Mapping of construction waste for eco-costs per value ratio (EVR) index using Google My Maps in Shah Alam, Malaysia

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Abstract. Construction waste is one of the major challenges faced in our world today. The residential, commercial and infrastructure industries in Malaysia are recognised as rapidly growing sectors that indirectly bring economic growth to our country. However, the generation of waste in the construction industry is increasing in proportion to the development of new construction. This increase has resulted in negative environmental impacts. To address these issues, the present study focused on the mapping of construction waste generation in low-rise residential construction sites in Shah Alam district, Selangor, using the Google My Maps application. Information on construction waste generation data such as coordinates, photos, types of materials, types of waste, quantity of waste, gross floor area, labour cost, material life-spans and eco-costing per value ratio (EVR) index for monitoring was gathered manually through case studies and site observations over 14 months—the contract period. The collected data was inserted into Google My Maps and AppSheet for the mapping process. The findings of this analysis were based on five selected sample sites in Shah Alam that were under construction from 2013 to 2017. The results identified a total of nine types of construction waste, i.e. rebar and BRC, concrete grade 25, timber formwork, bricks, plaster cement, tiles, drywall, metal deck roofing and ceiling. These types of waste accounted for varying values of the EVR index in the construction projects during the contract period. The system proposed by this study will help to monitor the total construction waste generated from the start of a project and will potentially result in the reduction of construction waste, thereby contributing to sustainable construction.

1. Introduction
The construction industry plays an important role in the world economy. However, the large amount of construction waste generated by the construction industry negatively affects the environment and causes serious health problems. Construction waste is defined as any product, material or industrial activity that has no residual value [1]. Construction waste is generated by construction activity such as sub-structures, super-structures, renovation and demolition.

The types of waste produced are divided into physical and non-physical waste. Physical waste consists of mainly concrete, bricks, steel and packaging waste while non-physical waste includes cost overruns and time delays. Due to the increase in the volume of construction projects worldwide, there has been a corresponding increase in the amount of construction waste disposed of in landfills.
Various types of waste management strategies including reducing, reusing and recycling of construction waste, reducing liability, site waste management plans to keep the sites clean and conserving valuable landfill space have been adopted in the construction industry [1]. Nonetheless, factors such as over-production, poor materials handling, improper storage, error in materials purchased, design changes and poor workmanship have contributed to material waste.

[2] citing [3] stated that around 1 to 1.2 million dollars can be lost as waste per project. Hence, due to the different types of activities at construction sites, various types of waste are generated that cost projects millions of dollars each year.

Consequently, there is a need for a proper monitoring tool to control construction waste generation in order to minimise construction waste production at construction sites. If construction waste is managed well and minimised, construction companies and developers would be able to save costs and be more profitable companies. Thus, the present study focused on Google My Maps as a monitoring tool in construction waste generation, which is discussed in detail in the next subsection.

2. Google My Maps via AppSheet

Google My Maps is a computer tool for capturing, sorting, editing, analysing and reviewing geographical data for a particular set of purposes. This tool is used to generate the optimal route for reviewing the data of EVR indexes. Google My Maps not only incorporates data from Excel and Google spreadsheets but also provide a platform to store the data for future monitoring. This tool is easily accessed through a computer.

In addition, AppSheet was developed as an app to monitor generated data from Google My Maps to allow the assessor to continuously review construction waste generation during the inspection. This allows any township development consisting of more than one project to be easily identified through the coordinates and review of the data gathered. Users of Google My Maps can progressively upload photos of waste disposal, types of waste produced and the total number of workers used for housekeeping using Excel and Google spreadsheets.

Therefore, the objectives of the present study were to incorporate the EVR assessment process into Google My Maps via AppSheet to devise a simple monitoring process of construction waste generation within the targeted construction sites in Shah Alam.

3. Material and Method

This study focused on Shah Alam, Selangor, and was based on five sample sites observed during the years 2013 to 2017. Due to the increase of construction waste during the contract period, the EVR index was adopted to monitor the waste disposal process by the persons who handled the waste.

The present study sought to determine if it would be helpful for the housing developers of the selected sample sites to monitor the total waste produced within the contract period. These locations were chosen to determine the EVR index during the construction waste disposal process. The EVR index identified the projects’ waste generation rate within the contract period.

Thus, this study was carried out via the site inspection and observation approach to collect the EVR index data for a duration of between fourteen to sixteen months. The collected data for eco-costing considered in this study included the:

i. purchase cost and delivery lost;
ii. labour cost;
iii. total waste generated
iv. wastage disposal cost; and
v. landfill cost.

Besides the cost waste generation rate (WGR), the waste index (WI) and the waste level (WL) were identified as well in this analysis. The major data extracted included the:
i. gross floor area (GFA);
ii. material order quantities and material work done quantities from bills of quantity (BQ);
iii. construction debris disposal trip records;
iv. purchase and delivery costs; and
v. costs associated with waste generation and the total project cost (the contract sum).

Figure 1 below shows the causal loop diagram of the EVR to identify the variables associated with material flow. A feedback loop would be determined as positive if it included an even number of negative causal links and as negative if it contained an odd number of negative causal links [4]. The construction waste was classified into recyclable and non-recyclable waste.

Figure 1. Causal loop diagram of EVR on construction waste management.

A feedback loop is a closed-loop diagram in which one variable relies on another arrow’s direction so that either a positive or a negative feedback loop is created. In the end, all feedback loops complete the causal loop diagram. To evaluate the EVR index, the following process flows were adopted.

i. **Feedback causal loop cluster A**
Eco-costing per value ratio (EVR) index → Construction waste generation (labour cost, delivery lost, total waste generated, waste disposal cost, landfill cost) → Total eco-costs → Waste distribution (timber waste, bricks, plaster cement, concrete waste, tiles) → Non-recyclable → Eco-costing per value ratio (EVR) index.

ii. **Feedback causal loop cluster B**
Eco-costing per value ratio (EVR) index → Construction waste generation (labour cost, delivery lost total waste generated, waste disposal cost, landfill cost) → Total eco-costs → Waste distribution (ceiling waste, rebar and BRC, drywall, metal deck) → Recyclable → Eco-costing per value ratio (EVR) index.

This study assessed eco-costing as the result or consequence of the waste produced. In addition, it was developed in Google My Maps and AppSheet for continuous monitoring. Moreover, during the process of inspection and observation of the coordinates of the waste locations, site waste disposal photos and data on types of waste materials were gathered.

The coordinates of the waste locations were determined using Google My Maps for easy monitoring purposes. The data for Google My Maps was extracted from a Google spreadsheet, which
could be edited and monitored easily. Figure 2 shows the developed smartphone AppSheet to enable easy monitoring access.

![Figure 2. Data monitoring using Google My Maps via AppSheet on smartphone.](image)

Photos of construction waste material taken during site inspections, the data from the edited spreadsheet and the locations of the sites selected were included in this AppSheet. Furthermore, it could be deleted if there was no monitoring required by the assessor. The waste volume was assessed using an Excel spreadsheet to calculate the EVR index for each project. Figure 3 below shows the algorithm of the EVR index calculation.

![Figure 3. Algorithm view of EVR index calculation.](image)
Based on Figure 3, the EVR index was calculated based on the site inspections by the assessor, either on a daily, weekly or monthly basis, to collect and measure the data on total waste volume at the construction sites. The data was evaluated in the Excel spreadsheet to obtain the final value of the EVR index. Figure 4 below shows the general data available in AppSheet.

![Figure 4. Data on information for EVR index in AppSheet.](image)

Based on Figure 4, the extracted data from the Excel spreadsheet was formalised and evaluated in Google My Maps and AppSheet. For example, the total waste volume was calculated as pyramidal and rectangular shapes (as below) if the construction waste material was not placed at the designated areas.

**Pyramidal-shaped waste**

![Pyramidal-shaped waste](image)

**Rectangular-shaped waste**

![Rectangular-shaped waste](image)

*Total volume of waste, \( (vw) = (LxBxH) \)*
Where:
L is the length; B is the width; and H is the height [1]. The above method was also used by [5] and [6].

Figure 5 shows the pyramidal-shaped and rectangular-shaped waste types of construction waste gathered during site clearance before they were transported out from the site. They were measured based on the calculation method above.

![Pyramidal- and rectangular-shaped construction waste](image)

**Figure 5.** Pyramidal-shaped and rectangular-shaped construction waste.

Table 1 below shows the sample calculation of volume using the pyramidal and rectangular shapes of construction waste. The total volume for each type of waste was calculated using this method.

| Total Volume of Waste (Vw) | Quantity |
|---------------------------|----------|
| Pyramidal-shaped waste (m³) |          |
| Length (L) | 3        |
| Width (B)  | 5        |
| Height (H) | 3        |
| Total (m³) | 45       |

| Total Volume of Waste (Vw) | Quantity |
|---------------------------|----------|
| Rectangular-shaped waste (m³) |          |
| Length (L) | 2        |
| Width (B)  | 4        |
| Height (H) | 1        |
| Total (m³) | 8        |

Table 1. Excel spreadsheet calculation of waste volume

Once the volume of segregated waste was calculated based on the above method, the total volume per month based on the type of work was calculated. In addition, the total waste generated by the project was calculated using truck volume, which was based on the size of the RoRo bins and the total number of loads for waste disposal (see Figure 6 and Table 2 below).

The identified construction waste was gathered by general workers before it was transferred out from the construction site. The waste was based on the condition of the material. If it could no longer be used, the construction waste material was dumped into RoRo bins using machinery. During this stage, the total volume of waste was calculated.
The construction waste was transferred into the RoRo bins by site workers before it could be disposed of at the nearest landfill. Materials such as rebar or steel were usually directed to vendors. Table 2 shows the sample calculation using an Excel spreadsheet for waste volume calculation based on the number of trips. For the above selected sample site, construction waste was transferred out from the site approximately eight times.

**Table 2.** Excel spreadsheet calculation for waste volume for a one-month period

| Total Volume of Waste                                      | Quantity |
|------------------------------------------------------------|----------|
| Truck volume (m³) (V)                                      | 216      |
| Total number of loads for waste disposal (N)               | 8        |
| Total waste generated by project (VxN) (W) m³             | 1,728.00 |

**Figure 6.** Waste disposal process using RoRo bins.
The collected data from the inspection was developed through Google My Maps in order to review and monitor the construction waste, based on type, on a daily, weekly or monthly basis throughout the contract period. By the end of the contract period, the EVR index for the project site was calculated.

This procedure helped the assessor to continuously monitor the waste produced at the construction site by the nominated contractor in order to assess whether there was a reduction or whether it was more than the benchmarked value. Figure 7 shows the developed database using Google My Maps of the EVR index of construction waste distribution.

4. Conclusion
Construction waste management is an important element of sustainable development in the construction sector. To this end, the present study described the importance of a database in monitoring the construction waste disposal process and the EVR index in construction projects. Furthermore, the study showed how the relevant data was acquired and gathered to develop the database, which included mapping, coordinates, types of materials, photos and quantification of construction waste, using Google My Maps via AppSheet.

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