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Implementation of eco-costs per value ratio (EVR) on construction waste management in Shah Alam, Malaysia

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Abstract. The construction industry in Malaysia which is rapidly growing is indirectly contributing towards the economic influx to the country. However, the waste generation in construction is increasing proportionally with new construction developments. The current construction methods focus on minimal recycling process where most construction wastes are dumped at landfills because construction companies are required to set aside a higher preliminary cost for proper waste disposal. This study focuses on creating a more potential outcome in decreasing the construction waste by implementing eco-costing in development for the construction waste generated from the beginning stages of a project. Therefore, this study discusses the construction waste management using the eco-costing per value ratio (EVR) assessment. The EVR assessment for eco-costing were targeted to the construction waste products from Shah Alam. The analysis included 5 selected sample sites in Shah Alam conducted within the year 2013 to 2017. The findings indicated that EVR index ranged between 0.054-0.1225 for conventional and semi industrialised building system (IBS) method based on five-selected sample of sites. This range signify on current EVR index which will be compared with Malaysian EVR benchmarking in result and discussion. Furthermore this result is useful to evaluate EVR index between residential for construction waste management towards sustainable development.

1. Introduction

Construction industries consume a large number of raw materials [1]. The types of raw materials used in the industry include sand, aggregates, water, clay, rock, wood and manufacturing goods such as cement, timber, bricks, plaster cement, tiles, drywall, concrete, rebar, ceiling, and metal. As a result, the residual raw material from such a large amount of these resources results in a significant amount of construction waste, which impacts the environment. The total environmental impact of a construction product during its entire life cycle can be determined using the Life Cycle Analysis (LCA) method. EVR is an LCA based technique to analyse the utilisation designs, business procedures, and design outline choices regarding eco-effective esteem creations. According to Firman et al. [2], EVR is used to benchmark products and service systems. The EVR is a marker to sustainable and unsustainable utilization designs, where the eco-cost is an indicator for the natural contamination of products, while the esteem is the cost paid for the product in the market. The EVR ratios can be used to indicate the level of environmental pollution. As such, poor waste management leads to hazardous environmental impacts and financial losses as the companies eco-costs become greater [3] [4]. The EVR method was

adopted in this study because the construction waste management at the selected project sites still has room for waste minimisation improvement. Hence, EVR can be used as a tool to reduce and monitor the construction waste throughout the contract period.

Based on the analyses, the selected five projects were not within the range of benchmarks. The EVR benchmark for the Malaysian construction industry is within 0.0024 – 0.0028 for typical multi-storey projects applying conventional or partial semi-IBS, and up to 0.0014 for projects utilizing full IBS system or projects with exceptionally good waste management awareness and practice [2].

2. Materials and method

Five project sites (Project A – Project E) in Shah Alam constructed from 2013 until 2017 were selected for the study, which mainly includes residential low rise. The construction involved a wide range of contractors employing conventional and sustainable building materials in their construction systems. The construction method in Malaysia has been based on the conventional timber formwork (including plywood) for many years. However, although the IBS system has started gaining acceptance and encouragement from the government, only a limited number of larger contractors have opted to use it [2]. Majority of IBS systems employed include metal formwork system (steel or aluminium), drywall panels and precast concrete system (for columns, beams, slabs, and wall) which relatively produce less waste. It is important to note that this study is focused on evaluating the eco-costs for waste generated during the construction phase only, and not the full life cycle.

The major construction materials which were taken into account include concrete, timber, reinforcement bars, bricks and blocks, tiles, and plaster. Whereby, waste generated during construction activities at superstructure phase or known the above groundwork was considered for this assessment because waste generated from substructure or below ground and during foundation works were considered minimum consisting mostly of soil. Moreover, the construction projects covered in the data collection process were from the low rise residential, conventional and the sustainable building material adopted systems within the Shah Alam area. The eco-costs considered in this study included; (i) the purchased cost and delivery cost, (ii) labour cost, (iii) wastage disposal cost, and (iv) landfill cost. Besides, cost waste generation rate (WGR), waste index (WI) and waste level (WL) were also identified in this analysis. Major data extracted included (i) Gross Floor Area (GFA), (ii) material order quantities, (iii) material work done quantities from Bills of Quantity (BQ), (iv) construction debris disposal trip record, (v) purchase and delivery costs, and (vi) costs associated with waste generation and total project cost (contract sum). This study assessed the eco-costs of produced wastes.

The first step in quantifying the carbon footprint is to determine the amount of wastage generated and wastage level for each specified material as described below:

$$Wastage\ level, (W_l) = \frac{Total\ wastage, (T_w)}{Total\ work\ order,\ (T_{wo})}\ x\ 100\%\ [2] \tag{1}$$

where,
    Wastage level (W_l) = The percentage of wastage between projects
    Total wastage (T_w) = Total wastage amount (RM) during the contract period
    Total work order (T_{wo}) = Quantity (RM) material work order

Meanwhile, the calculations for each cost are as in the following section.

2.1. The purchased cost and delivery cost

$$Purchased\ cost\ and\ delivery\ cost\ (\%) = \frac{Total\ wastage\ cost,\ (T_{wc})}{Purchased\ cost,\ (P_c)}\ x\ 100\% \tag{2}$$

where,
Purchased cost and delivery cost (%) is calculated to justify the percentage between total wastage cost and purchased cost.

$$\textit{Purchased cost and delivery cost} = \textit{Total wastage cost, (T}_{wo}) \textit{ x purchased cost, (P}_c) \text{ [2]} \quad (3)$$

where,
Total wastage cost, (T_{wc}) = Total wastage amount (RM) during the contract period
Purchased cost, (P_c) = Total material purchased and delivery cost

The price of materials used was obtained from the contract department of Setia Alam. However, the price for some materials that were not listed was obtained from various resources. The unit cost in the price list for each material was inclusive of the delivery unit cost.

2.2. The labour cost for construction waste disposal

$$\textit{Labour cost, (L}_c) = \textit{Total labour needed, (T}_{ln}) \textit{ x Total duration, (T}_d) \textit{ (hour) x Cost per hour, (C}_{ph})$$
$$\textit{x Total days required, (Td}_r) \textit{ x Total contract duration, (Tc}_d)\text{[2]} \quad (4)$$

where,
Total labour needed, (T_{ln}) = Quantity manpower required
Total duration, (T_d) (hour) = Total working hour for site clearance
Cost per hour, (C_{ph}) = Salary per hour
Total days required, (Td_r) = Total duration required
Total contract duration, (Tc_d) = Total contract period

Based on information obtained from Environmental Waste Management (EMS) reference documents, it was clear that the number of labours required per week for housekeeping and waste handling varied between projects and the cost per labour also varied for general construction building-worker in the Klang Valley.

2.3. The wastage disposal cost

Total waste generated by project (month's contract) $\mathbf{m^3}$
$$(\textit{v x n}) = \textit{w} \quad (5)$$

where,
Truck volume $(\mathbf{m^3})$, $(\mathbf{v})$ = the volume of waste bin
Total number of loads for waste disposal, $(\mathbf{n})$ = Total trip of disposal
Total waste generated by project per month, $(\mathbf{w})$ = the volume of waste bin x Total trip of disposal

$$(\textit{t x c}) = \textit{Total wastage disposal cost} \quad (6)$$

where,
Cost per trip, $(\mathbf{c})$ = Cost per single trip
Total Trip, $(\mathbf{t})$ = Total trip of disposal

2.4. The waste index

Waste index is calculated to justify the index rate by total waste generated between projects divided with gross floor area of a project as shown below:

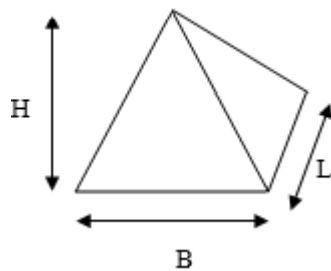$$\textit{Waste index, (W}_i) = \textit{w /gross floor area (GFA)} \text{ [5]} \quad (7)$$

where,
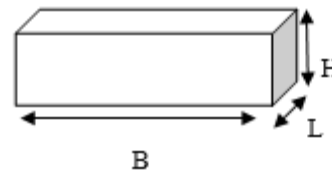Gross floor area (GFA) = Total built-up per unit x total units [2]

The cost per trip data provided for project A was manipulated to fit the other 4 project costs as it was assumed to be the same as project A following the range of length. This is because the cost per trip is relatively the same since the location of the dumping ground was within a specific range. However, the cost still depends on the size of the waste bin, falling within the range of RM 150-RM 250. Besides, data for the number of trips was extracted from the Environmental Waste Management (EMS 14001) index calculation.

Total waste volume can be calculated as pyramidal and rectangular shape as below if the construction waste material not placed at a designated area.

Pyramidal shape waste   **Rectangular shape waste**

$$Total\ volume\ of\ waste,\ (vw)=(LxBxH)[6] \tag{8}$$

where,
    L = length
    B = width
    H = height

$$Landfilling\ cost = Total\ waste\ volume\ x\ Cost\ per\ volume\ [2] \tag{9}$$

This above-mentioned equation (9) was also used by [6] [7] in their studies to evaluate the volume of waste produced at site. Based on the data obtained from Perbadanan Pengurusan Sisa Pepejal and Pembersihan Awam (PPSPPA), the landfilling cost was assumed to be approximately RM 200 per m3 of waste [2]. The data for total waste volume was also extracted from the Environmental Waste Management (EMS 14001, 2015) index calculation. This total waste volume required to justify the overall construction waste produced by selected five project sites. Thus, EVR can be described as the total eco-costs divided by the total value of the project as seen below.

$$Waste\ generation\ rate,\ (WGR) = \frac{total\ wastage\ amount\ per\ month,\ (T_{wa})\ x\ 100\%\ [8]}{Gross\ floor\ area\ (GFA)} \tag{10}$$

where,
    Total wastage amount per month, (m^3) = Total volume of waste monthly basis
    Gross floor area (GFA) = Total built-up per unit x total units

2.5. EVR ratio

$$EVR = \frac{Eco\text{-}costs\ (RM)\ [2]}{Total\ project\ cost\ (RM)} \tag{11}$$

where,

    Eco costs = Purchased cost and delivery cost (RM) + Total Wastage Disposal Cost (wc) (RM) + Total Labour Cost (RM) + Landfilling cost (RM)

    Total project cost (RM) = Contract Sum (RM)

Although this study did not fully include all attributes proposed by [4], it was expected that the costs considered in this study should represent the eco-costs for every project objectively. The attributes that were not included in the scope of the study are the cost of impacts, cost of emission from equipment, and cost of depreciation of equipment.

Figure 1 illustrates the process of construction waste disposal at the selected project site. Waste quantity or volume obtained by truck trip.Based on the data collected, the waste classification and justification were only made for superstructures since substructure waste products were of low to moderate level. A total of nine types of waste materials were identified such as rebar, concrete, timber formwork, bricks, plaster cement, tiles, drywall, metal deck roofing, and ceiling. With the large consumption of materials at constructions currently, the implementation of EVR can help developers to keep the construction waste produced during the contract period under control. This would lead to sustainable construction which creates a sustainable building environment and human health through efficient use of resources. Table 1 summarises the spreadsheet on EVR calculation for the selected construction projects in this study.

Figure 1. Construction waste disposal process (adapted from EMS 14001 records).

Table 1. EVR calculation based on five-project site.

Project	A	B	C	D	E
Type of building	Low-rise residential 72 units (Double Storey)	Low-rise residential 127 units (Double Storey)	Low-rise residential 108 units (Double Storey)	Low-rise residential 48 units (Triple Storey)	Low-rise residential 80 units (Double Storey)
Construction Method	Semi IBS (drywall for partition),shear wall for party wall and conventional method for rest	Semi IBS (drywall for partition),shear wall for party wall and conventional method for rest	Semi IBS (drywall for partition),shear wall for party wall and conventional method for rest	Semi IBS(,shear wall for party wall) and conventional method for rest	Semi IBS (drywall for partition),shear wall for party wall and conventional method for rest
Total Construction	December 2016-March	October 2016-January 2018 (	October 2016-January 2018 (	December 2016-April	November 2016-February

Period	2018 (15 months)	15 months)	15 months)	2018 (17 months) (on-going)	2018 (15 months)
GFA (m2)	136,800	208,280	189,000	163,200	133,600
Contract Sum (RM)	14,217,543.46	24,152,992.65	19,103,112.53	18,864,702.25	12,601,026.77
Wastage %	Rebar & BRC 10%,Concrete grade 25 (5%),Timber formwork 10%, Bricks 10%, Plaster cement 25%, Tiles 10%, Drywall 5%, Metal deck rofing 6% and Ceiling 5%	Rebar & BRC 12%,Concrete grade 25 (6%),Timber formwork 100%, Bricks 10%, Plaster cement 13%, Tiles 9%, Drywall 5%, Metal deck rofing 4% and Ceiling 5%	Rebar & BRC 13%,Concrete grade 25 (5%),Timber formwork 100%,Bricks 8%, Plaster cement 13%, Tiles 9%, Drywall 5%, Metal deck rofing 4% and Ceiling 5%	Rebar & BRC 8%,Concrete grade 25 (7%),Timber formwork 100%Bricks 8%, Plaster cement 9%, Tiles 10%, Drywall 0%, Metal deck rofing 4% and Ceiling 3%	Rebar & BRC 8%,Concrete grade 25 (7%),Timber formwork 100%, Bricks 8%, Plaster cement 9%, Tiles 10%, Drywall 2%, Metal deck rofing 4% and Ceiling 3%
Wastage Level (%)	10.39%	13.15%	14%	11.17%	22%
Total Unit and Delivery Lost (RM)	764,850.42	1,756,357.03	1,170,626.14	793,390.90	1,225,036.43
Total Unit and Delivery Lost (%)	0.09%	0.13%	0.14%	0.11%	0.22%
(vw)	25,920.00	42,120.00	51,840.00	48,384.00	69,120.00
(wc) (RM)	30,000.00	48,750.00	60,000.00	56,000.00	80,000.00
(WGR) (%)	0.0126	0.0135	0.0183	0.0185	0.0323
Waste index (wc/GFA) (%)	0.0146	0.0156	0.0212	0.0214	0.0374
Total Labour Cost (RM)	33,750	39,375	61,200	36,000	46,080
Landfilling cost (RM)	72,000.00	117,000.00	144,000.00	134,400.00	192,000.00
Total eco-costs (RM)	900,600.42	1,961,482.03	1,435,826.14	1,019,790.90	1,543,116.43
Material Lifespan	Timber formwork (4 - 5 times), shearwall panel 2 sets	Timber formwork (4 - 5 times), shearwall panel 4 sets	Timber formwork (4 - 5 times), shearwall panel 4 sets	Timber formwork (4 - 5 times), shearwall panel 2sets	Timber formwork (4 -5 times), shearwall panel 4 sets

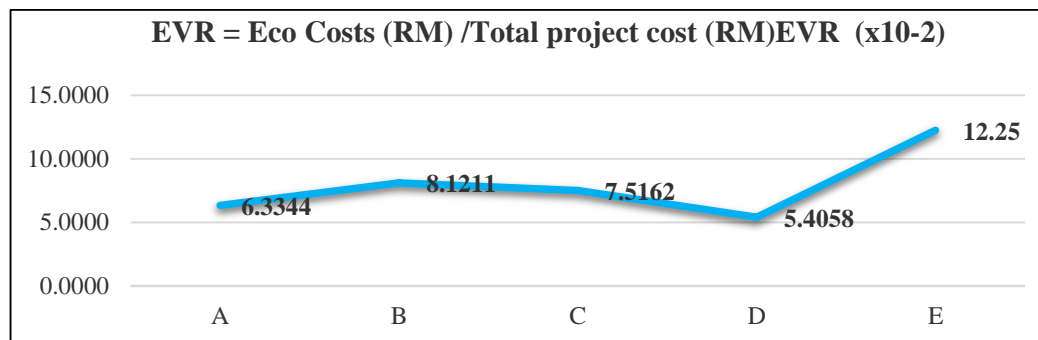| EVR = Eco Costs (RM) /Total project cost (RM)EVR (x10-2)	6.3344	8.1211	7.5162	5.4058	12.25

Figure 2. EVR ratio between five projects.

Based on Figure 2, the EVR index for Project D (0.054) was identified as the lowest among the other projects. The calculated EVR index values can serve as a contributing factor to the betterment of the waste management at the project areas by its developers. Furthermore, the waste index tabulated in Table 1 for Project A to Project E ranges from 0.014% to 0.040%. These index values will aid in monitoring the total waste disposal cost during any stages of the construction period. Besides, the project developers will be able to establish a better resources management plan towards sustainable development.

3. Conclusion

Construction waste management is an important element in construction for a sustainable development. The intention of this study was to develop a sustainable waste eco-cost model based on case study approach during the construction stage. The detailed assessment of the waste disposal cost saving between the conventional and sustainable building materials was performed using EVR method. The project D that adopted semi industrialised building system (IBS) with combination of shear wall and conventional method obtained better EVR index of 0.054 compare to other projects. However, for overall assessment of EVR index there are few steps of calculation required as above. The assessment provides efficient solutions to handling construction wastes which leads to sustainable construction waste management. Poor waste management can lead to unsafe environmental impact along with financial losses, the increase of the eco-costs for any project [13]. The increase in total waste produced from each material will increase the eco-costs for a project with lower gross floor area (GFA), hence, elevates the EVR index. Therefore, to lower the EVR index, total waste produced should be reduced indefinitely. The lower the EVR index, the better it is for society.

Acknowledgements

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