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Identifying factors influencing demolition waste generation in Hong Kong

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ABSTRACT

Among all construction activities, demolition normally generates the largest proportion of construction and demolition (C&D) waste, to which requires more importance being attached for effective management. Previous studies have attempted to understand demolition waste generation (DWG) but the understanding remains relatively insufficient, largely due to the erratic and poor quality data available. This research aims to identify factors impacting DWG by making use of a big dataset which has recently become available as a result of C&D waste management practices in Hong Kong. Using big data analytics, it is confirmed that DWG, demolition cost, and duration of conducting the demolition work are dependent on each other. It is also found that geographical location, building usage, and the public-private nature of a building project also have a significant impact on DWG in the Hong Kong context. Based on the correlations between DWG and these identified factors, stakeholders may introduce proper managerial or policy interventions to effectively minimize DWG. For example, public policy-makers may formulate more tailor-made regulations to attach more importance to the locations, usages and public-private nature, which have more potentials for demolition waste minimization.

1. Introduction

Construction and demolition (C&D) waste, is defined as the surplus and damaged products and materials that arise from construction, renovation, demolition, and other construction activities (Roche and Hegarty, 2006). In some settings, 'C&D waste' and 'construction waste' are used interchangeably for simplicity, or when the sources of waste are not the focus. In economically developed countries, demolition activities are usually limited. For example, Bergsdal et al. (2007) reported that in Norway demolition comprised just 8% of national C&D activities (m^2/year) in 1998, while new construction and renovation comprised 52% and 40%, respectively. By contrast, demolition in economically developing economies is often in large scale when existing structures are demolished to provide new land for the urgent demands of housing and other facilities (Lu et al., 2016c). In Shanghai, for example, the demolition floor area in 2014 reached 1,185,800 m^2, declining from 2008's plateau (SSB, 2015). In many developing and developed countries or cities, demolition is a quite wasteful activity if the waste is not properly managed. In the UK, the waste amount from C&D activities has remained at around 100 million tons annually in recent years (DEFRA, 2015), while demolition accounted for around 32.7 million tons in 2007 (CRWP, 2009), which means demolition waste takes about 30% of all annual construction waste generated. Another developed country Norway logged 1.8 million tons of C&D waste generated in 2013, 31.3% of which was from demolition activities (Statistics Norway, 2015). Demolition in Hong Kong is estimated to produce, by weight, more than 10 times the amount of waste produced from construction of new buildings (Poon et al., 2001; Lu et al., 2015). In China, annual C&D waste generation reportedly reached one billion tons in 2013, 74% of which resulted from demolition activities (NDRC, 2014; Lu et al., 2016c). Minimizing demolition waste is thus often a priority in mitigating its adverse impacts, including land deterioration (Ofori, 1992), resource depletion (Kofoworola and Gheewala, 2009; Ferguson, 1995), and various forms of pollution such as noise, dust, air pollution and discharge of toxic waste (Lu and Yuan, 2011).

Previous studies have attempted to understand the nature of

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DWG. This can be investigated at either project level or regional level (Bergsdal et al., 2007; Llatas, 2011; Yost and Halstead, 1996; Andersen et al., 2007; Bergsdal et al., 2007; Bohne et al., 2008). It is important to understand DWG at a project level mainly for two reasons. First, construction works, either new building, renovation, or demolition, are normally organized as projects. Second, by summing up DWG of various projects, it is able to understand the overall DWG in a region. Lu et al. (2011) investigated factors affecting C&D waste generation at project level in new building construction, but not demolition. These studies concern C&D waste after it has been generated. In contrast, Kleemann et al. (2016) introduced a method for determining a building's material composition and future demolition waste, mainly for further planning. Moreover, various reduction, reuse, and recycling strategies (Peng et al., 1997), and the more proactive deconstruction strategy (Dantata et al., 2005), have been introduced to manage and minimize DWG.

Previous studies have reported that DWG is determined by a building's internal factors such as age (Poon, 1997), type (Wang et al., 2004), geometrical characteristics (Wang et al., 2004; Shi and Xu, 2006), structure (e.g. steel, precast concrete, or brick) (Poon et al., 2001), or construction technologies used (e.g. prefabrication or cast in-situ) (Jaillon et al., 2009). It is also known that DWG is influenced by external factors such as demolition technologies (e.g. deconstruction, wrecking ball, or implosion) (Kibert et al., 2000; Kourmpanis et al., 2008; Poon et al., 2004), duration of demolition (Yuan et al., 2011), surroundings (Hendriks and Janssen, 2001), and constructors' C&D waste management capability (Mcdonald and Smithers, 1998). However, in-depth, accurate understanding of DWG, in particular relating to these internal and external factors, is lacking.

The paucity of understanding of DWG may be attributable to the erratic and poor quality data available for research. Data collection methods adopted by previous C&D waste management studies are diverse and include: direct observation (Poon et al., 2001; Formoso et al., 2002), questionnaire survey (McGregor et al., 1993; Wang et al., 2010), direct measurement (Bossink and Brouwers, 1996; Lau et al., 2008; Wu et al., 2014), interviews (Treloar et al., 2003; Tam et al., 2007); and tape measurement and truck load records (Skoyles, 1976). However, in real-life practice, when a demolition project is completed, construction companies are unable to provide relative accurate data because contractors are not obliged to record and report the qualitative and quantitative characteristics of the waste generated (Fatta et al., 2003). Most previous studies thus adopted sampling and ethnographic methods during construction or demolition processes. Although using objective methods, these studies had a relatively small sample or sampled relatively small sites due to the difficulties involved in conducting a full coverage survey (Katz and Baum, 2011; Lu et al., 2011). These studies are thus inherently limited by their inability of accounting for the totality and accuracy of waste generation data throughout the demolition process.

This study is aiming to examine external and internal factors that influence DWG at a project level by making use of a big dataset that has recently become available in Hong Kong's active construction sector. This study identifies the factors that influences DWG that can be generalized from individual projects to reflect the prevailing demolition waste management picture of an economy. It can alleviate the many problems (e.g. limited sample size on demolition activities) that have arisen in previous studies of this kind and facilitate more robust research findings in order to provide a clearer understanding of DWG. This rest of the paper is divided into four main sections subsequent to this introductory section. Section 2 is a critical assessment of the existing studies on potential factors influencing DWG. Section 3 delineates the methodology, and the analyses and results are presented in Section 4. Section 5 discusses the results and Section 6 concludes the study.

2. Factors affecting waste generation in building demolition

A large number of factors influencing demolition waste generation (DWG) were mentioned by relevant regulations and scholarly studies. In Hong Kong, the *Code of Practice (CoP) for Demolition of Buildings* was published in 1998 and updated in 2004. It defines *demolition as dismantling, razing, destroying or wrecking any building or structure or any part thereof by a pre-planned and controlled method* (HKBD, 2004). The CoP considers the prevailing building structures in Hong Kong, i.e. high-rise concrete composite buildings, and other special buildings such as the ones adopting precast and pre-stressed concrete. It emphasizes a philosophy of planning (especially asbestos abatement, and removal of hazardous or regulated materials), precautionary measures (e.g. hoarding, scaffolding, and protecting traffic), operation, and close supervision and inspection.

Demolition method is a factor that is attributable to DWG. Different demolition methods (e.g. top-down using manual methods or machines, use of hydraulic crushers with a long boom arm, use of a wrecking ball, implosion) and their associated practices are introduced in the CoP (HKBD, 2004). A 'selective demolition' method should be adopted as far as practicable; this involves demolition and removal of waste in stages according to category of waste, with the goal of facilitating recycling (HKBD, 2004). Implosion may be adopted when the aim is to expedite building demolition, for example when the land is to be redeveloped, or when other demolition methods are unsuitable due to the nature of a structure. Some parts of a building (e.g. metal members, glass, and non-load bearing partitions) can be removed during the implosion preparation stage, but the rest of the building will likely end up as demolition waste comprising a mixture of inert and non-inert materials not conducive to segregation, reuse, or recycling. In some extreme cases, entire buildings become waste (Wang et al., 2004). Deconstruction, in contrast, is a less wasteful method of demolition. It can be considered as a reversal of the construction process. Buildings are systematically taken apart, which allows materials to be kept intact as they are separated, making them easier to reuse and recycle. Some recyclable materials with high market value or high disposal costs, like metals, heavy timber, gypsum drywall and concrete, are salvaged. However, deconstruction is more expensive, labor-intensive, and time-consuming than other demolition methods (Dantata et al., 2005).

DWG also relates to waste management practice adopted by the demolition contractors (Poon et al., 2001; Lu and Tam, 2013). Emphasizing C&D waste management is to avoid too much waste generation or even to achieve the goal of zero waste, but this goal is correlated with time and cost (Dantata et al., 2005; Lauritzen and Hahn, 1992; Poon et al., 2001; Yuan et al., 2011). On-site sorting of demolition waste is strongly recommended by the CoP, and the effectiveness of this practice has been examined by Poon et al. (2001) and Lu and Tam (2013). Recyclability of demolition waste, which depends on on-site separation and on-site reuse, is crucial to the amount of waste ultimately sent to waste receiving facilities.

Interestingly, previous studies (e.g. Tam et al., 2007; Lu et al., 2016c) discovered that the public-private nature of a project could cause a noticeable disparity in waste management performance, even though the construction work is performed by the same pool of contractors. Construction work could be initiated by public clients (e.g. a government to develop town halls or institutional buildings), private clients (primarily involved in the development of real estate such as private offices and residential buildings), or through more recently populated public-private-