Automation in Construction 35 (2013) 142–156

Contents lists available at ScienceDirect

Automation in Construction

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

Web-based construction waste estimation system for building construction projects

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ARTICLE INFO

Article history:
Accepted 3 May 2013
Available online 26 May 2013

Keywords:
Construction waste
Decision support system
Estimation
Online analytical processing
Sustainable development

ABSTRACT

This paper proposes a web-based construction waste estimation system (WCWES) for building construction projects incorporating the concepts of work breakdown structure, material quantity takeoff, material classification, material conversion ratios, material wastage levels, and the mass balance principle. The WCWES integrates online data input modules and online analytical modules for the quantification of different kinds of waste generated in the construction process at the project level. It facilitates accessibility, interfacing, connectivity and information sharing of users in carrying out a wide range of construction waste estimation tasks for sustainable construction waste management. A hypothetical building construction project is used to demonstrate the application and usefulness of the WCWES.

1. Introduction

Construction waste is a major source of municipal solid waste in all the megacities around the world, frequently accounting for 10% to 30% of the total waste landfilled. For example, in Hong Kong, construction waste consists of 30% to 40% of the total waste. In 2005, construction waste delivered to landfills was 6556 ton/day, which was 37.08% of the total waste landfilled (17,503 ton/day) [25]. In Chicago, 4,656,037 tons of construction waste was generated in 2007, accounting for 60.71% of the total waste (7,669,097 tons) generated that year [4]. The large amounts of construction waste are a big challenge to the sustainable development of many large cities in both developed and developing countries/regions.

Efficient construction waste management necessitates a systematic approach supported by various decision making tools. One such tool is a practical construction waste estimation system, which would be quite useful for both the government and the construction industry in accurately quantifying and effectively managing construction waste. From the perspective of the government, relevant authorities can establish appropriate policies, guidelines, strategies and codes of practice for sustainable construction waste management based on informed estimation of construction waste, for example, in the development of optimal waste treatment facilities and in the determination of the right level of waste charge. From the perspective of the construction industry, construction companies can take active waste prevention, reduction and utilization plans within and across construction projects to deal with the various kinds of estimated waste to be generated from different projects.

A number of methods have been proposed to quantify construction waste generation. These methods can be broadly divided into three categories:

(1) The first waste estimation method is to estimate the total waste from a construction project as a percentage of the total amount of construction materials consumed in this project. Through a survey of some construction projects, the average waste percentage of the total amount of construction materials consumed in these projects can be determined. This average percentage is then used to estimate the total waste to be generated from other construction projects. For example, Bossink and Brouwers [1] analyzed the total quantities of construction waste from five housing projects from April 1993 to June 1994 and concluded that waste from a construction project lies between 1% and 10% of the purchased materials in the Netherlands.
(2) The second waste estimation method is based on some generic project parameter/variable (e.g., the floor area of a building project) to predict the total quantity of waste from a construction project. In general, the total construction waste from a construction project is equal to the product of the quantity of this generic variable and the waste per unit quantity of this generic variable. For example, construction waste estimation models based on the construction area of a project have been developed in Greece by Fatta et al. [8] and Kourmpanis et al. [13], in Spain by Villoria Sáez [23] and in Thailand by Kofoworola and Gheewala [12]. Specifically, in these models, the total amount of waste from a construction project is calculated by multiplying the total construction area of this project by an estimated quantity of waste per unit of the construction area. Besides the construction floor area, the wastage level [14,19,21], structure type & function [9] and construction stage [11] can also be utilized to estimate construction

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http://dx.doi.org/10.1016/j.autcon.2013.05.002

waste generation.

(3) The third waste estimation method is based on some macro-level variables to predict the total construction waste generated from an industry, region or country. One common macro-level variable is the population size (Martínez Lage 2010) [16]. Other macro-level variables include construction project permits [24] and construction material productions [7,20]. Specifically, Bruvoll and Ibenholt [3] and Ibenholt [10] presented a multi-sectoral equilibrium model that employs macroeconomic variables such as real capital invested, labor used, material input, energy consumption and purchase prices to forecast waste generated in the Norwegian manufacturing industry.

In addition to these theoretical estimation methods, SMARTWaste is utilized as a tool in construction waste management [2]. The SMARTWaste system tends to improve contractors' waste management strategy by means of defining their environmental and other key performance indicators (EPIs and KPIs) and quantifying major waste components' sources and management methods. This system requires the user to input waste generation amount in order to generate the site waste management plan.

In view of the fact that the construction industry is project-based, this paper proposes a web-based construction waste estimate system (WCWES) for building construction projects. As a supportive platform, the WCWES integrates online data input modules and online analytical modules for the quantification of different kinds of waste generated in the construction process at the project level. Furthermore, the WCWES facilitates accessibility, interfacing, connectivity and information sharing of users in carrying out a wide range of construction waste estimation tasks for sustainable construction waste management.

2. Overall methodology of building project waste estimation

Zhang and Li [27] developed a quantitative construction waste estimation model for building construction projects. The overall methodology of this project-based waste estimation model is shown in Fig. 1. Specifically, this model integrates the following concepts: work breakdown structure (WBS), material quantity takeoff, material classification, material conversion ratios, material wastage levels in each terminal work package and the mass balance principle. The project-based waste estimation model is able to predict the various kinds of waste generated in each work package of a building construction project. Details of this project-based construction waste estimation model are discussed in the following sections.

3. Construction waste estimation according to work packages

3.1. Construction waste from terminal work packages

Work packages at the lowest practical level of the WBS of a building project are referred to as terminal work packages. The quantity of construction waste of a particular kind of material from a terminal work package is a function of the quantity of this material used in this terminal work package and the wastage level of this material in this terminal work package. The wastage level is the percentage of the quantity of a material used in a terminal work package that becomes waste. Basic procedures to estimate construction waste from a terminal work package are discussed in the following:

Step 1: Develop the WBS of a building construction project
A building construction project can be broken down into four hierarchical levels [26]: system, component, element and sub-element. The sub-element is the terminal work package. Specifically,

(1) A system s of a building is denoted as W_s, where $s = 1, 2, \ldots, S$, and S is the total number of systems in this building.
(2) A component c in system s is denoted as W_c^s, where $c = 1, 2, \ldots, C_s$, and C_s is the total number of components in system s of a building.

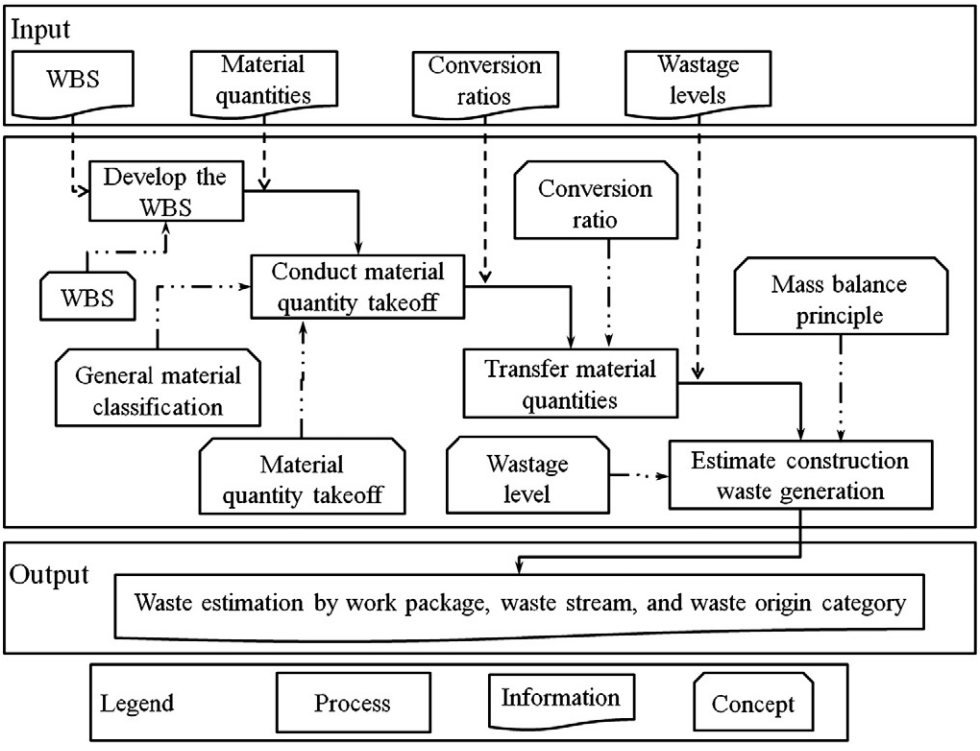

Fig. 1. A quantitative construction waste estimation model.