ECO-COSTS PER VALUE RATIO ASSESSMENT OF CONSTRUCTION WASTE: A STUDY IN KLANG VALLEY, MALAYSIA

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ABSTRACT

There is a need to quantify and assess the environmental impact of waste generated from construction activities. In terms of environmental impacts, Life Cycle Assessment (LCA) is commonly known as one of the most comprehensive and accurate tool for quantitative analysis of environmental impact over all life cycle stages of product’s life. The latest breakthrough in LCA analysis is the eco-costing concepts. Eco-cost per value ratio (EVR) was introduced as part of LCA studies using economy-ecology approach, especially for consumer products. However, there are very few publications available on eco-costing and EVR applications in favor of construction waste generation. Therefore, this study shall assess eco-costs as the result or consequences of waste produced for the context of Malaysian construction industry, particularly in Klang Valley. This study focused on evaluation of eco-costs for waste generated during construction phase only, not the full life cycle. Major construction materials such as concrete, timber, reinforcement bars were taken into account. Construction projects covered in data collection process were residential, commercial, office buildings employing conventional and IBS systems within the area of Klang Valley in Malaysia. Eco-costs considered in this study include: the product unit cost, delivery cost/unit, cost of recycling/salvaging, cost of waste disposal, cost of landfilling (acquired from authority), cost of labor for waste collecting and sorting cost. Major data extracted include: Gross Floor Area (GFA); material order quantities and material worked quantities from Bills of Quantity (BQ); construction debris disposal trip record; purchase and delivery costs and costs associated with waste generation; total project cost (contract sum). Results have shown that the wastage EVR benchmark for Malaysian construction industry shall lies at around 0.0024 – 0.0028 for typical multi-storey projects applying conventional and/or partial semi-IBS, and shall be considerably less, by up to 0.0014 for projects utilizing full IBS system or projects with exceptionally good waste management awareness and practice.

Key Words: Construction waste, Eco-costing, Value ratio, Life Cycle Assessment, Environmental impact Cost, Impact assessment

INTRODUCTION

Construction industry consumes large quantities of raw materials. The type of materials produced to serve the industry are ranging from raw goods such as sand, aggregates, soil and water to manufactured goods such as bricks, cement, plasterboard, metals (steel and iron), timber, concrete, cement and plaster. As a consequence of large consumption of these materials, waste is generated in large quantities, which can have significant impacts on the environment. A recent study from EPA shows that construction is the third largest industry sector in terms of contributions to greenhouse gas emissions in the United States. Although carbon emissions generated is low, the construction phase portion
of the total life cycle of a building releases significant amount of carbon emissions in a relatively short time horizon. Thus, there is a need to quantify and assess the environmental impact of waste generated from construction activities. In terms of environmental impacts, Life Cycle Assessment (LCA) is commonly known as one of the most comprehensive and accurate tool for quantitative analysis of environmental impact over all life cycle stages of product s’ life. The latest breakthrough in LCA analysis is the eco-costing concepts which assess environmental impacts as marginal prevention costs.

Eco-costs are “costs” that take into consideration the direct and indirect environmental impacts costs generated from the use of resources. Eco-costs are defined as the costs of prevention measures, which are required to reduce current emissions to a sustainable level. These costs are related to measures that have to be taken to make and recycle product in line with the earth’s estimated carrying capacity. Material waste occurs throughout the lifecycle of construction projects. Meanwhile, Eco-cost per Value Ratio (EVR) model is a tool introduced by Vogtlander to achieve the double aims, sustainability and economy. EVR was introduced as part of LCA studies using economy-ecology approach, especially for consumer products. However, there are very few studies available on eco-costing and EVR applications in favor of construction waste generation, particularly for Malaysian context. Publications related to construction waste for Malaysian perspective are mainly concerning qualitative approaches such as waste management practices. Therefore, this study focused on quantitative assessment for evaluating environmental load cost due to waste generation for the context of Malaysian construction industry, particularly in Klang Valley. Klang Valley is Malaysia’s most populated urban area which is mainly Kuala Lumpur Metropolitan area. This urban area of 7.2 million people has had the most rapid development in recent years.

**AIMS AND OBJECTIVES**

The objectives of this study are: to identify the costs associated with waste generation and; to quantify and assess the EVR index resulted due to waste generation from construction waste generated for various types of projects in Klang Valley employing various construction methods. EVR is a practical tool for decision making which features a single indicator for level of sustainability that shows the link between economy and ecology (environmental impacts) as a result or consequences of waste generation during construction phase. This study only considered data collection of residential, commercials, offices and buildings employing conventional and IBS systems within Klang Valley area. Demolition, refurbishment and civil engineering or infrastructure projects were not considered due to their limited number of on-going projects and lack of available data. The output can be a basis in method selection that incorporates environmental considerations in construction planning and design for relevant parties or stakeholder. Nowadays, ecological impacts tend to be dominated by economic argument whereby quantification of the costs of action against the costs of the consequences of inaction must at least be attempted.

**Literature Review**

Eco-costs are measure to express the amount of environmental burden of a product on the basis of prevention of that burden. Eco-costs are marginal prevention costs that needed related to cost of the measures that must be taken in order to reduce emission to a sustainable level. The value of the eco-costs is the price that must be invested to make, for example CO₂ reduction system to balance the impact of a product or service to the environment. The calculation of eco-cost is done by taking into consideration both the direct and indirect environmental impacts. The estimation is based on a “what if” condition. Eco-costs are described as the sum of: the virtual pollution prevention cost; the cost of energy; the material depletion cost; the cost of depreciation (use) of equipment, buildings, etc and the cost of labour. Eco-cost per value ratio (EVR) model is a model developed by Vogtlander as a practical tool for decision making in order to achieve sustainability and economy. This tool features a single indicator for several environmental impacts (material depletion, energy consumption and toxic emission) and indicator that show the link between economy.
and ecology (value chain and ecological product chain). Low EVR is indicating that the product is considered sustainable in the future. The result from EVR assessment can be used as guidelines to define the appropriate approach to minimizing the environmental burden from construction activities. Value or fair price of a project or a product is determined by its image, service quality and product quality while the costs consist of the purchased material, required energy, depreciation and labor. Profit and tax are the difference between value and costs. Direct eco-cost include the virtual cost of prevention or reducing emission, the eco-cost of energy and eco-costs of material depletion, while indirect eco-costs include depreciation and labour. Fig. 1 describes the decomposition of eco-costs. In general, calculation of eco-cost element is conducted according to LCA method as in ISO 14041.

For construction industry, the calculation of eco-costs for this phase could be done in the same way as the estimation of traditional economic costs, which is by elemental bills of quantities for materials used. The method is related to the fact that the characteristics of building projects are that every project consists of combination of semi-finished products, which are assembled on-site. With this approach, the eco-cost in construction phase is considered as the sum of the eco-costs of semi-finished products as well as the assembling activities. Emission and depletion data for the basis of calculation can be found at database such as IDEMAT. Attempts were made to calculate the eco-cost of construction labour with the assumption that all the costs of equipment and facilities used by construction workers on building sites are designated to the building site costs while the commuting expenses and the use of service vans, energy for production activities, and working clothes are designated to the cost of labour. On the other hand, it was concluded that the eco-costs of construction activities will include waste control, recycling and reuse, waste disposal, repair, impact, eco-policy, labour, equipment, emission, and energy with each of this element has its own costs breakdown. However, there are least number of studies and publication on eco-costing of construction waste.

**MATERIAL AND METHODS**

Six projects in Klang Valley constructed between 2009 – 2010 had been selected for this study, which mainly include residential, commercial and office building projects conducted by a wide range of contractors employing conventional and IBS systems. Conventional timber formwork (including plywood) has been the backbone of construction method in Malaysia for many years, but IBS systems have starting to gain some acceptance and encouragement from government, although it is only limited to a small number of larger projects.
The majority of IBS systems employed are metal formwork system (steel or aluminium) and precast concrete system (for columns, beams, slabs and wall) that relatively produce less waste. This study focused on evaluation of eco-costs for waste generated during construction phase only, not the full life cycle. Major construction materials such as concrete, timber, reinforcement bars, bricks and blocks, tiles, and plaster/mortars were taken into account. Only waste generated from construction activities at superstructure phase was considered as waste generated from substructure and the foundations works were considered minimum which consisted of mostly soil. Construction projects covered in data collection process were from the high rise and low rise residential, commercial, high rise and low rise office, governmental buildings, education buildings employing conventional and IBS systems within the Klang Valley area.

Eco-costs considered in this study include: the product unit cost, delivery cost/unit, cost of recycling/salvaging, cost of waste disposal, cost of landfilling (acquired from authority), cost of labor for waste collecting and sorting cost. Most disposal companies charged disposal fees based on the number of trip, some by daily rate basis with extra rate for overtime. The fees were ranging between RM 150 – RM 250 per trip. According to Malaysian Solid Waste Management and Public Cleansing Agency, landfill tipping fees charged was RM 200 per m$^3$ or RM 150 per tonne. Cost of energy; cost of equipments emission; and cost of depreciation of equipments would not be considered as performed previously due to lack of available.

4Major data extracted include: Gross Floor Area (GFA); material order quantities and material workdone quantities from Bills of Quantity (BQ); construction debris disposal trip record; purchase and delivery costs; and costs associated with waste generation; total project cost (contract sum). This study shall assess eco-costs as the result or consequences of waste produced. The first step in quantifying the carbon footprint is to determine the amount of wastage generated for each specified material which described as:

\[
\text{Wastage} = \text{Cumulative order quantity} - \text{cumulative workdone}
\]  

(1)

Meanwhile, the calculations for each cost are as follow:

**Unit cost and delivery cost**

Unit and delivery cost = Wastage x unit purchased x purchased cost  

(2)

The price of material used is taken from data provided by courtesy of Commerce House Sdn Bhd, however from some materials that is not listed price is taken from other varies sources. Delivery unit cost was already included in Price list.

**Labor Cost**

Labor cost = No of labor needed/week x Length of work x cost per labor  

(3)

Based on information obtained from most interview sessions, it was found that the number of labor required per week for housekeeping and waste handling was assumed to be ten people per week and the cost per labor is assumed to be the same of average wage for general construction worker-building in Kuala Lumpur which is RM 50/day/person.

**Total disposal trip cost**

Total disposal trip cost = Number of trip x Cost per trip  

(4)

Cost per trip data is provided for project B. Other project cost is assumed to be the same as project B as for a range of length, cost for a trip is relatively the same. Project D is an exception where the total disposal trip is already provided. Data for the number of trips shall be extracted from waste index calculation.

**Landfilling cost**

Landfilling cost = Total waste volume x Cost per volume  

(5)

Based on data obtained from Perbadanan Pengurusan Sisa Pepejal and Pembersihan Awam (PPSPPA), land filling cost is assumed as RM 200 per m$^3$ of waste. Data for total waste volume shall be also extracted from waste index calculation. Thus, EVR can be described as the total eco-costs divided by the value or “fair price” of a project as seen below:

\[
\text{EVR} = \frac{\Sigma \text{Eco Costs (RM)}}{\text{Total project cost (RM)}}
\]  

(6)

Although this study did not fully include all attributes proposed by Yahya and Boussabine, it
was expected that the costs considered in this study shall represent the eco-costs of each project objectively. This is because the cost attributes such as the cost of impacts, cost of emission from equipments, and cost of depreciation of equipment were not included in the scope of the study.

RESULTS AND DISCUSSION

Wastage EVR results for chosen sites in Klang Valley can be recapitulated individually in Table 1. Product and delivery cost/unit, cost of waste disposal, cost of land filling and cost of labor for waste collecting were identified as eco-costs accounted in assessments. EVR results are derived from wastage portion. Thus, their outcomes shall be greatly determined by wastage percentage for each specified materials. It seems that construction method, waste management and building design play a major role in EVR outcomes. Wastage EVR outcomes were not correlated with the actual debris disposed to landfills. Project D which utilized both precast concrete elements and metal formwork system demonstrated a tremendous performance in wastage EVR outcome. This finding proofs that IBS system can substantially reduce the usage of “big three materials” (concrete, timber and reinforcement steels) and shall greatly decrease these wastages due to improved quality of works and inventory control. Project E has the lowest wastage EVR value even though it was applying conventional system. Project E has the lowest wastage EVR value even though it was applying conventional system due to excellent environmental practice as required by GBI Certification and steel-framed structural design of the building which has resulted in lesser usage of concrete and timber based traditional cast-in-situ structure. The finding shows that, wastage EVR benchmark for Malaysian construction industry shall lies between 0.0024 – 0.0028 for typical multi-storey projects applying conventional and/or partial semi-IBS and shall be considerably less, by up to 0.0014 for projects utilizing full IBS system or projects with exceptionally good waste management awareness and practice. It is pointed out that poor waste management can leads to hazardous environmental impact as well as direct financial losses which make the eco-costs become greater. Thus, it can be concluded that wastage EVR result shall be improved if less “big three materials” consumption and wastage was generated. This is similar to findings reported which suggested that timber and cast-in-situ concreting are major contributors of construction debris. Thorough analysis on wastage EVR methodology shall implies that wastage EVR is actually the percentage of cumulative costs associated with waste generation out of total project cost. During data collection phase, most contractors claimed that the cost spent for waste management was almost negligible, which were less than 1% of total contract sum. However, based on the findings, wastage EVR assessment proofed that actual direct and indirect financial losses due to wastage produce are much more costly than the figure claimed.

According to a study, EVR value for typical office building could reach up to 37% of total project sum, for scope covering overall construction phase which ranging from the superstructure to finishing stage. Therefore, design stage is very crucial for planning and decision-making in developing sustainable project as indicated by EVR assessment. EVR can be regarded as one of the indicators for sustainability level of construction projects. Low EVR figure signifies that a project is fit for use in a future sustainable society, while high EVR figure suggests it may not fit in the future because the cost of delivering (construction) is higher than its actual value. The lower the EVR value, the better it is for society. There are several environmental strategies to improve or lower the EVR of a project. These strategies include improvement of production process (in this case, the construction method) by using sustainable materials (which often lead to higher initial cost), to dedicate on “savings” (e.g. transportation and energy consumption), and improvement of the perceived value from the building aspect.

CONCLUSION

To sum up, construction waste generation poses more severe impacts than it was generally perceived. This study unveils the construction waste issue from a different angle of perspectives instead of the general solid waste problems widely studied, reported and published. By analyzing from overall and more holistic point of view, it is
<table>
<thead>
<tr>
<th>Project</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of building</td>
<td>Low rise education &amp; office, 4 storey</td>
<td>High Rise Education &amp; Office, 12 storey</td>
<td>Low-Rise Commercial, 4 storey</td>
<td>High-End Residential (Condominium)</td>
<td>Governmental Office, 8 storey</td>
<td>Low Rise Education, 6 storey</td>
</tr>
<tr>
<td>Method of construction</td>
<td>Conventional (plywood)</td>
<td>Semi-IBS (f.work system) for &amp; slabs, conventional for the rest</td>
<td>Mostly conventional, columns IBS (fwork system) for columns</td>
<td>IBS-composite (precast small portion using system for slabs)</td>
<td>Conventional panels and f.work</td>
<td>Conventional</td>
</tr>
<tr>
<td>GFA (m²)</td>
<td>17,000</td>
<td>15,800</td>
<td>143,600</td>
<td>123,002</td>
<td>14,229</td>
<td>15,000</td>
</tr>
<tr>
<td>Project Value/Cost (RM)</td>
<td>63,500,000.00</td>
<td>37,033,274.60</td>
<td>152,000,000.00</td>
<td>331,450,000.00</td>
<td>75,000,000.00</td>
<td>31,350,600.71</td>
</tr>
<tr>
<td>Wastage %</td>
<td>Rebar 5.15%, concrete 10.54 %, timber 100%, bricks &amp; blocks 5.19%, plaster 8.03%, tiles 8.00%</td>
<td>Rebar 10.34%, concrete 10.20%, timber 100%, bricks 4.87%, cement 3.36%, tiles 3.20%</td>
<td>Rebar 5.71%, concrete 5.26%, timber 100%, bricks &amp; blocks 3.63%</td>
<td>Rebar 9.63%, concrete 4.41%, bricks 5.06%, blocks 5.23%, cement 1.59%</td>
<td>N.A*</td>
<td>Rebar 7.69%, concrete 1.01%, timber 9.77%, bricks &amp; blocks 3.45%, plaster 8.09%, tiles 7.17%</td>
</tr>
<tr>
<td>Total unit and delivery loss (RM)</td>
<td>1,055,193.00</td>
<td>468,813.38</td>
<td>3,110,853.32</td>
<td>1,008,101.29</td>
<td>405,841.70</td>
<td>290,718.89</td>
</tr>
<tr>
<td>Total labor cost (RM)</td>
<td>364,000.00</td>
<td>364,000.00</td>
<td>1,977,500.00</td>
<td>4,480,000.00</td>
<td>472,500.00</td>
<td>364,000.00</td>
</tr>
<tr>
<td>Total disposal trip cost (RM)</td>
<td>15,450.00</td>
<td>15,300.00</td>
<td>209,550.00</td>
<td>756,679.00</td>
<td>21,750.00</td>
<td>20,250.00</td>
</tr>
<tr>
<td>Landfilling cost (RM)</td>
<td>115,360.00</td>
<td>154,224.00</td>
<td>3,121,604.00</td>
<td>204,120.00</td>
<td>145,000.00</td>
<td>204,120.00</td>
</tr>
<tr>
<td>Total eco-costs (RM)</td>
<td>1,550,003.00</td>
<td>1,002,337.38</td>
<td>8,419,507.32</td>
<td>6,448,900.29</td>
<td>1,045,091.70</td>
<td>879,088.89</td>
</tr>
<tr>
<td>EVR (x 10⁻²)</td>
<td>2.4409496</td>
<td>2.7065859</td>
<td>5.5391496</td>
<td>1.9456631</td>
<td>1.3934556</td>
<td>2.8040576</td>
</tr>
</tbody>
</table>

*) Note: Cumulative order and work done quantity data from BQ was unobtainable
apparent that problems associated with construction waste are not excessive debris disposed and shortage of landfills alone, but also resources depletion, massive carbon emissions, inefficiency, financial and other losses. Finding suggests that the entire tool featured in this study shall act as performance-based indicator to assess overall sustainability of construction project as shown by wastage produced.

The main purpose of these assessments is to provide evaluations for consequences and environmental loads of construction waste generation from a different angle and perspective. Result of this study illustrates that the baseline figures are highly contrast and scattered, which show inconsistency of sustainability level demonstrated among construction players. For that reason, benchmark figures shall be necessarily established by authorities and shall be achieved by construction players. Benchmarks are crucial to gain deep understanding of construction waste issue and to assess the current status of the industry while thriving to progressively reach achievable targets based on long-term goals. Policy-making and effectiveness of measures are launched or evaluated based on benchmarks accomplished. Finally, sustainable development shall be educated and socialized to all stakeholders in construction industry to reach the expected level.

Construction players shall put more emphasize on “designing-out” waste, rather than focusing on “end-of-pipeline” waste management, reuse, recycling, and material control. Despite good waste management practice, construction activities still generate unavoidable waste due to the nature of this industry. Recycling of construction waste is very difficult to implement because it involves on-site waste sorting and segregation which is very tedious and time-consuming process. Meanwhile, with an exception to steel reinforcement bars, construction waste usually exists as mixed and heterogeneous debris. IBS system was concluded as the most effective measures to minimize extent of wastage and associated impacts/losses resulted from construction waste generation as proven in this study. Benchmarks for sustainability shall be met and must be treated as integral part of project objectives.

Construction industry needs a breakthrough and modernization to achieve long term goal in sustainable development. Malaysian construction authorities shall provide their full support to achieve a more sustainable practice of industry, especially the implementation of IBS system. IBS construction method is not new, but it is still very difficult to implement. Advantages, hindrances, and measures to improve IBS implementation have been repeatedly studied in many countries and should be useful references. Assessment tools, methodologies, and findings of this study shall benefit the authorities to develop and establish sustainable policies and guidelines.

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REFERENCES


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*We have modified our environment so radically that we must now modify ourselves to exist in this new environment.*

Norbert Wiener