studies on carbon reduction in construction in recent years. The related research studies can be funneled into three main streams: technology advancements, mechanism establishment and behavioral studies (Wong and Zapantis 2013). Technological advancement studies mainly focus at reducing the reliance of heavy carbon embodied materials, enhancing the efficiency of construction operations and better the building systems. Researches in mechanisms focused at establishing benchmarks and reviewing the effectiveness on the policies being put in place to help the industry to reduce carbon. Behavioral studies looked into helping the construction

practitioners to cope with the difficulties in regards to the change of practice that helps reduce carbon emissions. Nonetheless, the research findings obtained from these streams of studies are vast and scattered. Furthermore, it remains unclear if these streams of studies interact with each other. The ambiguity surrounding these three streams may be due to the different research approaches taken by the researchers. This study aims to adopt a holistic approach to review previous publications in carbon reduction research in construction. A conceptual model that depicts the major factors that determine the success and failure of the carbon reduction research is developed. The conceptual model would enhance the appreciation of the needs to further studies about alleviating the environment impact brought by the construction activities.

2 THE RESEARCH METHODOLOGY

An approach for systematic review adopted by Mayring (2010) is employed. The same approach has been successfully adopted in a similar study conducted by Klewitz and Hansen (2013). The approach consists of the following 4 steps as depicted in Figure 1.

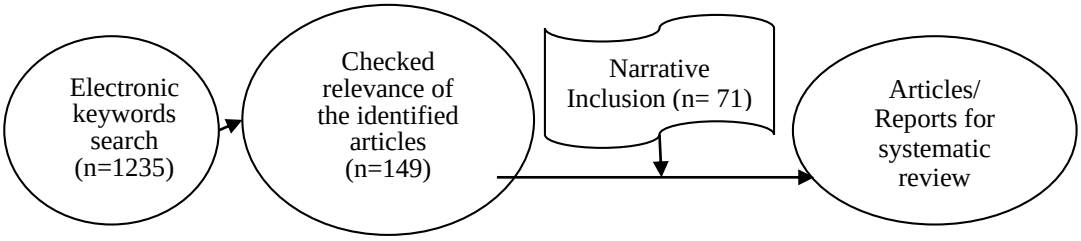

Figure 1. Four-steps approach for systematic review.

An electronic keywords search was conducted in Step 1. Keywords combinations "carbon emissions + construction", "carbon emissions + technology", "carbon emissions + policy" and "carbon emissions + behaviour" were used for the search of relevant articles. Dissimilar to prior studies that were purely based on the author's choice and judgment, the relevant articles for review in this study were identified from an objective electronic search through three major databases of peer-reviewed literatures, namely Scopus, Proquest and Science Direct. As stated by Bapuji and Crossan (2004), an electronic search approach is a relatively objective approach for 'identifying the publications that belong to the field: as decided by the field'. A total of 1235 articles that published between 1994 and 2013 were identified in the first step of review. In the next step, the relevancy of the identified articles was checked through reading the articles' abstracts. Furthermore, only papers with full texts available from Scopus, Proquest and Science Direct were selected for further reading. As a result, 149 articles were included. It is noted that the above searching process may not sufficiently cover some important industry-based reviews. As a remedy, an additional search is conducted to include official reports published by the construction professional bodies and the governments in this review study. Relevant documents were searched from the web pages of the respective government departments and the professional institutes. Overall, 220 publications were included in this systematic review. However, constrained by the page limitation of the conference proceedings, only articles that are directly related to the

factors that affect the success and failures of carbon reduction research (as presented in the conceptual model) are reported in this paper.

3 DISCUSSIONS

Based on the systematic review, five factors that contribute to the success and failure of the carbon reduction research in construction are identified:

3.1 Factor 1: The Adequacy of the Cost/Benefit Assessment

Although there is a plethora of research studies that aimed to advance the technology in carbon reduction, some of the proposed solutions were commented as too costly to implement in the project-based environment (Rowe 2011). Through a computer simulation, Taylor (2009) successfully demonstrated how emissions can be cut by up to 50% in a typical hotel in the U.K. without compromising guest comfort. However, he made due caveat on his findings as they mainly dealt with the technical feasibility of emissions reductions in hotels without due regard to the cost effectiveness. Similarly, Mao *et al.* (2013) assessed the difference between pre-fabricated walls and conventional walls. Their findings indicated that the semi-prefabrication method produces less carbon emissions as compared to the conventional approach. However, they expressed their concern over the acceptance of the market because semi-prefabrication method is more expensive. Such technological advancement based studies nicely brought about the need of drivers that can induce behavioral change. In this regard, advocates strongly believed that mechanisms like carbon tax or emission trading schemes can help raise revenues to subsidies advanced technology implementation in construction activities (Wong *et al.* 2013). However, such perception may not work well to reflect the fact that additional cost of carbon tax can be passed onto the end-users of the buildings.

3.2 Factor 2: End-users' Involvement

It is not difficult to observe that policy makers and the industry experts have put great effort in establishing mechanisms like energy efficiency rating systems (EERSs) to benchmark building performance. However, researchers also warned that some of the EERSs may not well connect to the end users' needs (Parag *et al*. 2009). In this regard, Baird (2011) emphasized the importance of end-users' involvement to make EERSs implementation a success. Baird (2011) found that EERS mainly focuses on the technical aspects within the building which doesn't account for the end users' expectations and behaviors. Similar findings were reported by Schweber (2013) who found that end-users' involvement was often discouraged as the project decisions are often dominated by the building designers. Findings from the studies in organizational behavior are generally in line with the above reported studies. Results from a systematic review conducted by Parag *et al.* (2009) indicate that current EERS related policies demonstrate a lack of cohesion among the government, suppliers and end-users.

3.3 Factor 3: Diversity

The literature collectively showed the possibility of applying vast range of advanced technologies to reduce carbon produced from the construction activities (Taylor 2009). Notwithstanding, some technologies remain in the research and development phase and their practically were questioned (Parag *et al*. 2009). With years of development, research studies about mechanism becomes more sophisticated, but inevitably more diverse. The diverse range of EERSs was established. However, it triggers problems in regards to the ability of to assess buildings' energy efficiencies under different baselines (Ng *et al.* 2013). With regard to organizational behavior, scholars argued that due to the increasingly fragmented business processes and technologies, the upfront cost required for carbon reduction is substantially increasing (Parag *et al*. 2009). The above review indicates that the diversifying carbon reduction solutions and policies may discourage innovations because research is heavily dependent upon funding input. At the flip side, it is understandable that governments cannot fund some plans that are not sustainable or self-maintained in long term. In this sense, this rationalizes the research development in carbon reduction to become more pragmatic.

3.4 Factor 4: Legitimacy of Change

Research findings from previous studies also indicate that the practitioners' behavior in carbon reduction can be obscure (Wong *et al.* 2012). In this regard, mechanisms like the EERSs catalyze behavioral changes (Wong and Zapatis 2013). However, it is not hard to find research that has become entangled with barriers within EERS that may discourage technological advancement (Sev 2011). Sev (2011) summarized that current EERSs fall short in: accounting for social and economic sustainability within the adopting region, the applicability of the cultural variety, appropriate assignment of weights according to the region priorities, actual performance data of building operation, site specify, avoiding double counting and contradicting credits. These deficiencies hamper real behavioral change of the construction industry.

3.5 Factor 5: Familiarity

Some papers have highlighted the idea that technologies may be easily misunderstood (von Borgstede *et al.* 2006). New technologies are considered too technical and therefore the goals of some research studies are to raise awareness and create tools to assist the end users. The lack of knowledge, leads to extravagant over consumption style of living, domestic appliances and comfort creep. In a study by Newton and Tucker (2011) on pathways to de-carbonizing the housing sector it is stressed that regulations need to focus on becoming a driving force for change on occupant's integration with the building, rather than acting as a mechanism for eliminating the poor operating energy performance of the building design. Occupants choosing the best of the range in low carbon intensive appliances can save 52% in carbon emissions when compared to average household appliances. The study of Von Borgstede *et al*. (2006) indicates that individual professionals who advocate for carbon reduction activities within their company or institution are hindered by the company structure they work within.

4 CONCEPTUAL MODEL DEVELOPMENT

Towards this journey of the systematic literature review, it is noted that individual studies the research team reviewed are typically dedicated to one of the three streams: technology advancement, mechanism establishment and human behavior. But taking together they may help laying a better pathway for further studies. Findings of the selected articles were critically analyzed. It should be reminded that these five factors that were reported in Section 3 can become the success factors if we address them in an integrative manner to improve the practicality of the carbon reduction research. On the flip side, they can also be the obstacles if we ignore them while conducting carbon reduction related research. Having considered the five factors, a conceptual model of carbon reduction research in construction is developed and shown in Figure 2. Three directions for successful future carbon reduction research are suggested: [1] Devising pragmatic technology based solutions: In order for new technologies to be implemented, further research is suggested to be justified by appropriate cost-benefit assessments. The related methodologies can be derived through the directives of government mechanisms and policy. However, they should facilitate proactive thinking in devising solutions that are acceptable by the industry; [2] Closing the gap between ideology and functionality: New research in the area is suggested to embrace the end user's needs in order to foster cohesion between ideology and functionality; [3]

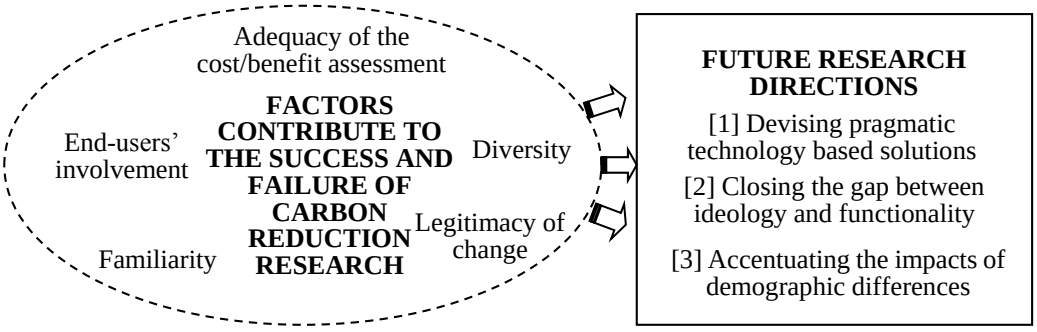

Figure 2. Conceptual model of carbon reduction research in construction.

5 CONCLUSIONS

The study bases on a systematic review to identify five dimensions that contribute to the success and failure of the carbon reduction research in construction. The discussions of the factors in the section 3 lead us to identify directions to enhance future research. This study contributes to better our understanding about the current status of carbon reduction research development. This may lay a pathway for further research and devising pragmatic carbon reduction solutions for the construction sector.

As with many literature review studies, this study consists of limitations. Firstly, despite the reported findings are backed by a systematic review, they are suggested to be cross validated by quantitative analyses. Secondly, while future directions are derived

through the conceptual model, how these studies can be conducted are yet to be discussed. Appropriate methods are suggested to be devised in the future studies.

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