ECO-COSTS OF SUSTAINABLE CONSTRUCTION WASTE MANAGEMENT

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ABSTRACT: Sustainable waste management encourages the generation of less waste, the reuse of consumables, and the recycling and recovery of waste that is produced. In order to support the declaration of Agenda 21, specifically focused on the environmentally sound management of solid wastes, the United Kingdom (UK) has implemented the European Union (EU) strategy by developing the idea of a basic 'waste management hierarchy'. This paper will discuss construction waste management that involves five important elements, namely process, policy, technology, impact and cost. The objective of the study will take into account all possible environmental costs involving the six important elements mentioned above. A framework for developing construction waste management eco-costs will also be presented and discussed.

Keywords - construction, waste, management, sustainable.

1. INTRODUCTION

Sustainable development is a process that takes the issue of the environment as a priority. One of the key themes of 'sustainable development' is managing waste (Williams, 1998). Sustainable waste management encourages the generation of less waste, the reuse, recycling and recovery of waste that is produced. Farmoso et al. (1999) defines waste as any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client. Symond (1999) defines wastes as any substance or object, which the holder intends, or required to discard. Construction activity requires and consumes a large amount of natural resources. Besides its negative impact on the environment due to the depletion of natural resources, it may increase the amount of waste and pollution if there are no measures taken to tackle the problem. Hence, this paper, reviews construction waste minimisation strategies, addresses the issues that are related to construction waste management and presents an integrated approach to whole life cycle management of construction waste. Finally, an attempt is made to model the eco-costs associated with construction waste.

2. WASTE MINIMISATION BY THE GOVERNMENT.

The European Environment Agency, EEA (2002) defines waste minimisation as a broader term than prevention, which includes; prevention, reduction at source, re-use of product, quality improvement and recycling. The idea of 'sustainable development' has been incorporated into the theme of the Waste Strategy 2000 for England & Wales. This requires countries within the EU to give careful consideration to the environmental impacts of waste disposal. The UK has implemented the EU strategy by developing the idea of a basic 'waste management hierarchy'. This encompasses the processes of reduction, re-use, recycling and recovery, in that order of priority as shown in Figure 1.0.
The challenge now is to move the management of waste further up the waste hierarchy. The top priority is to reduce the quantity of waste produced. The second step is re-use, through delaying the material from entering the waste stream. The third step, recovery, includes composting, recycling and energy recovery. The least desirable option for waste management is disposal to landfill or incineration.

3. WASTE AND THE CONSTRUCTION INDUSTRY

In general all construction activities that produce cost whether direct or indirect, but do not add value or progress to the product can be called waste (Serpell and Alarcon, 1998). In the construction industry, waste may arise from any activity or process from one or more of the following (Wyatt, 1974); manufacturer, designer, construction process and client (the use of building). Gavilan and Bernold (1994) and Craven et.al (1994) describe the main causes of waste generation, which among others include error in contract document, changes to design, ordering error, accidents, lack of site control and lack of waste management, damage during transportation and off cuts from cutting materials to length. However, Chen et al. (2002) emphasise that construction waste is still beyond control because of three factors, firstly construction firms are reluctant to adopt low-waste disposal techniques as it is expensive to use; secondly, design coordination has a major impact on waste generation; thirdly, on-site construction waste. In the handling and distribution of components from the manufacturer or supplier to the site, potential loss or damage to the materials may be unavoidable. Figure 2.0 shows the life cycle of construction and demolition (C&D) waste. As can be seen from Fig. 2.0 the life cycle the waste management process starts at a very early stage of construction material manufacturing, followed by design specifications that minimise waste. At this stage all necessary actions should be taken to weed out waste from the construction process. The following stages are concerned with waste disposal strategies at the construction and operation phases. The following sub sections will describe waste life cycle components in more detail.

3.1 Manufacturing Waste

Manufacturing waste is classified as an unavoidable type of waste, arising from a range of sizes and shapes of material and component. The different sizes and shapes are due to the requirement of the designer and construction practice on site. Ideally, unavoidable waste arises from the
factors outside the control of the parties involved in construction. Waste from the manufacturing sector occurs mostly at offsite construction. Wyatt (1974) categorises waste generated from this sector under two levels: in the manufacturing process from the mining or extracting of raw material through to the processing of material for use; in the production process of the manufacture of a component in the factory environment. The amount of waste at the manufacturing stage is significant. For example, timber-manufacturing facilities generate large amounts of wood residues as a by-product of processing round logs into square and rectangular shaped timber products. Materials like steel and copper originate from ores, and require extraction during the manufacturing stage. Manufacturing may have undesirable side effects such as emission of pollutants into the atmosphere and waterways.

![Diagram of life cycle of construction and demolition (C&D) waste](image)

**Figure 2: Life cycle of construction and demolition (C&D) waste [Adopted from Treloar et al. (2003)]**

### 3.2 Design Waste

The design and specification stage would contribute to the reduction of waste onsite. Skoyle and Skoyle (1987) categorise waste at this stage as direct waste. Direct wastes will generate direct costs. Direct costs are defined as costs that have a direct impact on the construction process (McGrath and Anderson, 2000). Inadequate consideration at the design stage may lead to various levels of waste; excessive cutting, rejection of poor quality materials, excessive excavation and
many more. This has also been identified as one of the factors influencing the generation of waste onsite.

3.3 Construction Process

Material waste in the construction process comes from many different sources and can be classified into several categories. Poor management on handling material may lead to loss by damaging the material. Lack of material control can also lead to waste due to theft and vandalism. Some researchers have also identified faulty conversion of measuring units as a cause of on-site waste. For example, the measuring unit used during the design stage has to be converted to the unit used onsite; i.e. m³ to tonnes. Failure to protect items during installation and unnecessary cutting instead of looking for suitable available materials is also identified as a main source of waste. When working with bulk materials, working to incorrect dimensions has been identified as waste. Excessive excavation may lead to materials removed and possibly backfill. The total amount of waste that builds up on a site can be significant in reality and can cost a lot of money to dispose.

Construction wastes are also related to all types of generated wastes from the construction, remodelling and repairing of individual residences, commercial buildings, and other civil engineering structures. Though it seems that construction waste makes a smaller contribution to the generation of C&D waste it is still important to quantify and analyse despite the lower volumes in comparison with demolition waste. Some construction sites take the simplest way of disposal of material e.g. timber, plywood and such like, by burning on-site. Even in practice, some authorities has given permission to allow burning activities, provided that dark smoke does not arise, but it still may harm the environment and the surrounding areas as burning releases some toxic gases into the atmosphere. This could also cause depletion of natural resources.

3.4 Demolition Waste

Any wastes from razed buildings are normally defined as demolition wastes (Spivey, 1974; Oglesby et al., 1989; Spencer, 1989,1990; Apotheker, 1990; Kalin, 1991; Wood, 1992; Gavilan and Bernold, 1994; Huang et al., 2002). C&D activity is one of the major waste contributors to landfill sites. It has been classified as one of the major types of waste in the European Waste Catalogue (EWC). The European Environment Agency (EEA) has stated that total waste generation by European Union countries is about 1300 million tonnes per year where, C&D and manufacturing industries generate half of the total waste (EEA, 2001). Research figures shown by Boussink and Browers (1996) indicate that the weight of generated demolition waste is more than twice the weight of generated construction waste.

4. A FRAMEWORK FOR SUSTAINABLE CONSTRUCTION WASTE MANAGEMENT

Construction activities are closely related to the amount of waste generated (Poon, 2003). Environmental cost related to environmental impacts of waste from construction is one of the important issues in whole life cycle costing. The philosophy of construction waste management consists of five important elements that are closely related amongst each other. All these elements fall into the whole life cycle risk management category, where risk management is a
part of the techniques used nowadays to assist decision makers in evaluating whole life alternatives in order to maximise the investment success in a building asset. Hence, the study will propose a framework for construction waste management that will be implemented into the construction project at the construction stage as shown in Figure 3.0 The framework consists of the following components:

4.1 Identification Of Construction Waste Management Processes

The process begins with the identification of the operations or activities involved in the typical construction process. Ideally, the best example of the construction process is building construction. Building construction involves many activities that could also involve many parties like main contractors, sub-contractors and statutory undertakers. Activities may broadly be grouped as: site preparation, road and sewer; substructure work; superstructure; internal carcassing and service installation; finishing; energising phase prior to handling; landscaping and completion of external works.

4.2 Investigation Of Waste Management Policies

At this stage, investigation will be made to identify current policy on handling the waste especially with respect to construction activities. In-depth review of policy taken by the respective parties in some countries will be made including the aspect of conserving landfill space from construction and demolition (C&D) waste. Encouraging the relevant bodies to adopt waste sorting before disposal, economic incentive on which landfill charging system is used,
introducing the preparation of a waste management plan during the bidding process, where the authorities could evaluate how each bidder would approach the management of waste. Investigation on the strategy taken by some governments will be made in order to compare and broaden the idea on how to tackle waste. For example, the Waste Strategy 2000 for England & Wales describes the policies concerning the recovery and disposal of waste. These policies are a requirement of all countries in the European Union (EU).

4.3 Construction Waste Management Technologies

The choice of the most suitable technologies for dealing with waste is among one of the major planning problems. Generally, many technologies that are either currently available or have been proposed for the reclamation, treatment, or disposal of solid waste are here discussed under a number of headings, namely: recycle and reuse, landfill, transfer or treatment prior to landfill and incineration.

4.4 Determination Of Environmental Impact Of Construction Waste

Major potential sources of pollution from construction process are; waste materials, emissions from vehicles, noise and release of contaminants to atmosphere, ground and water. Though construction waste makes a smaller contribution to the generation of C&D waste than demolition waste, this research focuses on construction waste. Construction waste is an important topic to quantify and analyse despite the lower volumes in comparison with demolition waste, since; construction waste is more difficult to recycle due to high levels of contamination and a large degree of heterogeneity. Prevention of construction waste is preferable to recycling of demolition waste "at the end of the pipeline". Construction waste contains a relatively larger amount of chemical waste, a cost reduction caused by preventing the generation of construction waste is of direct benefit for most of the participants who work at the construction project (Brooks et al. 1994).

4.5 Ecological Costing Of Construction Waste Management

The combination of mounting waste, environmental cost, emission and reduction of resource etc. has created an interest in eco-costs of asset ownership. The ecological cost includes the direct and indirect environmental cost of the construction process, which includes pollutant and impact output from the construction process. Eco-costs of the construction process will include the following stages: building production cost of energy, packaging, transport, waste and emissions; eco-costs at construction stage, due to the resources expended in the building process, transport and waste; eco-costs at reuse, recycling and disposal stage.

4.5.1 Conceptual Eco-Costs In Construction Process

Construction is a unique process. Different types of construction involve different types of activities. Each activity requires many types of resources; from materials, labour, time, cost capital etc. At the construction stage, whether in the form of indirect or direct, negative impact on the environment will occur. One important element that should be considered in order to assist decision makers in the building industry is the environmental cost or the eco-costs of
construction wastes. Each of these elements has its own cost breakdown that contributes toward
the main heading of cost structure of the eco-costs. The identification of these elements of each
category will help to clarify the specific cost related to the environment during the construction
stage.

The cost structure of the eco-costs of construction waste at the construction stage includes
[Adopted from Senthil Kumaran, D et al. (2000)]:

\[ C_{wc} = \Sigma \text{Cost of waste control} \]
\[ C_{wt} = \Sigma \text{Cost of waste treatment} \]
\[ C_{rr} = \Sigma \text{Cost of recycling and reuse} \]
\[ C_{wd} = \Sigma \text{Cost of waste disposal} \]
\[ C_{r} = \Sigma \text{Cost of rehabilitation} \]
\[ C_{i} = \Sigma \text{Cost of impact} \]
\[ C_{ep} = \Sigma \text{Cost of eco policy; taxes and levy} \]
\[ C_{e} = \Sigma \text{Cost of energy} \]

The eco-costs breakdowns of each variable are as follows:

\[ \Sigma \text{Cost of waste control, } C_{wc} = C_{wc1} + C_{wc2} + C_{wc3} \]  \hspace{1cm} (1)

Where, \( C_{wc1} = \text{cost of waste control system implementation} \)
\( C_{wc2} = \text{cost of waste control system operation} \)
\( C_{wc3} = \text{cost of waste control system maintenance} \)

\[ \Sigma \text{Cost of waste treatment, } C_{wt} = C_{wt1} + C_{wt2} + C_{wt3} \]  \hspace{1cm} (2)

Where, \( C_{wt1} = \text{cost of waste treatment system implementation} \)
\( C_{wt2} = \text{cost of waste treatment system operation} \)
\( C_{wt3} = \text{cost of waste treatment system maintenance} \)

\[ \Sigma \text{Cost saving of recycling and reuse, } C_{rr} = C_{rr1} - ( C_{rr2} + C_{rr3} ) \]  \hspace{1cm} (3)

Where, \( C_{rr1} = \text{cost of implementation/operation} \)
\( C_{rr2} = \text{cost of saving from recycling strategies} \)
\( C_{rr3} = \text{cost of saving from reuse strategies} \)

\[ \Sigma \text{Cost of waste disposal, } C_{wd} = C_{wd1} + C_{wd2} + C_{wd3} \]  \hspace{1cm} (4)

Where, \( C_{wd1} = \text{cost of waste collection} \)
\( C_{wd2} = \text{cost of waste transportation} \)
\( C_{wd3} = \text{cost of waste landfill or incineration} \)

\[ \Sigma \text{Cost of impact, } C_{r} = C_{r1} + C_{r2} \]  \hspace{1cm} (5)

Where, \( C_{r1} = \text{cost of all damage like accidents, health disorder} \)
\( C_{r2} = \text{cost of production losses caused by the damage} \)

\[ \Sigma \text{Cost of eco policy, } C_{ep} = \text{any cost involving taxes, levy, penalties etc.} \]  \hspace{1cm} (6)

\[ \Sigma \text{Cost of energy, } C_{e} = \Sigma C_{ei}, \ i = 1 \text{ to } n \text{ (energy consumption and production)} \]  \hspace{1cm} (7)
The cost breakdowns of eco-costs for construction waste during construction stage are based on the following simple eco-costs algorithm:

$$\text{Total of Eco-costs} = C_{wc} + C_{wt} + C_{wd} + C_{ep} + C_{e} + C_{r} + C_{t} + C_{i} + C_{r}$$  \hspace{1cm} (8)

The above modelling attempt will be further developed and refined to include all the elements related to eco-impacts that are linked to construction waste. It is anticipated that a format will be developed for quantifying all the construction eco-costs attributes. This format will be submitted to construction waste stakeholders for comments and data gathering.

5. CONCLUSION

Research on construction waste management is part of the contribution of the construction industry towards sustainable development. It is the author's intention to develop a sustainable waste quantification eco-costs model based on an empirical study approach in the construction stage. The implementation of the above eco-costs algorithm will be made in each of the activities during the construction processes. The literature review has shown that data availability on material waste in the building industry is relatively scarce and most of the current research has focused on a fairly limited number of materials in a few construction sites. Past research shows that, the construction waste management is a broad and unique problem to be solved in order to make development sustainable in the future. It is also the author's hope to complete this research with the cooperation of construction waste stakeholders.

6. REFERENCES


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