Waste Management 34 (2014) 1683–1692

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Quantifying construction and demolition waste: An analytical review

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ARTICLE INFO

Article history:
Received 27 November 2013
Accepted 6 May 2014
Available online 23 June 2014

Keywords:
Construction and demolition waste
Quantification methodology
Review

ABSTRACT

Quantifying construction and demolition (C&D) waste generation is regarded as a prerequisite for the implementation of successful waste management. In literature, various methods have been employed to quantify the C&D waste generation at both regional and project levels. However, an integrated review that systemically describes and analyses all the existing methods has yet to be conducted. To bridge this research gap, an analytical review is conducted. Fifty-seven papers are retrieved based on a set of rigorous procedures. The characteristics of the selected papers are classified according to the following criteria - waste generation activity, estimation level and quantification methodology. Six categories of existing C&D waste quantification methodologies are identified, including site visit method, waste generation rate method, lifetime analysis method, classification system accumulation method, variables modelling method and other particular methods. A critical comparison of the identified methods is given according to their characteristics and implementation constraints. Moreover, a decision tree is proposed for aiding the selection of the most appropriate quantification method in different scenarios. Based on the analytical review, limitations of previous studies and recommendations of potential future research directions are further suggested.

1. Introduction

The stream of construction and demolition (C&D) waste generally results from the construction, renovation and demolition of buildings, roads, bridges and other structures (Peng et al., 1997; Yuan and Shen, 2011). According to its generation phase, C&D waste can be divided into three categories: construction waste (CW), renovation waste (RW) and demolition waste (DW). Typical components in C&D waste are inert materials (e.g., concrete, bricks, etc.), which are generally believed have little damage to the environment (EPD, 2012). Therefore, C&D waste is considered having a "priority" to be recycled according to the EU Waste Strategy (Banias et al., 2011). However, there are also some hazardous components (e.g., asbestos, particulate matters, etc.) in this particular stream. If these components are not disposed of properly, negative impacts will be made on the environment. Consequently, how to establish an effective C&D waste management system, which is environmentally sound and economically feasible, is a global hot topic requiring comprehensive exploration and discussion.

It has been acknowledged that proper quantification of C&D waste is of great importance for establishing an effective management system at both project level and regional level (Bergsdal et al., 2007; Li and Zhang, 2013; Yost and Halstead, 1996). Quantification at project level refers to forecast the C&D waste production in a particular project. It can help the project managers to adjust the material purchase schedule, to arrange the stockpiling on-site and to determine the potential waste recycling benefit and disposal cost. Quantification at regional level refers to estimate the total C&D generation of all projects in a specified region. The information of regional waste generation can assist decision-makers in making more realistic policies, determining the establishment of new waste facilities, and arranging labour and truck resources.

In literature, numerous quantification methodologies have been proposed to quantify the C&D waste generation. However, a systematic review that analyses these methodologies and discusses their application scopes does not yet exist. It is essential for decision-makers to have a clear idea of the characteristics and implementation constraints of the alternative quantification methodologies before choosing an appropriate one. Therefore, a systematic review is of significance to bridge the gap. The objectives of this research are as follows:

- To summarize the existing C&D waste quantification methodologies according to the designated criteria.
- To give a critical comparison and to propose a relevance tree for guiding the stakeholders to select the most appropriate C&D waste quantification method.

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http://dx.doi.org/10.1016/j.wasman.2014.05.010
0956-053X/

- To explore limitations of current research and provide recommendations for potential research directions.

This paper starts with the background of C&D waste quantification, followed by a description of adopted research methodology and an overview of previous research. Then, C&D waste quantification methodologies are summarized and discussed according to three designated criteria. A critical comparison of the identified methods and a proposed decision tree are given for selecting an appropriate C&D quantification method. Finally, limitations of previous studies and recommendations of potential future research directions are suggested.

2. Research methodology

To make a comprehensive understanding of the current C&D waste quantification methodologies, a strict literature retrieval process was conducted based on the two most world-famous indexed databases: the SCI database (http://www.webofknowledge.com/) and the EI database (http://www.engineeringvillage.com). The worldwide publications indexed by these two databases have been peer reviewed and regarded of high quality. The procedure for retrieving relevant paper was as follows.

- Comprehensive search of potential related papers. The potential related papers were searched in the designated databases with a time span of 01/01/1990–31/10/2013. In addition, five international journals were selected for further paper retrieval, including "Waste Management", "Waste Management and Research", "Resources, Conservation and Recycling", "Construction Management & Economics" and "Journal of Construction Engineering and Management". These five journals were selected because they publish the largest number of papers concerning C&D waste management (Lu and Yuan, 2011; Yuan and Shen, 2011). After the scanning of contents issue by issue, more than 200 papers were collected.
- Detailed relevance identification of the collected papers. After the collection of potential related papers, a filtering process was then implemented to identify how the collected papers match the research scope by scanning titles and abstracts. As the scope of this study is reviewing quantification methodologies only on C&D waste, involving total waste stream and individual components, papers on quantifying other wastes streams (e.g., municipal solid waste) have been excluded. After this filtering process, 49 papers were left for further investigation.
- Cross-referencing examination of retrieved papers. A cross-referencing examination was further conducted to ensure the comprehensiveness of the research. All references cited by the selected 49 papers were browsed manually, then the titles of potential related articles were aggregated into an Excel table to avoid duplication. After reviewing their abstracts, additional 8 papers were found, and a total of 57 papers was then subjucted to an in-depth analysis.

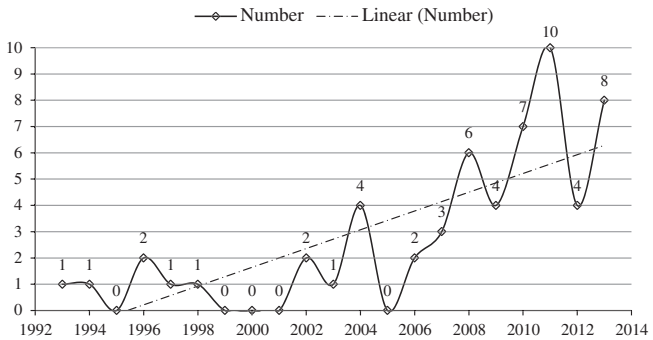

Fig. 1. Trend of research interest on C&D waste quantification.

A brief analysis has been made to reveal the research interest trend of C&D waste quantification, a graph of publishing year versus number of papers was plotted, as shown in Fig. 1. It can be concluded that this topic has been receiving continuous interest in the recent six years.

3. Classification of the selected studies

After a systematic review of the retrieved 57 papers, three characteristic classification criteria of the current literature were revealed: waste generation activity, estimation level and quantification methodology. Corresponding descriptions are given in the following sections and the selected papers are classified in Table 1 based on the identified criteria.

3.1. Waste generation activity

The C&D waste stream is produced throughout the lifecycle of a project, involving construction, usage/maintenance and demolition. During the usage/maintenance stage, waste is rarely generated unless renovation activities are implemented (Su et al., 2012). As a result, according to the waste generation amount, three primary waste generation activities can be classified: (i) construction of new buildings, (ii) demolition of old buildings, and (iii) civil and infrastructural works.

- Construction of new buildings. The generation of waste during construction phase is considered unavoidable (Tam and Tam, 2006). Typical causes of waste production in this phase include timber formwork, wet trade of finishing, concrete work, masonry work and material handling, accounting for 30%, 20%, 13%, 13% and 10% respectively (Poon et al., 2004a). Mokhtar et al. (2011) found that construction method, project size, building type, material storage method, human error and technical problem are the main factors that affect the waste generation of newly constructed buildings. Furthermore, studies have revealed that the attitude and behaviour of on-site workers can play an important role in producing waste as well (Al-Sari et al., 2012; Teo and Loosemore, 2001). In practice, the contractors usually assume that the wastage rate is equivalent to 1–10% of the purchased construction materials (Shen et al., 2005). The specific percentage is determined by their previous experiences derived from direct measurement on site. However, such information is not robust for making an effective waste management plan, classification systems have been introduced to tackle this problem (Llatas, 2011; Solis-Guzman et al., 2009).
- Demolition of old buildings. The demolition activities can produce a large amount of waste. Appropriate processing should be adopted to reduce the environmental impact because of the existence of hazardous substances (Trankler et al., 1996). Nearly 100% of the demolished structures were ended as waste except some materials that have mature secondary market (e.g. wood, metal, etc.) (Poon et al., 2004b). Selective demolition is regarded as an effective solution to reduce and recycle demolition waste (Kourmpanis et al., 2008a). However, in developing countries, blasting demolition is often employed because this method requires less time and labour. Therefore, the