A benefit–cost analysis on the economic feasibility of construction waste minimisation: The case of Malaysia

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Abstract

Construction waste is becoming a serious environmental problem in many large cities in the world. In Malaysia, the construction industry generates lots of construction waste which caused significant impacts on the environment and aroused growing public concern in the local community. Thus, the minimisation of construction wastes has become a pressing issue. This paper is based on a case study which involved construction waste generation and composition as well as reuse and recycling in the site. The case study also analysed the economic feasibility of waste minimisation such as reusing and recycling of construction waste materials by performing a benefit–cost analysis. This study provides an idea of the amount of waste generation, sources and compositions as well as reuse and recycling of materials on the construction sites taking into account the economic dimension. The study shows that waste minimisation is economically feasible and also plays an important role for the improvement of environmental management. In this view, economic instruments for minimising construction waste can be used to raise revenue for environmental policy, encourage prevention efforts, serve to discourage...
the least desirable disposal practices, as well as to avoid the negative consequences of environmental
unfriendly treatment and disposal practices of construction waste materials.
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Keywords: Waste generation; Construction waste materials; Reduce, reuse and recycling; Benefit–cost analysis

1. Introduction

Construction waste is becoming a serious environmental problem in many large cities
in the world (Chen et al., 2002; Ferguson et al., 1995; Shen et al., 2000, 2002; Smallwood,
2000; Wong and Tanner, 1997). According to statistical data, construction and demolition
(C&D) debris frequently makes up 10–30% of the waste received at many landfill sites
around the world (Fishbein, 1998). In Malaysia, the construction industry generates a lot
of construction waste which cause significant impacts on the environment and increasing
public concern in the local community. Thus, the minimisation of construction waste has
become a pressing issue.

In the Malaysian construction industry, data is not readily available on the current struc-
ture of construction waste flows by the source of generation, type of waste, intermediate
and final disposal and the amount of waste reduced at source, reused or recycled on-site or
off-site. A study by Hassan et al. (1998) shows that on average, the breakdown of waste
generation according to source: 36.73% from household waste, 28.34% from industrial and
construction waste while other sources (market and commercial waste, institutional waste,
landscaping waste and street sweeping waste) account for the remaining 34.93% in the
Central and Southern region of Malaysia (Fig. 1). This shows that in Malaysia construction
waste forms a significant portion of wastes which is finally disposed of in landfills.

This paper is based on a case study which involved construction waste generation and
composition as well as reuse and recycling in the site. The case study also analysed the
economic feasibility of waste minimisation such as reusing and recycling of construction
waste materials in terms of cost savings.

2. A review of some studies on economic feasibility of the solid waste management

With the demands in implementing major infrastructure projects in Malaysia, together
with many commercial building and housing development programmes, a large amount

![Fig. 1. Percentage of different types of solid waste generated (t/day) in 1994.](image)

of construction waste is being produced in the Malaysian construction sector. Extra construction materials are usually planned due to the lack of considerations given to waste reduction during planning and design stage to minimise the generation of waste. The excessive wastage of raw materials, improper waste management and low awareness of the need for waste reduction are common in the local construction sites (Begum, 2005). In recent years, reuse and recycling of waste have been promoted in order to reduce waste and protect the environment. The economic and environmental benefits to be gained from waste minimisation and recycling are enormous (Guthrie et al., 1999), since it will benefit both the environment and the construction firms in terms of cost reduction. Today, in most European countries, it is economically feasible to recycle up to 80–90% of the total amount of C&D waste and most demolition and recycling technologies are generally easy to implement and control (Lauritzen, 1998). The economic benefits of waste minimisation and recycling include the possibilities of selling specific waste materials and the removal from site of other wastes at no charge or reduced cost, with a subsequent reduction in materials going to landfill at a higher cost (Snook et al., 1995). Therefore, it can increase contractor’s competitiveness through lower production costs and a better public image. However, very few contractors have spent efforts in considering the environment and developing the concept of recycling building materials (Lam, 1997). Because contractors rank timing as their top priority, their effort is always focused on completing the project in the shortest time, rather than the environment (Poon et al., 2001). Their account books cannot reveal the potential savings resulted from reduction in construction wastes. Managing building material waste can in fact achieve higher construction productivity, save in time and improvement in safety (Chan and Ma, 1998; Gavilan and Bernold, 1994; Skoyles and Skoyles, 1987) while disposal of extra waste takes extra time and resources that may slow down the progress of construction.

The reduction of construction waste is highly beneficial to the community. Construction industry research and information association’s research (1993) indicates that the environmental benefits of waste minimisation include prolonging the life of landfill sites and reducing primary resource requirements. Lingard et al. (2000) added that social benefits include the avoidance of creating new and undesirable landfill sites, stemming potential environmental health risks associated with waste and its disposal reducing the cost of construction. Peng and Scorpio (1997) has supported that reduction of construction waste is one of the best solutions. Reduction is the best and most efficient method for minimising the generation of waste and eliminating many of the waste disposal problems. However, recycling of construction materials may also have its limitation. Peng and Scorpio (1997) also stated that recycling requires an aggressive marketing effort to locate markets and sell materials at the highest possible prices. The current rather low level of market developments means that significant time and money must be invested in establishing relationships, keeping track of pricing changes and becoming a reliable supplier of materials, in order to ensure a continuous intake of construction materials. The operator also has to locate and develop relationships with demolition and general contractors with projects in the area, to market their construction recycling business as the disposal option of choice for the contractors.

Existing professional economic literature on solid waste management is basically focused on three issues as (i) the applicability and viability of user charges in solid waste management, (ii) analysis of which are the best tools to alter the percentage of packaging in the waste
stream and (iii) the benefits and costs of using those instruments to foster waste reduction and recycling (Brisson, 1993; Dinan, 1991; Pearce and Turner, 1993; Repetto et al., 1992; Schall, 1992; Skumatz, 1993). Goddard (1995) pointed out that empirical knowledge is very suggestive on the first of these, sketchy on the second and virtually nonexistent on the third. There is also advocacy literature on both sides of the various solid waste management options, recycling being the current focus of attention, that relies on limited or no economic analysis (Denison and Ruston, 1990; Schall, 1992).

3. Methodology

The study involved the project site of a newly constructed, non-residential (institutional) building, with almost 49,662 m² of floor space. The project site (Kamis H) is located in Universiti Kebangsaan Malaysia (UKM), Bangi, Selangor (Fig. 2). The project site was selected because it involved conventional building and construction activities. Data was collected through interviews (using questionnaire) with the project quantity surveyor and site supervisor at the project site. The interview was conducted by the researcher, who was also part of a team of researchers that conducted site visits to survey the waste piles and obtain accurate information. The interviews and survey were conducted throughout the duration of the project, from October 2001 to July 2004. A benefit–cost analysis (BCA) was performed to show the economic feasibility of reusing and recycling of construction waste materials. Simple descriptive statistics such as averages, ranges and percentages were used to analysis primary data from the construction site.

Fig. 2. Map of the case study area in UKM, Bangi.
The study estimated the net benefits to evaluate the economic feasibility of reusing and recycling of construction waste materials on the project site. Net benefit can be expressed by Eq. (1) which is the subtract of the total costs from total benefits

\[ NB = TB - TC \] (1)

where \( NB \) is the net benefits, \( TB \) the total benefits and \( TC \) is the total costs.

The total benefits are all the advantages of reusing and recycling of construction waste materials. This is the sum of all direct, indirect and intangible benefits. So the total benefits can be expressed in Eq. (2)

\[ TB = PC_{CS} + R_{SM} + CS_{CT} + CS_{LC} + A \] (2)

where \( TB \) is the total benefits of reusing and recycling of construction waste materials on the site, \( PC_{CS} \) the purchasing cost savings by reusing and recycling of construction waste materials, \( R_{SM} \) the revenue from selling of scrap construction waste materials, \( CS_{CT} \) the waste collection and transportation cost savings by reusing and recycling of construction waste materials, \( CS_{LC} \) the cost savings from landfill charge by reusing and recycling of construction waste materials and \( A \) is the intangible benefits.

The total costs are all the incremental costs associated with the reusing and recycling of construction waste materials. This is sum of all direct, indirect and intangible costs. So the total costs can be expressed by Eq. (3)

\[ TC = CS_{C} + EC + SC + A' \] (3)

where \( TC \) is the total costs of reusing and recycling of construction waste materials on the site, \( CS_{C} \) the collection and separation costs of construction waste materials, \( EC \) the equipment purchasing cost, \( SC \) the storage cost, \( TC \) the transportation cost and \( A' \) is the intangible costs.

4. Results and discussion

The findings of the case study are discussed below. The discussion focuses on the composition and recycling of construction waste, and the economic feasibility of the waste minimisation at the project site.

4.1. Construction waste generation and composition on the site

In the study, generation of construction waste refers to the weight of materials and products as they enter the waste management system from the building construction process and before reuse, recycling and disposal. During the construction of this new building, it was estimated that total construction waste generation from the project site was 27068.40 t. This estimation was based on gross waste production in tonnage. The composition of C&D debris is highly variable and depends critically on the type of activity where sampling is done (US EPA, 1998) as well as the many different type of buildings and construction practices in existence.
The source of construction waste at the project site include materials such as soil and sand, brick and blocks, concrete and aggregate, wood, metal products, roofing materials, plastic materials and packaging of products. Table 1 summarises the estimates for the composition of construction waste generation in the site. The estimated total construction waste generation is done by material type. The composition of total waste generation is shown in Fig. 3 which is percentage by weight. Concrete and aggregate is the largest component with 65.8% followed by soil and sand (27%), 5% from wood based materials such as timber, lumber, etc., 1.6% from brick and block, 1% from metal products, 0.2% from roofing materials and 0.05% from plastic and packaging products such as papers, cardboards, etc.

### 4.2. Reused and recycled construction waste materials on the site

The practice of waste minimisation i.e. reuse and recycling of construction waste materials is common on the site. In the project site, construction waste materials contain a large

<table>
<thead>
<tr>
<th>Construction waste materials</th>
<th>Amount of waste generated (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil and sand</td>
<td>7200</td>
</tr>
<tr>
<td>Brick and Blocks</td>
<td>315</td>
</tr>
<tr>
<td>Concrete and aggregate</td>
<td>17820</td>
</tr>
<tr>
<td>Wood</td>
<td>1350</td>
</tr>
<tr>
<td>Metal products</td>
<td>225</td>
</tr>
<tr>
<td>Roofing materials</td>
<td>54</td>
</tr>
<tr>
<td>Plastic materials</td>
<td>33.5</td>
</tr>
<tr>
<td>Packaging products</td>
<td>0.90</td>
</tr>
<tr>
<td>Total</td>
<td>27088.4</td>
</tr>
</tbody>
</table>
percentage of reusable and recyclables. It is estimated that 73% of the waste materials is reused and recycled. Table 2 shows the amount of reused and recycled waste materials on the site. The highest amount of reused and recycled materials is concrete and aggregate, comprising 67.64% of the total reused and recycled material in the site followed by soil and sand (27.33%), wood (4%), brick and block (0.64%), metal products (0.27%) and roofing materials (0.03%). The study included excavated soil as a construction waste material, which is reused after piling, resulting in a large percentage (73%) of the total generated waste.

### 4.3. Economic feasibility of waste minimisation

Generally, economic feasibility is carried out using the standard measures of profitability such as, cost benefit analysis. Most studies revealed that there are many benefits associated with waste minimisation i.e. environmental, economic, liability, public image, etc. (EH&S, 1994; Lorton et al., 1988; US EPA, 2002). According to the US EPA (2002), waste minimisation makes good economic and business sense and at the same time, waste minimisation can improve production efficiency, profits, good neighbour image, employee participation, product quality and environmental performance. This study performed a benefit–cost analysis (BCA) to estimate the economic feasibility of construction waste minimisation in terms of cost savings.

The benefit–cost analysis is important for the implementation of waste management systems in the construction industry. In performing the benefit–cost analysis of waste minimisation such as reusing and recycling of generated construction waste materials in the site, all the benefits and costs are considered. The benefits come from all the direct, indirect and intangible benefits due to reusing and recycling of waste materials as well as the costs of all the direct, indirect and intangible costs involved of the reusing and recycling on the site. The study tried to quantify all benefits and costs in terms of monetary value and also those benefits and costs that do not have monetary value which is defined as an intangible term such as $A$ (intangible benefits) and $A^*$ (intangible costs). The benefit–cost analysis followed a conservative method of estimation as it is an initial study and the beneficial value is based on the opportunity cost approach.

<table>
<thead>
<tr>
<th>Construction waste material</th>
<th>Amount of reused and recycled</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil and sand</td>
<td>5400</td>
<td>27.33</td>
</tr>
<tr>
<td>Brick and block</td>
<td>126</td>
<td>0.64</td>
</tr>
<tr>
<td>Concrete and aggregate</td>
<td>13365</td>
<td>67.64</td>
</tr>
<tr>
<td>Wood</td>
<td>810</td>
<td>4.0</td>
</tr>
<tr>
<td>Metal products</td>
<td>54</td>
<td>0.27</td>
</tr>
<tr>
<td>Roofing materials (tiles)</td>
<td>5.4</td>
<td>0.03</td>
</tr>
<tr>
<td>Total</td>
<td>19760.4</td>
<td>100</td>
</tr>
</tbody>
</table>
4.3.1. Total benefits

The direct benefits of reusing and recycling consist of purchasing cost savings by reusing and recycling of construction waste materials and revenue from selling of scrap materials. The indirect benefits consist of waste collection and transportation cost savings and cost savings from landfill charge by reusing and recycling of construction waste materials. Purchasing cost savings explain that the company saved money after reusing and recycling of waste materials instead of buying these materials. If the company could not reuse and recycle these materials it would be needed to buy those materials. The estimated purchasing cost savings is shown in Table 3. In these estimations, soil and sand waste materials are not considered because the contractors usually do not buy soil and the amount of sand is negligible. Total purchasing cost savings is the sum of the cost savings from materials market price and transportation cost savings. The calculation of the total purchasing cost savings is based in the following formula:

\[
\text{total purchasing cost savings} = \text{cost saving from market price} + \text{transportation cost saving}
\]

where

\[
\text{cost savings from market price} = \text{average market price per unit} \times \text{total amount of reused and recycled of such individual waste materials}
\]

The result shows that the net purchasing cost savings of reused and recycled waste materials is RM 939874.00. On the site, the significant cost saving materials are concrete and aggregate, and wood. Total benefits of the reusing and recycling in the site is calculated using the Eq. (2) which is illustrated in Table 4. Total benefits of reused and recycled waste materials is RM 1055796.00 and some intangible benefits (A). It is shown that the most important sources of benefits are purchasing cost savings (RM 939874.00), cost savings

<table>
<thead>
<tr>
<th>Construction waste materials</th>
<th>Average market price per unit</th>
<th>Cost savings from market price</th>
<th>Transportation cost savings</th>
<th>Total purchasing cost savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick and block (t)</td>
<td>117.14</td>
<td>14780.64</td>
<td>8622.75</td>
<td>23382.39</td>
</tr>
<tr>
<td>Concrete and aggregate (t)</td>
<td>54.5</td>
<td>228392.5</td>
<td>728392.5</td>
<td>2594154.00</td>
</tr>
<tr>
<td>Wood (t)</td>
<td>600.00</td>
<td>486000</td>
<td>12150</td>
<td>327150.00</td>
</tr>
<tr>
<td>Roofing materials (tiles) (t)</td>
<td>533.33</td>
<td>2840</td>
<td>360.00</td>
<td>3240.00</td>
</tr>
<tr>
<td>Grand total</td>
<td></td>
<td>1252035.00</td>
<td>211352.75</td>
<td>1253184.89</td>
</tr>
<tr>
<td>25% deduction*</td>
<td></td>
<td>313291.22</td>
<td></td>
<td>939874.00</td>
</tr>
</tbody>
</table>

All prices and weights have taken in average.

* This study has deducted 25% of the grand total purchasing cost savings, because the material’s price are considered as the same as average virgin material’s price. Here, 25% is an assumption based on the informal discussion of the project site managers and supervisors.
Table 4

<table>
<thead>
<tr>
<th>Item of benefits</th>
<th>Monetary value of the benefits (RM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchasing cost savings by reusing and recycling of construction waste materials ($P_{CS}$)</td>
<td>939874.00</td>
</tr>
<tr>
<td>Revenue from selling of scrap construction waste materials ($R_{SM}$)</td>
<td>27000.00</td>
</tr>
<tr>
<td>Waste transportation cost savings by reusing and recycling of construction waste materials ($C_{CSCT}$)</td>
<td>39520.80</td>
</tr>
<tr>
<td>Cost savings from landfill charge by reusing and recycling of construction waste materials ($C_{CSLC}$)</td>
<td>49401.00</td>
</tr>
<tr>
<td>Intangible benefits ($A$)</td>
<td>A</td>
</tr>
<tr>
<td>Save landfill space</td>
<td></td>
</tr>
<tr>
<td>Reduced liability which including for environmental problems and workplace safely</td>
<td></td>
</tr>
<tr>
<td>Less chance of soil and ground water contamination</td>
<td></td>
</tr>
<tr>
<td>Improved public image and environmental concern</td>
<td></td>
</tr>
<tr>
<td>Total benefits of reusing and recycling of construction waste materials on the site ($TB$)</td>
<td>1055796.00 + A</td>
</tr>
</tbody>
</table>

All prices and weights have taken in average.

from landfill charge (RM 49401.00) and waste transportation cost savings (RM 39520.80) of reused and recycled of construction waste materials.

4.3.2. Total costs

Costs are the key determinant of decisions and choices in waste management technologies and practices (Chen et al., 2002; Coffey, 1999; Goddard, 1995; Mills et al., 1999; Poon et al., 2001; Wang et al., 2002). Coffey (1999) pointed out that construction solid waste management is generally seen as a low priority when financial constraints are present and suggested that considerable waste reduction can be achieved if waste management is implemented as part of project management functions. He further suggested that whilst the choice of the optimum waste handling methods should be determined by considering the cost implications, any practice which will induce waste reduction, must be encouraged. In fact, waste management has been receiving less attention from business senior management when compared to construction cost and time. The cost for implementing waste management is often given more concern than the possible benefits that the organisation can gain from the implementation (Shen and Tam, 2002).

Total direct costs of reusing and recycling are included with the costs of collection and separation of construction waste materials, equipment purchasing cost, storage cost and transportation cost. Waste collection and separation cost for reusing and recycling depends on the following factors in particular: the frequency rate of waste collection and separation in the site, average hours spending for collection and separation per day, total labour use for collection and separation per day, labour wage rate per day and the average amount of waste collection and separation per day. It is shown that there is no indirect costs involved with the reusing and recycling of waste materials in this site. Table 5 indicates the total costs of the reusing and recycling in the site, measured in terms of the Eq. (3). The result shows that...
Table 5

<table>
<thead>
<tr>
<th>Item of costs</th>
<th>Monetary value of the costs (RM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection and separation costs of construction waste materials (CSC)</td>
<td>185254.00</td>
</tr>
<tr>
<td>Equipment purchasing cost (EPC)</td>
<td>13500.00</td>
</tr>
<tr>
<td>Storage cost (SC)</td>
<td>–</td>
</tr>
<tr>
<td>Transportation cost (TC)</td>
<td>–</td>
</tr>
<tr>
<td>Intangible costs (A*)</td>
<td></td>
</tr>
<tr>
<td>Worker’s health risk cost</td>
<td></td>
</tr>
<tr>
<td>Cost of negative externality i.e. noising, bad smell</td>
<td></td>
</tr>
</tbody>
</table>
| Total costs of reusing and recycling of construction waste materials on the site (TC) | 198754.00 + A*                        

All prices and weights have taken in average.

total costs of reused and recycled waste materials is RM 198754.00 and intangible costs (A*) such as worker’s health risk cost, cost of negative externality i.e. noising, bad smell. Collection and separation cost (RM 185254.00) of waste materials is an important source of cost for reused and recycled construction waste materials.

4.3.3. Net benefits

To analyse the economic feasibility, this study estimated the net benefit (NB) by expressing the Eq. (1). The final result of benefit–cost analysis for the reusing and recycling of construction waste materials is shown in Table 6.

It is shown that the net benefit of reusing and recycling of construction waste materials is positive which means the benefits exceed costs. In monetary value, the net benefit of waste minimisation such as reusing and recycling is RM 857042.00. It also has some unmarketed benefits (A′) such as saving landfill space, reduced liability for environmental problems and workplace safety, less chance of soil and ground water contamination, improved public image and environmental concern. Thus, the study also found that reusing and recycling of construction waste materials is economically feasible in terms of cost savings on the site. The net benefit of the

Table 6

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total benefits (TB)</td>
<td>1055796.00 + A</td>
</tr>
<tr>
<td>Total costs (TC)</td>
<td>198754.00 + A*</td>
</tr>
</tbody>
</table>
| Net benefit (in RM)               | 857042.00 + A′                     

Note: it is assumed that A > A′ so that there is some intangible benefit (A′). The argument is that in monetary value total benefits are more than total costs as well as in terms of the items, the intangible benefits are more than intangible costs.
reusing and recycling on site is estimated to be 2.5% of the total budget (RM 34 million) of the project. Reusing and recycling of waste materials significantly affect contractor’s profit. Thus, construction site waste management and minimisation has a great opportunity to contribute to improvement of construction industry performance and solve waste management problems caused specifically by the construction sector.

4.4. Policy implications

By using fewer resources and reducing the amount of waste to landfills, contractor’s public image and environmental concern will be enhanced in the community. In this view, economic instruments for minimising construction waste can be used to raise revenue for environmental policy, encourage prevention efforts, serve to discourage the least desirable disposal practices, as well as to avoid the negative consequences of environmental unfriendly treatment and disposal practices of construction waste materials. For example, government can impose a subsidy for recycled construction products, tax credit for the construction companies that use recycled products, higher tax on the construction companies that use virgin products to encourage reducing, reusing and recycling of waste materials and also to improve environment and waste management as well. Moreover, contractors must be educated about possible cost savings from the waste minimisation measures and the environmental impacts of the waste. The merits of waste minimisation and environmental protection must also be promoted to the contractors and other clients. In line with this, CIDB can play an important role by disseminating the information on the cost savings of reused and recycled waste materials to the sub contractors, contractors, developers and other stakeholders of the construction industry. Finally, it can be suggested that waste minimisation (three R’s; reduce, reuse and recycling) of construction waste materials needs to be promoted and encouraged in the construction industry because it is one of the most significant wastes generated in Malaysia in terms of volume.

5. Conclusion

The case study demonstrates that construction materials contribute to the generation of large quantities of the construction waste. Waste minimisation is common in the project site where 73% of the waste material is reused and recycled. Waste minimisation is economically feasible and also plays an important role for the improvement of environmental management. The net benefit of reusing and recycling of waste materials is estimated at 2.5% of the total project budget. Thus, the construction industry can save money by implementing waste minimisation practices on the site.

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