Quantification of Waste in Conventional Construction

Siti Akhtar Mahayuddin and Wan Akmal Zahri Wan Zaharuddin

***Abstract*—Construction waste is generated throughout the construction process such as during site clearance, material use, material damage, material non-use, excess procurement and human error. The exact quantity and composition of construction waste generated throughout the projects are difficult to be identified as they are keep on changing due to the dynamic nature of the construction activities. Different stages of construction generates different types and composition of waste. Therefore the trend of waste generated throughout the construction stages need to be identified. This paper will critically review literature on construction waste in order to understand the nature of waste generation from construction activities. Based on the literature studied, this paper propose a method to quantify waste for conventional construction. The proposed method comprises four steps. First is identification of construction stages and expected waste generated. Second is selection of construction sites with similar characteristics for uniform investigation. Third is sorting and weighing of mixed waste collected in a dumpster. The last step is summation of the recorded quantity. It is expected that the proposed method should be practical and suits current situation of Malaysian construction projects and support the agenda of National Strategic Plan for Solid Waste Management.**

***Index Terms*—Construction waste management, conventional construction, quantification method, waste generation.**

I. Introduction

Construction industry contributes significantly to environmental stress in term of exploiters of natural resources, irreversible transformation of the natural environment and accumulation of pollutants in the atmosphere [1]. In addition, construction activities contribute negative impact on the environmental such as loss of soil, loss of agricultural land, deforestation and air pollution. This industry is also the major consumer of the world's non-renewable energy sources and minerals. Other negative impacts to the environment are generation of waste, ecological imbalance, changes in living environment, sewage, reduction in environmental resources and energy usage [2]. Solid and chemical waste from construction are found to be the sources of contamination in construction site [3]. Construction waste is generated throughout the construction process such as during site clearance, material use, material damage, material non-use, excess procurement and human error [4]. The largest contributor to the generation of construction waste is the building material surplus.

Construction projests are essentially a one-off events, after completion there will be little evidence of what actually transpired. The short period of construction projects, normally 24 to 36 months with different stages of construction makes estimation of waste quite difficult and inaccurate. The exact quantity and composition of construction waste generated throughout the projects are difficult to be identified and keep on changing due to the dynamic nature of construction activities. Different stages of construction generates different types and composition of waste. The variability in the quantity of construction waste generated also depends on the efficiency of site management and work practices during construction activities. Ineffective waste management practiced at construction sites exacerbates the generation of construction waste [5]. However, the generation of construction waste is predictable based on the building design and procurement of the building materials.

The nature of waste composition might be different at various construction stages. Thus, the trend of waste generation throughout the construction stages need to be identified. Based on literature, this paper discusses various quantification method of construction waste. It also focused on the concepts and practicality of construction waste quantification method for conventional construction in perspectives of Malaysian construction industry. This paper also will address future direction in quantification of waste in conventional construction taking into consideration of two research questions. The questions are why the current approach has limitation in identifying the waste generation trend and how new approach can quantify waste holistically.

II. Review on Construction Waste Quantification

A review on relevant journal articles on construction and demolition waste which focused on the quantification method provide basis of understanding to various concepts. The literature review also focused on construction waste management measures for generation rate, type and stages of construction, building material characteristics, construction management, evaluation of waste management and National Strategic Plan for Solid Waste Management [6] in Malaysia. This is to ensure that the propose quantification method of waste will be practical and applicable to conventional construction in Malaysia. So that the construction waste quantified can support the agenda of National Strategic Plan for Solid Waste Management.

The quantification of construction waste needs to be done early in the construction project but it is difficult to determine the exact quantity generated as well as the exact composition of construction waste at construction sites. Without the ability to specifically identify the characteristics of construction wastes being generated on construction sites, the site management would be unable to accurately track,

Manuscript received January13, 2013; revised March 12, 2013.

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monitor and quantify the total amount of wastes generated. Hence, accurate waste measurement would provide an effective method to evaluate the production system performance as it shows the improvement potential and identification of the major inefficient factors [7]. Construction waste quantity acts as an indicator to benchmark the construction waste management practices whether standard, good or best practices.

The prediction condition of solid waste generation trend in many developing countries is quite different from those in developed countries due to lack of sampling and analysis [8]. Therefore the historical record of solid waste generation and composition can never be completed in the long term. Earlier researcher has used various methods in quantifying construction waste. Various approach and methodology have been employed in the estimation and evaluation of construction waste. Among the early approach is sources of waste framework which based on a generic flow pattern of construction material on site [9]. Complete inventory by sorting and weighing of waste at construction site able to provide details characteristics of waste generated [5], [7], [10]. However limited numbers of waste were covered in the inventory and static evaluation. Waste quantification also can be conducted through site audit where regular site visit, check list and estimation on the disposal record were conducted to produce construction waste index [11].

It is difficult to compare directly the waste generation rate between countries because of the various techniques, work procedures and construction practices employed [12]. For example, the generation of construction waste in Kuwait is higher than the total international quantity due to the Gulf War and the lack of material management in the construction industry [13]. The composition and quantity of construction waste generated on sites depend on the construction methods and materials used during construction activities [7]. The difference in waste composition is also caused by the different construction methods and technology used, workers' skill and building designs [14]. In fact, the distribution of data is not influenced by the geographical situation but is dependent on the type of house, specific practice by the contractors and lack of uniform standards in disposal and storage of the waste samples [15]. But experience, information and technologies related to the management of construction waste from various countries can be shared to help overcome the problems caused by the generation of construction waste.

Construction waste can be estimated either for its generation quantity or disposal quantity [16]. The generation quantity refers to the construction site, number of projects and generation rate per capita. However it is difficult to obtain data on quantity of waste generated at construction site [17]. In addition, lack of readily available data on construction waste limit the quantification method of construction and demolition waste [18]. Meanwhile construction waste disposed can be quantified based on the record at disposal site and waste flow.

Construction waste generation rate based on floor area is limited to building construction only and not applicable to infrastructure construction such as bridge and road. The construction waste generation rate, kg/m^2 can be used in estimating the quantity of waste generated in a region [18]. The rate is also used to estimate construction waste generated in a smaller scale. The quantification method needs to be modified according to the availability of data during the study. The amount of construction waste also can be quantified by considering the generated quantity of waste, floor area of new construction, volume of construction waste generated for every $100m^2$ floor area and the density of waste generated ($tonne/m^3$) [17].

The quantification of construction waste also can be estimated by quantifying the building area and building demolition works and converting the construction and demolition waste quantitative data from cubic metres to tonnes [19]. Another method of estimation is through the use of a construction waste index [20]. Construction waste index helps the project manager to estimate the projection of waste for future construction works and to create waste management awareness [20]. The quantities of waste in construction can be estimated by the transportation records of waste disposed off from the construction sites [21]. Material flow analysis is another approach to characterize waste [22]. Another method is accounting, generation and composition of construction and demolition waste a regional level [18].

System dynamic approach which was first introduced in 1958 by Forester found to be popular approach in the evaluation of waste [23]-[26]. This approach is concerned with creating models or representations of real world systems and studying their dynamics. The system dynamic model is able to deal with the complexity for the inter relationships and dynamics of any social, economic and managerial system. This dynamic model integrates major variables that affect construction and demolition waste reduction [26]. This approach is also used in a framework model for Newark urban region in the US and running a forecast simulation [24]. They incorporates the complexity of waste generation and management process in the dynamic system.

The prediction of waste flow can be modelled through the building elements at the construction stages [27]. Quantification of waste at every building elements is necessary as construction activities are dynamic [28]. With reference to the European waste list, the researcher employ a systematic structure on the construction process, waste classification system and analytical expression based on factors before waste sorting and weighing according to the list at every building element. This approach is applicable if there is a standard list of waste.

III. Waste Quantification for Conventional Construction

In Malaysia, conventional construction refers to the reinforced concrete frames and brick as infill, beam, column and roof which are cast in-situ using timber formwork while steel reinforcement is fabricated on-site. This type of construction involves three major trades on-site namely steel bending, formwork fabrication and concreting. These major activities generate large amount of construction waste. However, readily available data on construction waste quantity and composition generated on construction sites in Malaysia is limited. The waste quantity generated from the

construction activities need to be quantified for development of appropriate waste management for the construction project. A unified measurement for waste generation is needed so that waste management performance can be compared across various economies [29].

Based on the quantification method reviewed from research in construction and demolition waste and present situation of construction industry in Malaysia, successful, practicable and unified quantification of waste in conventional construction should address the following questions.

1) What are the expected waste for every stage of construction
2) Parameters or Indicator and prediction model of waste generation should be developed to help construction personnel in proper planning of construction waste management.
3) Standard parameters for construction stages, the building elements, construction activities and its expected major types of construction waste should be identified and developed.
4) Quantification of construction waste should be conducted for every stage of construction. Uniform observation and quantification can be conducted.
5) Cooperation from the construction personnel.
6) Standard classification of construction waste type.

Various parameters in quantifying waste in conventional construction also need to be identified. Therefore, the proposed quantification of waste in conventional construction can be conducted in four steps.

A. Identification of Construction Stages and Materials Used

Conventional construction involve major trade on-site so the stage of construction and major building materials used need to be identified. The identification of the building materials used will facilitate the prediction of types of waste generated on-site. Then the trend of waste throughout the construction stages can be identified. Studying the construction processess in building elements will provide a datum of waste sources with high degree of reliability [28]. The construction stages can be identified as site clearance, sub-structure works, super-structure works, finishing works and infrastructure works. Table I below shows the expected waste for every stage of construction.

TABLE I: EXPECTED WASTE GENERATED FROM CONVENTIONAL CONSTRUCTION

Construction stage	Expected major construction waste
1-site clearance	Soil, rock
2-sub-structure works	Reinforced concrete, steel bar, concrete, wood
3-super-structure works	Wood, steel bar, cement, sand, aggregate, brick
4-finishing works	Cement, sand, aggregate, tiles, paint, lime
5-infrastructure works	Bituminous materials, timber, concrete

B. Identification of Construction Sites

As construction projects are dynamic and completed in short period of time, a simultaneously waste investigation is proposed. At least 5 construction sites with similar characteristics are needed. All the sites must be at different stage of construction. So the selection of construction sites should possess the following characteristics:

- Different state in Malaysia, to avoid the effect of local work traditions and habits
- New residential projects
- Projects are at different stage of construction
- All sites must represent conventional construction method
- Waste is removed routinely from the construction site in special dumpsters by an independent sub-contractors

C. Weighing of Construction Waste

The quantification will use weight per construction area approximation. The gross floor area of the project needs to be calculated from the building plan and recorded in the inventory form for calculation of waste generation rate. All the waste should be classified for systematic and adequate quantification. Then waste quantification for every stage of construction should be conducted by following these four steps:

- Provide adequate dumpster for collection of all types of construction waste. This is due to space constraint for dumpster placement and to minimise interference to construction activities.
- Sort the mixed waste and weigh
- Record in an inventory form
- Summation of waste quantity

D. Calculation of Waste Generated According to Each Stage of Construction.

- Data from the inventory forms will be added
- together to get the quantities of waste generated for every stage of construction
- The construction waste generation rate will be calculated by using the following equation (1), adapted from previous research [21].

$$C = \frac{W}{GFA} \tag{1}$$

where:

W = total waste generated from each construction stages of the project (tonne)
GFA = gross floor area
C = waste generation rate (i.e. construction of 1 m^2 gross floor area generates C tonne of waste)

IV. CONCLUSION

Previous studies show that waste quantification is possible despite the difficulties. This paper proposes waste quantification method for conventional construction. It is expected that the quantification of waste for various stages of construction will contribute additional knowledge on waste generation rate and trend. In conclusion, the potential application of waste generation rate and trend could benefits contractors, properties developers, consultants and local authorities in prediction of waste generation and facilitate future planning of waste management.

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