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Review

A BIM-based system for demolition and renovation waste estimation and planning

Jack C.P. Cheng, Lauren Y.H. Ma *

Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong

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ABSTRACT

Due to the rising worldwide awareness of green environment, both government and contractors have to consider effective construction and demolition (C&D) waste management practices. The last two decades have witnessed the growing importance of demolition and renovation (D&R) works and the growing amount of D&R waste disposed to landfills every day, especially in developed cities like Hong Kong. Quantitative waste prediction is crucial for waste management. It can enable contractors to pinpoint critical waste generation processes and to plan waste control strategies. In addition, waste estimation could also facilitate some government waste management policies, such as the waste disposal charging scheme in Hong Kong. Currently, tools that can accurately and conveniently estimate the amount of waste from construction, renovation, and demolition projects are lacking.

In the light of this research gap, this paper presents a building information modeling (BIM) based system that we have developed for estimation and planning of D&R waste. BIM allows multi-disciplinary information to be superimposed within one digital building model. Our system can extract material and volume information through the BIM model and integrate the information for detailed waste estimation and planning. Waste recycling and reuse are also considered in our system. Extracted material information can be provided to recyclers before demolition or renovation to make recycling stage more cooperative and more efficient. Pick-up truck requirements and waste disposal charging fee for different waste facilities will also be predicted through our system. The results could provide alerts to contractors ahead of time at project planning stage. This paper also presents an example scenario with a 47-floor residential building in Hong Kong to demonstrate our D&R waste estimation and planning system. As the BIM technology has been increasingly adopted in the architectural, engineering and construction industry and digital building information models will likely to be available for most buildings (including historical buildings) in the future, our system can be used in various demolition and renovation projects and be extended to facilitate project control.

1. Introduction

In recent years there is a global trend towards sustainable development in the architectural, engineering and construction (AEC) industry. According to a report conducted in 2009 by McGraw-Hill Construction, 80% of contractors in the United Kingdom believed that sustainable waste management would become an important practice by 2014 — an increase of 19% compared to five years ago (McGraw-Hill Research and Analytics, 2009). With this recognition, construction and demolition (C&D) waste issues have received increasing attention from both practitioners and researchers around the world (Lu and Yuan, 2011). However, the amount of C&D waste is still growing continuously and not effectively managed in most of the countries in the world. C&D waste consists of waste that is generated during new construction, renovation, and demolition of buildings, roads, bridges, and other infrastructure facilities. In many developed regions, the amount of demolition and renovation (D&R) works as well as the amount of waste generated are growing fast recently. For example, the gross value of D&R works outweighed that of new construction works in Hong Kong in 2006 and 2008, according to the Hong Kong Quarterly Survey of Construction Output (Hong Kong Census and Statistics Department, 2011). Therefore, it is vital that the industry strives to reduce and manage D&R waste effectively to realize sustainable waste management.

Researchers pointed out that the lack of benchmarking will hinder the implementation of more sustainable and innovative practices in industry and decision-making should be based on quantified measurements/estimations expressed in numerical terms (Yuan and Shen, 2010). Therefore, quantification of C&D waste is essential for effective waste management. The estimation results could provide fundamental data for practitioners to evaluate the true size of the waste and hence, make the adequate

* Corresponding author. Address: Room 2126, Academic Building, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong. Tel.: +852 5173 8009; fax: +852 2358 1534.
E-mail addresses: cejcheng@ust.hk (J.C.P. Cheng), yingzi@ust.hk (L.Y.H. Ma).

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decision for their minimization and sustainable management (Jalali, 2007). However, available tools for C&D waste estimation are lacking. Existing tools and methods are not convenient enough for contractors to be willing to utilize without spending too much time and effort since information such as material volume needs to be either measured or retrieved from available documents manually. Building information modelling, however, provides the opportunity to fill this gap.

Building information modeling (BIM) represents the process of development and use of a computer generated model to simulate the planning, design, construction and operation of a building facility. The resulting model, a building information model, is a data-rich, object-oriented, intelligent and parametric digital representation of the building facility (AGC, 2005). BIM technology has been increasingly adopted in the AEC industry in the last decade. In this paper, we present a BIM-based system that we developed for convenient and prompt waste estimation and planning of D&R waste. The system could extract and process the component information of each building element in a digital virtual BIM model for waste estimation. As an example, waste management practices in Hong Kong are also integrated in the system to realize practical waste estimation and planning.

This paper is organized as follows: Section 2 provides a general background of current C&D waste management strategies and limitations in Hong Kong showing the urgent need for a waste estimation tool. Section 3 reviews the current waste estimation methods and their limitations. Section 4 discusses the potential of BIM to facilitate D&R waste estimation and introduces the BIM application programming interface (API) which allows further development of the software with regard to the user's need. Section 4 also presents the system layout and functionalities of our BIM-based waste estimation and planning system. This system can not only serve as a waste estimation tool before demolition or renovation, but also serve as a tool to calculate waste disposal charging fee and pick-up truck requirements. Section 5 demonstrates the features of the BIM-based system through a Revit BIM model of a 47-floor high-rise residential building typical in Hong Kong. Detailed results generated by the system are presented in this section. Section 6 concluded the functions of this system with a short discussion of this system's applicability. Last section concludes this paper with a brief summary and discussion on future work.

2. Needs for C&D waste estimation in Hong Kong

2.1. Prediction of waste disposal charges

Table 1 shows the intake amount of total solid waste and the intake amount of waste from the construction sector at landfills in Hong Kong from 2001 to 2010. In 2010, the mixed construction waste accounted for about 26% by weight of the total waste intake at the existing landfills (HKEPD, 2011). The Hong Kong Environmental Protection Department (HKEPD) introduced the Construction Waste Disposal Charging Scheme (CWDCS) in December 2005 to ensure that disposal of C&D waste is properly priced to reduce the amount of the C&D waste. Table 2 shows the charging scheme imposed by the HKEPD. As shown in the table, C&D waste can be disposed to (1) public fill reception facilities, (2) sorting facilities, and (3) landfills. Fig. 1 shows the distribution of these waste disposal facilities in Hong Kong. The acceptance criterion is based on the percentage of inert waste since inert waste cause much less pollution to the environment than non-inert waste. Common inert C&D waste is concrete, asphalt, sand, bricks, rocks, rubbles, and soil. Common non-inert C&D waste is wood, metal, plastic, and other organic materials. Public fills only accept inert C&D waste. Non-inert C&D waste has to be disposed to either sorting facilities or landfills. Disposal to landfills costs the most while disposal to public fills costs the least. Sorting facilities are seldom used in public projects because the Hong Kong government requires on-site sorting of C&D waste into inert and non-inert for public projects. Only private projects are allowed to use sorting facilities if on-site sorting is not specified in their contracts.

Table 1
The intake amount of waste from the construction sector and the intake amount of total waste at landfills in Hong Kong from 2001 to 2010. *Source*: HKEPD (2011, 2006).

Year	Total waste from the construction sector (Tons per day)	Total solid waste (Tons per day)	Percentage of waste from the construction sector in total solid waste (%)
2001	6408	16,817	38
2002	10,202	21,158	48
2003	6728	17,758	38
2004	6595	17,503	38
2005	6556	17,679	37
2006	4125	15,039	27
2007	3158	13,901	23
2008	3092	13,503	23
2009	3121	13,326	23
2010	3584	13,817	26

Table 2
Construction Waste Disposal Charging Scheme imposed by the Hong Kong Environmental Protection Department. *Source*: HKEPD (2005).

Government waste disposal facilities	Type of construction waste accepted	Charge per ton (HKD)
Public fill reception facilities	Consisting entirely of inert construction waste	$27
Sorting facilities	Containing more than 50% by weight of inert construction waste	$100
Landfills	Containing any percentage of inert construction waste	$125

According to a survey conducted by researchers to evaluate the effectiveness of the Hong Kong CWDCS, there has been a great reduction of construction waste by approximately 60% in landfills, 23% in public fills, and 65% in total C&D waste in the first year when the scheme was executed (Hao et al., 2008). However, the impact only lasted for less than 3 years as the amount of C&D waste started to grow again in the year 2009 (HKEPD, 2011), probably due to the increased amount of C&D works in the recent years in Hong Kong. Contractors are often unaware of the construction waste disposal charging fee. They will know the exact amount of charging fee they need to pay only after waste disposal and receiving the bills from HKEPD. Therefore, contractors often lack motivation and would not spend too much effort for recycling and reuse of C&D waste.

2.2. Recycling practices

Recycling and sustainable use of resources are increasingly promoted in construction activities, and efforts have particularly been made in recycling materials such as concrete, timber and steel. Materials such as steel, wood, and paper are commonly recycled while concrete and soil are commonly reused. Glass and plastics often have a low recycling and reuse rate. However, the recycling and reuse rate varies from site to site and from contractor to contractor. In Hong Kong, records of recycling amount of different materials are often kept by contractors. According to a survey conducted by Tam (2011), except for metal which has a highly profitable recycling market, there is still a lot of room for improvement in increasing recycling rate of other construction waste materials.