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The effects of green building on construction waste minimization: Triangulating ‘big data’ with ‘thick data’

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ABSTRACT

In contrast with the prolific research examining the effects of green building (GB) on property value, energy saving, or indoor air quality, there has been minimal focus on GB’s effects on Construction Waste Minimization (CWM), which is also an important aspect of cultivating sustainability in the built environment. To address this significant knowledge gap, this study has two progressive objectives: (1) to ascertain the empirical effects of GB on CWM and; (2) to identify and understand the causes leading to the ascertained effects. This is achieved by triangulating quantitative ‘big data’ obtained from government agencies with qualitative ‘thick data’ derived from case studies and interviews. The study found that BEAM Plus, the latest version of the Building Environmental Assessment Method developed by the Hong Kong Green Building Council (HKGBC), gave rise to a 36.19% waste reduction by weight for demolition works, but no statistically significant waste reduction for foundation or building works. It is because CWM, the basis for a demolition project to obtain GB credits, makes up only one of many ways for foundation or building works to earn credits, e.g., site aspects, lighting. In any case, CWM measures typically prove costlier means of acquiring credit, further causing developers to pay less attention to CWM in their GB tactics. The study’s results, i.e., CWM in GB significantly influences demolition, but only marginally for foundation and building works, provide useful scientific evidence to inform GB councils and other responsible bodies and encourage continuous improvement in GB practices. While the study in general sheds light on how the triangulation of big, empirical data with conventional, qualitative data, e.g., interviews with GB professionals, helps to better understand the subject of the investigation, i.e., the effects of GB on CWM.

1. Introduction

Buildings house the vast majority of social and economic activity, as well as influence human health and behavior. They also exert serious adverse impacts on the natural environment in the form of resource depletion, greenhouse gas (GHG) emissions, noise, dust, and waste. In the United States alone, buildings account for almost 40% of the country’s CO_2 emissions, but LEED-certified buildings have 34 percent lower CO_2 emissions, consume 25 percent less energy and 11 percent less water, and have diverted more than 80 million tons of waste from landfills. Construction work and buildings are responsible for 40% of the consumed raw materials, 40% of the waste deposited in landfills, and 30% of energy-related greenhouse gas emissions (Napier, 2016). The global green building (GB) movement has advanced a myriad of strategies for fostering a better built environment, while alleviating the adverse impacts human development has caused the natural world thus far. A polysemous word, building here both refers to the noun of a physical building and the gerund of building activities. Various green building rating systems (GBRS) define GB standards and award GB certification. Notable ones include Leadership in Energy and Environmental Design (LEED) in the USA, Building Research Establishment Environmental Assessment Method (BREEAM) in the UK, Green Building Label (GBL) in China also known as China Three Star, Building Environmental Assessment Method (BEAM) in Hong Kong, Green Star in Australia and New Zealand, Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan, and Building Construction Authority Green Mark Scheme in Singapore.

GB projects normally incur higher upfront costs than ordinary buildings due to the use of more sustainable, less conventionally marketed materials and Mechanical, electrical, and plumbing (MEP) systems. GB institutions propagate that the higher cost

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can be paid off in the long run through improved environmental performance and thus lower utilities bills, higher property value and rates of occupancy, and greater levels of occupant comfort and productivity (Kats et al., 2003). A plethora of research exists to support these claims, e.g., Fuerst and McAllister (2011) on GB effects on property market price; Shuai et al. (2018) on carbon emission reduction; Castleton et al. (2010) on energy savings for retrofits; Singh et al. (2010) on employee health and productivity; Zhang and Altan (2011) on occupant comfort. In contrast, research into the effects of GB on Construction Waste Minimization (CWM) appear to be few and far between.

Building generates a significant portion of the world's total solid waste. Statistics show that waste generated by building activities normally constitutes between 20 and 30% of the total solid waste deposited in landfills for most developed economies, such as that of the USA, Europe, Hong Kong and Japan (USEPA, 2016; European Commission, 2013; HKEPD, 2016; MoE, 2014). This rate is even higher for developing countries (Lu et al., 2016b). Landfilling construction waste leads to its anaerobic degradation and CO_2 and methane production, which further results in extensive amounts of air, water and soil pollution (Kightley et al., 1995). It also exhausts valuable landfill space (Lu and Tam, 2013). As worldwide building activity increases, so does the need to assuage construction waste. CWM plays an important role for the building industry in its pursuit of sustainability, reflected in various GBRS. Studies conducted to investigate the scope of GBRS have unanimously deemed CWM pertinent to GB development (Tam et al., 2004; Wu et al., 2016), accounting for 8–12% of credits in these systems, particularly in terms of sustainability assessment (Wu et al., 2016). However, there appears to be no studies convincingly utilizing big data approaches to examine whether GB development truly influences CWM.

This study aims to address this knowledge gap by determining the causal effects of GB development on CWM through two progressive objectives. Firstly, to ascertain the effects of GB certification on CWM, the authors assume an inverse relationship between the amount of construction waste sent to landfill and GB rating scores. This hypothesis is tested by making good use of a set of 'big data' derived from various sources to paint of a fuller picture of GB development in relation to CWM. The second objective concerns identifying and understanding the causes resulting in the ascertained effects by triangulating quantitative, big data with qualitative, 'thick data' (Rasmussen and Hansen, 2015) derived from case studies, archival research, focus group meetings, and interviews with GB professionals. This task helps probe into how sustainability deliverables are interpreted by and aligned with developers' GB strategies. For the sake of practicality, the research is contextualized in Hong Kong, where both the GB movement and CWM developed profusely. However, they are not juxtaposed to enable the formation of a holistic view of their dynamics. In order to provide an understanding of the inherent link between GB and CWM, Section 2 offers a review of building-related construction waste and GB movement literature, followed by an account of the research methodological approach in Section 3, an analysis of the data in Section 4, and a discussion of the results in Section 5. Conclusions are drawn in the final segment of the paper.

2. Literature review

2.1. Building-related construction waste

'Construction waste', often used interchangeably with 'construction and demolition (C&D) waste', concerns the surplus or damaged materials that result from building activities, such as new construction, renovation, and demolition (Roche and Hegarty, 2006). The composition of construction waste largely depends on the prevailing construction materials and technologies available to that construction project. The European Waste Catalogue (EWC) classifies C&D waste into eight categories, i.e., concrete, bricks, tiles and ceramics; wood, glass and plastic; bituminous mixtures; metals; soil; insulation; gypsum-based construction material; and everything else. In the UK and commonwealth countries, C&D waste often falls into either inert or non-inert categories. The former comprises soft inert materials such as soil, earth, silt, and slurry, as well as hard inert materials such as asphalt, rocks and broken concrete. Non-inert C&D waste normally include timber, bamboo, vegetation and other organic materials, glass, plastics and other packaging waste (Wu et al., 2014; HKEPD, 2013). Unlike inert materials, non-inert ones cannot be easily reused or recycled and thus have to be landfilled. Landfill non-inert waste will quickly consume landfills, which are often the valuable assets of a city.

C&D waste often constitutes a significant volume of the world's total solid waste. In the USA, for example, the estimated amount of C&D waste generated in 2014 before recycling was 534 million tons, over twice as much as the 258 million tons of municipal solid waste (MSW) recorded that same year (USEPA, 2016). The European Commission (2013) estimated construction waste comprised 25–30% of all the waste generated in the European Union. Lu et al. (2016b) calculated that China produced approximately 1.13 billion tons of C&D materials in 2014, about 30–40% of its total annual solid waste. HKEPD (2016) reported that the solid waste dumped in Hong Kong landfills reached 15,332 tons per day in 2016, 29% of which came from construction activities. Likewise, in Japan, construction contributes to 20% of all industries' total solid waste (MoE, 2014).

C&D waste is not entirely synonymous with environmental pollution and resource depletion. Successful examples of construction waste reuse and recycling abound, e.g., Park and Tucker (2017). A large proportion of waste, such as metals, rocks, and broken concrete, can be reused as architectural or material salvage or recycled as Portland cement clinker, artificial aggregates, road pavement, or reprocessed bricks. Nevertheless, a certain portion of C&D waste, the non-inert compositions in particular, cannot be reused or recycled, and therefore must be landfilled.

Landfilling waste leads to considerable pollution to air (Sam-Cwan et al., 2001), water (Mor et al., 2006), and soil (Garcıa-Gil et al., 2000). It also exerts tremendous pressure on valuable landfill space, particularly in compact urban spaces (Lu and Tam, 2013). As a concomitant by-product of building, construction waste must be properly managed (Teo and Loosemore, 2001).

CWM strategies can be understood through the "3Rs" principle, denoting reduce, reuse, recycle strategies, which are pursued according to their desirability given the situation (Wu et al., 2013). 'Hard' and 'soft' approaches characterize two common types of construction waste management. Environmental engineers have investigated how hard technologies can help reduce, reuse or recycle C&D waste through the introduction of prefabrication (Tam et al., 2005), the manufacture of recycled aggregates for various concrete applications (Rao et al., 2007), and site formation or land reclamation (HKEPD, 2013). Recognizing that waste constitutes a social issue, soft economical or managerial measures embrace implementing a waste disposal levy and mandating waste management plans (HKEPD, 2015), advocating 'design out' waste schemes (Baldwin et al., 2007; Osmani et al., 2008), or promoting onsite waste management (Wu et al., 2017; Shen et al., 2004).

2.2. The green building (GB) movement

Buildings are typically designed and constructed to meet building code requirements, whereas GB solicits design beyond