QUANTIFICATION OF CONSTRUCTION MATERIAL WASTE IN SRI LANKAN SITES

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ABSTRACT: This paper summarizes the results of a study which quantified the material wastage in Sri Lankan sites. The paper intends to provide the magnitude of waste, its causes and how it could be minimized. Sand was found to be having the highest wastage (25%) followed by Lime (20%), Cement (14%), Bricks (14%), Ceramic Tiles (10%), Timber (10%), Rubble (7%), Steel (7%), Cement Blocks (6%), Paint (5%) and Asbestos Sheets (3%). It was also found that in any waste prevention programme in Sri Lanka, Cutting and Management waste should be given priority over other causes. Cutting waste could be reduced mainly by design interventions. Management waste can be avoided by providing adequate supervision and proper organization of site activities.

Keywords: Construction, Material Reconciliation, Waste, Waste Prevention, Sri Lanka

1. INTRODUCTION

Ganesan (2000) states that materials account for the largest input into construction activities, in the range of 50% - 60% of the total cost. In addition a wide variety of materials are used in the construction industry. Construction industry consumes 25% of virgin wood and 40% of the raw stone, gravel, and sand used globally each year (Hobbs, 2001). Evidence shows that approximately 40% of waste generated globally originates from construction and demolition of buildings (Roach, 2001). Construction and demolition waste has taken a major portion of the solid waste discarded in landfills around the world. For instance, approximately 29% of landfill volume in USA (Bossink and Brouwers, 1996) and 44% in Australia (McDonald and Smithers, 1998) are taken up by construction and demolition waste. Many researchers have shown that there is a positive correlation between waste prevention and environmental sustainability [Federle(1993), Gallagher and Needham (2000), Lingard et al (2001), Mason (2000)].

In Sri Lanka, concrete and mortar showed 21% and 25% of wastage respectively due to the excess use of materials in rectification of inaccuracies (Jayawardane, 1994). The significance of money thrown away as waste is noted by Coomaraswamy (1979). Waste of materials in construction to a certain extent is unavoidable. Thus, any action taken to prevent the ‘unavoidable’ portion will create another waste in terms of either money or resources. However, Jayawardane (1992) noted that the wastage of materials in most of the construction sites in Sri Lanka is beyond acceptable limits.

This paper focuses on a quantitative analysis of material waste in Sri Lankan sites and their causes using on-site studies. This information is useful in planning waste management programmes. When the causes of waste are understood, preventive procedures have grater probability of being effective.

2. OBJECTIVES AND METHODOLOGY

Study of construction waste is a topic that has received considerable attention in developed countries. Except Jayawardane (1992) and Jayawardane (1994), no other research work has been carried out in Sri Lanka on this subject. Jayawardane's study quantified waste in terms of work items such as concrete, mortar etc. This constituted labour, material and plant together. Even though this work is useful in certain areas, quantification of material waste has direct use in the area of waste management. Therefore, this study was carried out with the intention of quantifying the material waste in Sri Lankan sites. As such, the objectives of this research effort were:

1. to quantify the wastage in commonly used construction materials,
2. find the causes of waste, and
3. to determine how these waste could be minimized.

Nineteen on site case studies have been conducted to quantify material wastage. A brief description of the case studies are given in Table 1 . The sample represents a variety of building projects. These nineteen sites were selected from six M1 grade contractors. Restricting the study among Grade M1 contractors is due to data availability. Table 2 shows the distribution of projects among the six contractors.

Waste quantification could be performed using work-studies or material reconciliation. Limited precision can be obtained from the former as the aggregation of waste arising from each stage of the construction is lesser than the total waste found from site records [Skoyles and Hussey (1974), Gavilan and Leonhard (1994)]. Material reconciliation is preferred over work studies due to:

1. inaccuracies and difficulties of measuring waste during construction work,
2. criminal waste will not be identified as any records on criminal wastage do not exist,
3. waste arising due to rectification of work will not be noticed, unless it is measured at that particular stage.

Further, this method is acceptable, as similar studies have been successfully carried out using this method in other countries (Skoyles and Hussey, 1974). Since material reconciliation is a very tedious process, waste quantification was limited to the most commonly used materials in Sri Lankan construction sites.

To identify the most commonly used construction materials in Sri Lanka, data were collected from a sample of 96 recently completed building projects. Bill of Quantities of these projects were analyzed to obtain the cost of each material input as a percentage of the total cost. From these input percentages the commonly used materials were selected for the study.

Table 1: Profile of the sample (n=19)

Item	Category	Number of projects
Cost of project	Less than Rs. 100 million	11
	Rs. 100-200 million	3
	Rs. 200- 300 million	3
	More than Rs. 300 million	2
Type of project	Social and Institutional	11
	Housing and Apartments	5
	Commercial	3
Type of client	Private	12
	Public	7
Location	Colombo	14
	Outstation	5

Table 2: Number of projects selected from each contractor

Contractor	A	B	C	D	E	F	Total
Number of projects	1	2	2	2	7	5	19

3. SCOPE OF THE STUDY

This study focuses only on the process waste at construction sites. Demolition waste is not included in the study. Within the scope of process waste, only material wastage has been taken into account. Labour and plant wastages are not within the scope of this study.

4. MOST COMMONLY USED MATERIALS IN SRI LANKA

The methodology described in ICTAD (1998) for computation of input percentages from the Bill of Quantities work items is used in this study. The methodology explains how the work items of a Bill of Quantities are analysed to obtain the list of materials that goes into the project. Composition of material, labour and plant in the work items is computed based on the norms of Building Schedule of Rates (BSR).

Table 3 summarises the results of data analysis. Accordingly, the most commonly used materials in building projects are cement, rubble, steel, timber, aluminium and so on. The standard deviations of rubble, steel, timber and cement are relatively high indicating inconsistency in use. Based on these results only 11 materials were selected for material reconciliation. Materials related to Building Services were ignored due to non-availability of data with the main contractor as most of the services work are procured through specialised sub-contractors (either domestic or nominated).

Table 3: Input percentages of Construction Materials Based on Cost (n = 96)

	Item	Input Percentage	
		Mean	Standard Deviation
Material	Cement	10.39	5.54
	Rubble	9.92	13.08
	Steel	9.54	9.34
	Timber	5.81	6.87
	Aluminium	3.41	4.51
	Ceramic Tiles	2.48	4.63
	Bitumen	2.40	5.12
	Electrical Fittings	2.30	4.24
	Sand	2.26	1.72
	Bricks	1.92	3.03
	PVC Pipes	1.85	4.79
	Cement Blocks	1.68	4.16
	Asbestos Sheets	1.68	4.61
	Sanitaryware	1.45	2.46
	Paint	1.29	1.68
	Electrical Wires	1.03	1.62
	Lime	0.33	0.90
	Glass	0.20	0.52
	Clay Roofing Tiles	0.11	0.52

	Ironmongery	0.10	0.52
	GI products	0.09	0.41
	Hume Pipes	0.06	0.50
	Zink Alum Sheets	0.03	0.22
	Coloured Pigments	0.01	0.05
Labour	Skilled Labour	10.13	4.73
	Unskilled Labour	9.65	4.26
	Semiskilled Labour	0.74	1.94
Equipment	Heavy Equipment	4.21	7.92
	Small Equipment	1.65	2.92
	Fuel	3.28	3.32
All other insignificant inputs		10.00	
Total		100.00	

5. MATERIAL WASTAGE IN SRI LANKAN SITES

As described in Research Methodology, six M1 Grade contractors participated in the study. The selected nineteen case studies comprises of projects that have just been completed or nearing completion. Material Reconciliation was carried out by comparing the difference between the store records and the actual requirement of the material according to the Bill of Quantities work items. Norms of the Building Schedule of Rates (BSR) were taken as the basis for analysing the work items of Bill of Quantities. This is justifiable as most contractors use BSR for estimating and material requisition. Wastage allowances are expressed usually in proportion to the actual quantity of work. Accordingly, this study considers wastage as proportionate to the actual work, as shown below.

$$\text{Material Waste Quantity} = \text{Store records - Actual material requirement}$$

$$\text{Material Wastage (\%)} = \frac{\text{(Store records - Actual material requirement)}}{\text{Actual material requirement}} \times 100$$

The average waste obtained from the case studies are summarised in Table 4. Figure 1 gives the summary statistics (Median, First Quartile, Third Quartile, Minimum and Maximum Values) for the wastage of each material. The Boxplot gives a very good idea on the centre and spread of wastages and a comparison among them. It is very clear that sand has the highest waste percentage (25%) followed by lime (20%), cement (14%), bricks (14%) and so on. The spread of sand, bricks and timber are high indicating inconsistency in results.

Table 4: Wastages of materials

Material	Waste as a Percentage
Sand	25
Lime	20
Cement	14

Bricks	14
Ceramic Tiles	10
Timber (Formwork)	10
Rubble	7
Steel (Reinforcement)	7
Cement blocks	6
Paint	5
Asbestos sheets	3

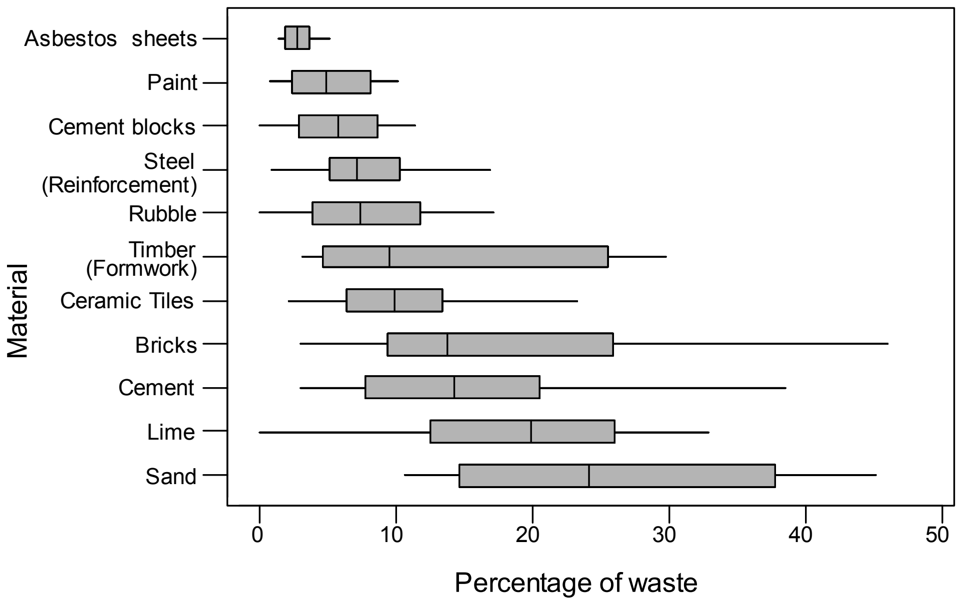

Figure 1: Wastage of materials (n =19)

6. CAUSES OF MATERIAL WASTE

Construction process waste can be divided into 2 categories as direct and indirect waste. Waste that can be prevented and involves the actual loss of material is called *direct waste* (Skoyles and Skoyles, 1987). With *indirect waste*, the material does not get wasted physically, but payments are made for non-usable end product (Skoyles and Skoyles, 1987). Most of the time, the cost of direct waste does not end up in the cost of material alone, but followed with the cost of removal and disposal. Thus, prevention of direct waste will undoubtedly bring benefits to the contractor [Johnston and Mincks (1995), Hobbs (2000), Mills et.al. (1999)]. Direct waste can occur at any stage of the construction process starting from delivery of material to the stage even after it is being incorporated in the end product. Types of direct waste can be summarized as follows (Skoyles and Skoyles, 1987).

1. Delivery Waste
Losses occur during transportation of materials to the site, unloading, and placing into the initial storage.

2. Stockpile waste
Wastage of stockpiled materials due to exposure to rain, pedestrian and vehicular traffic.

3. Cutting Waste
Losses due to cutting materials into various sizes and uneconomical shapes.

4. Fixing Waste
Occur due to dropped, spoiled or discarded material during fixing.

5. Residue Waste
Remaining portion of materials in containers and cans when they are not properly sealed. This category also include hardening of excess material stored after use.

6. Waste Caused by Other Trades
Damages occurred by succeeding trades.

7. Criminal Waste
Waste due to theft and vandalism.

8. Management Waste
Losses due to lack of supervision or incorrect decisions of the management.

9. Waste due to Wrong Use
Occur due to wrong selection of material.

How actual waste occur in construction sites? How the above causes are linked to material wastage? These are some of the questions which arise in a study like this. To answer these questions an on-site observation study was performed among case study sites which are still in operation. The researcher selected some pre-determined time periods, in consultation with the contractor to visit and observe the actual construction work. The generation of waste was observed during different stages starting from the material delivery, storage, handling and transportation within the site and finally during the incorporation of the material into the building. "Criminal waste" and "Waste due to wrong use" were impossible to detect using this method and were excluded from the analysis. Remaining seven types were included and observed for all eleven materials under consideration.

Table 5 shows the relationship between material wastage and the causes based on the observation study. This table indicates only the major causes. Causes which are insignificant have been omitted for clarity. It shows that lime and cement could be identified as similar in character and has only one major waste type, namely, the Management Waste. Lime has a higher waste percentage compared to cement due to lack of supervision. Excessive use of lime to increase workability is one example of wastage due to lack of supervision. Formwork and Reinforcement bars could be placed together as these two materials are subject to considerably high Cutting Waste. Paint is the only material which could be categorized under Residue Waste. Sand and Rubble has two major types of waste, namely Stockpile Waste and Management Waste. The waste percentage of Sand is more than three times that of Rubble mainly due to the difference in size of the material. The fineness of sand lead to increased waste compared to Rubble. Delivery, Cutting and Fixing are the three major waste types related to Ceramic Tiles and Asbestos Roofing Sheets. Bricks and Blocks have the highest number of waste types and considerably differ on the waste percentage. This difference could be explained using the brittleness of Bricks compared to Cement Blocks.

When the overall results are considered, Cutting Waste has the highest total frequency of occurrence. The frequency of occurrence for materials over 10% of wastage is highest for the Management Waste. Generally, what the above results indicate is that in any waste prevention programme the Cutting and Management waste should be given priority over the other causes.

Table 5: Observed waste types

Material	Delivery	Stockpile	Management	Cutting	Fixing	Other Trade	Residue	Wastage
Lime Cement			▲ ▲					20% 14%
Form work Reinforcement bars				● ●				10% 7%
Paint							●	5%
Sand Rubble		▲ ●	▲ ●					25% 7%
Ceramic Tiles Roofing Sheets	● ●			● ●	● ●			10% 3%
Bricks Cement Blocks	▲ ●			▲ ●	▲ ●	▲ ●		14% 6%
Total frequency of occurrence	*5*	*3*	*4*	*6*	*4*	*2*	*3*	
Frequency of occurrence for over 10%	*2*	*1*	*3*	*1*	*1*	*1*	*2*	

Note: ▲ Indicating materials having percentage waste more than 10%
● Indicating materials having percentage waste between 1% -10%

Even though cutting waste is unavoidable to a certain extent, deciding the acceptable limit of this waste is a problem. Thus, more consideration should be given to minimize this potential waste at the design stage. This can be done mainly through dimensional coordination. This is a method where the design of the building considers the production process by incorporating the components and elements to fit the site dimensions. Further, by integrating the dimensions throughout the building with the components or elements sizes, cutting waste can be avoided. For instance, off-cuts from a timber floor can be used elsewhere in a window reveal. Thus prevention of cutting waste could be done mainly through design interventions.

However, Management waste is entirely under the preview of the contractor. Management Waste could be avoided by providing adequate supervision and proper organization of site activities. In addition by adapting controlled delivery of materials to the sites (by ordering the materials on time) on exact and economical quantities, considerable portion of material waste can be avoided. Attitude of workers, supervisors and top management has a great impact on prevention of Management waste.

7. CONCLUSIONS

Materials account for the largest input into construction activities. This paper summarized the results of a study which quantified the material wastage in Sri Lankan sites. Sand was found to be having the highest wastage (25%) followed by Lime (20%), Cement (14%), Bricks (14%), Ceramic Tiles (10%), Timber (10%), Rubble (7%), Steel (7%), Cement Blocks (6%), Paint (5%) and Asbestos Sheets (3%). The statistical spread of sand, bricks and timber were found to be high indicating inconsistency in results.

The study found that Cutting waste and Management waste are the two most important causes of waste in Sri Lanka. In any waste prevention programme, Cutting and Management waste should be given priority over other causes. Cutting waste could be prevented by design interventions. Dimension coordination during design stage is the most effective way of reducing Cutting waste. Management waste could be avoided by providing adequate supervision and proper organization of site activities.

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