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Quantitative Analysis Of Building Construction Project Management And Waste Production Strategies In Highly Urbanized Cities Of Surabaya: A Case Study Of Kalidami Street Office

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Abstract

Surabaya is a second densely populated city with high-rise developments, and its construction waste generation is increasing annually. Existing landfills should be allocated properly to support the development, including the office building area. In fact, the current famous location for office location is centre nearly to the Kalidami street and mostly waste product from the construction development are coming from the project of that area. In Construction waste management in Surabaya has been implemented for years with mixed results. To investigate and formulate strategies and measures for effective construction waste reduction in highly urbanized cities. Furthermore, building waste has a negative economic impact by adding to the cost of construction due to the requirement to replace discarded materials. However, in order to reduce waste, construction managers must investigate management methods such as trash reduction, recycling, and disposal. Reduction is the highest priority among waste management strategies, but effective reduction cannot be achieved without a thorough understanding of the trash's origins. As a result, the goal of this work is to report the findings of a study on the contribution rates of 18-recognized sources of construction. Establishing the contribution rates of various waste sources will improve knowledge-based decision-making in designing an effective plan for construction waste mitigation. This study used a quantitative research method, a survey questionnaire, to analyse the frequency and severity of contribution of waste sources. One of the study's conclusions was that residual waste, was the largest contributor to construction trash. As a result, this study indicated that trash contributes significantly to building costs.

Keywords: Waste Cost, Waste Causal Factor, Waste Mitigation

Introduction

Waste can be formed during both the extraction and processing of raw materials, as well as the eventual consumption of end products derived from them. Construction activities such as demolition, building renovation, and new construction generate rubble and other waste materials (Formoso et al. 2003). The building sector has a long history of being ecologically unfriendly (Yu et al. 2013; Yuan et al. 2012). Construction cultural practices lead to waste by rewarding trade contractors for speed rather than their care for the environmental impact of their job (Ferronato 2019).

Furthermore, construction activities consume a considerable number of resources and energy while producing an intolerable amount of solid waste (Kabirifar et al. 2020). Every year, the construction sector utilizes 25% of virgin timber and 40% of raw stone, gravel, and sand globally (Formoso et al. 2003). In the United States, 40 percent of extracted resources are used in the production of building components and the construction process itself (Teo and Loosemore 2010). Land development, land deterioration, resource depletion, trash generation, and other forms of pollution are all consequences of construction operations (Kabirifar et al. 2020; Weisheng and Hongping 2012).The building industry accounts for approximately 35% of global industrial waste (Fadiya, Georgakis, and Chinyio 2014; Peng, Scorpio, and Kibert 2010).

According to Vivian et, al (2006), the last few decades the manufacturing industry has shown an increase in productivity improvement. At the same time the construction industry is still trying to deal with the problems caused by waste with a very large amount, comparing waste level between conventional in site practices and prefabrication (Tam et al. 2006). This is inversely proportional to the achievement of growth in manufacturing field that managed to achieve the level of added value from its product result over than 50% and suppressed by products in the form of waste to become over than 30% (Ferna, Leiva, and Vilches 2005).

Some of the waste that often occurs in a multi-storey building project include wood formwork, reinforcement iron, cement, coral, and sand (Putra et al, 2018). It can also author observes directly around the project area researched that waste material in the office building construction project at Kalidami Street Surabaya there are similar materials, especially formwork wood, reinforcement iron, some cement sack, and other materials.

Therefore, this research focuses about the largest waste material analysis on multi-storey building construction and identifying factors that cause waste material and finding the right waste mitigation, the study is titled "Waste Analysis and Mitigation on Office Projects in Kalidami Street Surabaya".

Literature Review

The use of materials is a very important resource element in realizing the planning goals of a construction project. However, it is different when viewed in reality in the field when the use of materials is often allocated optimally and efficiently. This will have an impact towards to lots of material leftovers wasted in vain, causing deviations in the plan's material budget with actual conditions. This condition is often referred to as the waste material (Ferronato 2019).

Inside the European Union, the building industry accounts for a significant portion of total waste generation, resulting in two to five times the quantity of home garbage (Fadiya et al. 2014). According to sited publication Rethinking Construction assessment on the condition of the Indonesia construction industry, up to 30% of all construction is reworked, labour is used at half its potential efficiency, and at least 10% of all building materials for every construction project is squandered (Gardner et al. 2018; Kamandang and Casita 2018). However, the massive amount of garbage produced by construction activities has a detrimental environmental, economic, and social impact. The environmental consequences of unregulated landfills include soil and water contamination, as well as landscape damage (Dhir et al. n.d.; Habert 2013). Material waste adds significantly to construction costs since fresh purchases are frequently necessary to replace wasted materials; rework, delays, and disposal expenses entail financial losses to the contractor (Mattei 2017). Furthermore, building waste has social consequences such as worker health and safety, as well as the construction industry's society image (Fadiya et al. 2014; Ferna et al. 2005; Rao, Jha, and Misra 2007).

Construction lean management is the most important waste management strategy, followed by reduction, recycling, and disposal as the example of steel construction or most used cold-formed steel materials(Indra Komara, Taşkin, et al. 2017; Indra; Komara, Wahyuni, et al. 2017; Komara et al. 2018; Komara, Wahyuni, and Suprobo 2016; I. Komara, Wahyuni, and Suprobo 2017; Wahyuni, Suswanto, and Komara 2015). Construction management should prioritize waste reduction, reuse, sorting, and recycling before disposal (Rao et al. 2007; Weisheng and Hongping 2012; Zhang, Wu, and Shen 2012). Previous research on construction waste reduction has included operational attitudes toward waste reduction (Banias et al. 2011), direct observation of trash generation (Andrew et al. 2019), and waste material sorting and weighing (Tam et al. 2006). Recycling is critical for preserving lands for future urban growth while also improving local environmental conditions (Pertiwi, Komara, and Fristian 2021; Susanti et al. 2021).

Identification of Waste Material Construction

Waste Level

This waste level is calculated using the general formula approach to find the volume of waste from each material item studied (Sugiyarto, 2017). This waste level is calculated using the formula:

$$\text{Waste level} = \frac{\text{volume waste}}{\text{volume of used materials}} \times 100\% \quad (1)$$

$$\text{true cost} = \text{purchase price} + \text{transportation cost} + \text{handling} + \text{storage cost} + \text{disposal} + \text{loss of salvage revenue} \quad (2)$$

If in the project does not have a management waste plan then it can use other methods, namely by using the following general formula approach (Sugiyarto, 2017):

$$\text{Waste cost} = \text{waste level} \times \text{workload} \times \text{total contract value} \quad (3)$$

where;

Purchase price	:	waste costs resulting from the difference in the cost of purchasing material plans with actual.
Transportation cost	:	the cost of transporting waste and its carriers.
Handling	:	waste handling costs.
Storage cost	:	the cost to providing a waste material hoarding place.
Disposal cost	:	waste disposal costs.
Loss of salvage revenue	:	the cost of losing material value due to unused.
Workload	:	Amount of Material Price / Total Contract Value
Amount of Material Price	:	Vol Material Used × Unit Price

Construction Wastes Sources

Construction waste is generated during the design, logistics, and physical construction stages. Construction wastes are materials that have been damaged and are intended for disposal, reuse, or recycling in the context of this study. According to Kenai (Kenai 2018), waste on building sites is caused by design, operational procurement, and material handling features. According to previous research, project design accounts for around 33% of on-site waste. As a result, waste reduction should not be only the duty of the construction business, as the customer and designer can make environmentally friendly decisions in the program of requests and designs (Andrew et al. 2019; Zhang et al. 2012). According to studies, material waste is frequently higher than the normal values considered by construction companies in their estimates (Formoso et al. 2003). While some construction trash is unavoidable, the potential benefit of minimizing waste generation on site can be significant. Furthermore, one of the goals of sustainable development is waste reduction, which includes both reduction at the source and recycling to minimize both quantities and dangers (Kenai 2018; Rao et al. 2007).

In addition to recycling, inert end-of-life products such as infill materials for land reclamation can be reused (Formoso et al. 2003). Construction trash has a considerable recovery potential, with 80 percent of total waste recyclable. Countries like Denmark, the Netherlands, and Belgium have accomplished the aforementioned recycling rate, despite a paucity of raw materials and disposal locations (Fadiya et al. 2014). Nonetheless, the most bulk of building debris is still disposed of in landfills (Ferronato 2019).

Waste sources	Causes
Procurement	Ordering error, supplier's error resulting in excessive materials on site
Design	Changes to design, documentation error
Material handling	Transportation, off-loading, and inappropriate storage
Operations	Tradesperson's error, for example, installing wrong materials and having to remove such materials
Weather	Humidity, temperature
Vandalism	Inadequate security
Misplacement	Untraceable materials, abandonment
Residual	Cutting materials to sizes
Others	Lack of waste management plan

Figure 1. Construction waste sources and causes(Fadiya et al. 2014)

Figure 2. Research stages according to quantitative analysis

Research Methods

The quantitative research method was used in this study in the form of a questionnaire sample survey. Quantitative research is described as an investigation into a social or human problem that is focused on testing a hypothesis made of variables with numbers and analysing the results with statistical procedures to determine whether the hypothesis is true. The most common quantitative research approaches are sample survey and experiment. The researcher manipulates certain controlled settings in order to establish the relationship between specific variables and explain cause and effect relationships (Fadiya et al. 2014; Peng et al. 2010). Statistical approaches are employed in questionnaire surveys to create a representative sample from which findings can be generalized to the entire population (Banias et al. 2011; Ferronato 2019; Zhang et al. 2012). The sample survey technique of quantitative research is consistent with the study's purpose, which is to assess the knowledge-based opinions of UK construction experts on the causes of trash on building sites. The stages of the research can be seen in Figure 2.

Research Design

With construction waste sources as the independent variables, a survey questionnaire was developed to measure the opinions of building contractors on the severity and frequency of these sources' contribution using a Likert scale, which is a multi-item measuring scale with response levels anchored with consecutive integers and symmetrical about a neutral middle. It is a valid method for obtaining the strength of beliefs by employing numbers to reflect implicit meanings(Fadiya et al. 2014; Ferronato 2019; Tam et al. 2006). Respondents were given the following response levels on a 5-point scale:

(1) intensity of contribution: 1 (none), 2 (little), 3 (moderate), 4 (great), and 5 (severe);

(2) frequency of contribution: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), and 5 (extreme) (always).

The questionnaire was split into two sections. The first section inquired about the respondent's background, the size of their organization, the catchment region of their projects, annual turnover, and headcount. The second section attempted to quantify the severity and frequency of waste generating sources. The severity rating is a measure of the extent of these sources' influence in terms of the volume of waste that can be generated, whereas the frequency rating is a measure of how frequently the sources contribute to construction waste. The sum of the severity and frequency ratings will yield the significance of the sources' contributions. Table 1 is an example of a questionnaire question and response.

Table 1. The severity of the sources of building waste's contribution.

Waste source	Contribution rate				
	None	Little	Moderate	Great	Severe
	1	2	3	4	5
(a) Procurement errors such as ordering errors and supplier errors caused by incorrect data		✓			
(a) Design issues, such as design changes and contract document errors			✓		
(c) Material handling issues such as transportation damage, off-loading, on-site distribution, and improper storage				✓	
(d) Errors in operation, such as tradesperson error and equipment failure				✓	
(e) Weather-related damage, such as temperature and humidity			✓		
(f) Security, such as vandalism on the building site.			✓		
(g) On-site material misplacement				✓	
(h) Residual such as off-cuts from cutting materials to length and packaging			✓		
(i) Others such as lack of site materials control and waste management plans			✓		

Severity of construction waste sources: Please grade the following waste sources based on the extent to which they contribute to building material waste (1 being no contribution and 5 being extreme contribution). Write down into the information below which also indicate the waste cost of the materials.

Data collection and sampling

Statistical approaches should be employed in a questionnaire survey to design a representative sample that will yield findings that are representative of the entire community (Yu et al. 2013; Zhang et al. 2012). The sample was chosen to reflect building and civil engineering contractors in Kalidami street, Surabaya, with the goal of getting comments from contractors who operate locally and nationally.

Table 2. Waste source indications from most common formwork

No	Material item	Unit	Volume	Unit price (IDR)	Amount (IDR)	Cuumulative amount (IDR)	Total percentage (%)	Percentage cummulative (%)
a	b	c	d	e	d x e	f	g	h
1	Steel rebar Ø8 plain	kg	39,498.20	Rp 12,000.00	Rp 473,978,420.37	Rp 473,978,420.37	28.22	28.22
2	Steel rebar D13 deformed	kg	36,628.48	Rp 12,000.00	Rp 439,541,757.96	Rp 913,520,178.33	26.17	54.40
3	concrete mix Fc 25 Mpa	m3	492.14	Rp 870,000.00	Rp 428,158,498.33	Rp 1,341,678,676.66	25.49	79.89
4	Formwork plywood 12mm	lbr	1,401.32	Rp 152,000.00	Rp 213,000,210.86	Rp 1,554,678,887.52	12.68	92.57
5	Steel rebar D10 deformed	kg	3,780.52	Rp 12,000.00	Rp 45,366,248.92	Rp 1,600,045,136.44	2.70	95.27
6	Hollow 100x50x2 mm	m	208.47	Rp 75,000.00	Rp 15,635,220.59	Rp 1,615,680,357.02	0.93	96.20
7	Plywood meranti 4/6	m3	3.73	Rp 4,100,000.00	Rp 15,283,488.00	Rp 1,630,963,845.02	0.91	97.11
8	Screw	kg	429.31	Rp 22,000.00	Rp 9,444,820.00	Rp 1,640,408,665.02	0.56	97.68
9	Wiremesh M8	lbr	11.40	Rp 725,000.00	Rp 8,265,000.00	Rp 1,648,673,665.02	0.49	98.17
10	Steel rebar Ø6 plain	kg	656.04	Rp 12,000.00	Rp 7,872,480.00	Rp 1,656,546,145.02	0.47	98.64
11	Concrete mix Fc 30 Mpa	m3	8.15	Rp 920,000.00	Rp 7,498,000.00	Rp 1,664,044,145.02	0.45	99.08
12	Bendrat	roll	22.25	Rp 320,000.00	Rp 7,118,991.94	Rp 1,671,163,136.96	0.42	99.51
13	Hollow 50x50x2 mm	m	157.43	Rp 27,000.00	Rp 4,250,647.06	Rp 1,675,413,784.02	0.25	99.76
14	Hollow 40x40x2 mm	m	79.88	Rp 22,500.00	Rp 1,797,220.59	Rp 1,677,211,004.61	0.11	99.87
15	Cement 40 Kg	zak	13.82	Rp 63,000.00	Rp 870,912.00	Rp 1,678,081,916.61	0.05	99.92
16	Hollow 20x40	m	26.11	Rp 25,000.00	Rp 652,850.49	Rp 1,678,734,767.10	0.04	99.96
17	Coarse aggregate mix	m3	1.11	Rp 466,000.00	Rp 516,452.27	Rp 1,679,251,219.37	0.03	99.99
18	Fines aggregate mix	m3	0.71	Rp 232,100.00	Rp 165,202.15	Rp 1,679,416,421.52	0.01	100.00
TOTAL					1,679,416,421.52		100.00	

Results and Discussions

Analytical evaluation of material recapitulation from the investigation using pareto diagram is conducted.The questionnaire results were analysed using ordinal logistic regression to calculate the probability of rating categories (1, 2, 3, 4, and 5) for the severity and frequency of the contribution of the sources of construction waste. The probability of a category (e.g., 2) is calculated by dividing the number of respondents who chose the category by the total number of respondents in the sample. Table 5 highlights the results of the ordinal logistic regression study of the severity of design in contributing to construction waste. Following the development of probabilities for severity categories and the frequency of contribution of each waste source, these probabilities were averaged to produce severity and frequency indices.

Tables 2 illustrate the severity and frequency indices computed for the sources of construction waste considering the item of most used materials compared to the waste cost of the materials. As a guide, the severity index of design modification was calculated using the probabilities indicated in Table 1. After grading the value, the cost of anticipated waste source indications was being analysed. According to the 18-investigation coming from the detail of the responses, steel rebar problem become the main issues followed by the placement of pouring concrete using mix design of ready mix 25 MPa. Those three become the highest rate of comment with high intensity of waste cost.

The severity and frequency indices in Tables 1 and 2 were merged using current unit cost in Surabaya to produce the contribution indices based on the waste cost analysis. The contribution material factorwas measure of the significance of each source, while the severity index is a measure of the extent of contribution and the frequency index is a measure of how frequently a source contributes. Furthermore, the contribution indices were transformed to rates according to (g and f) in order to calculate percentages of the sources' contribution to construction waste. As a result, the rates of contribution of the sources of construction waste will be taken.

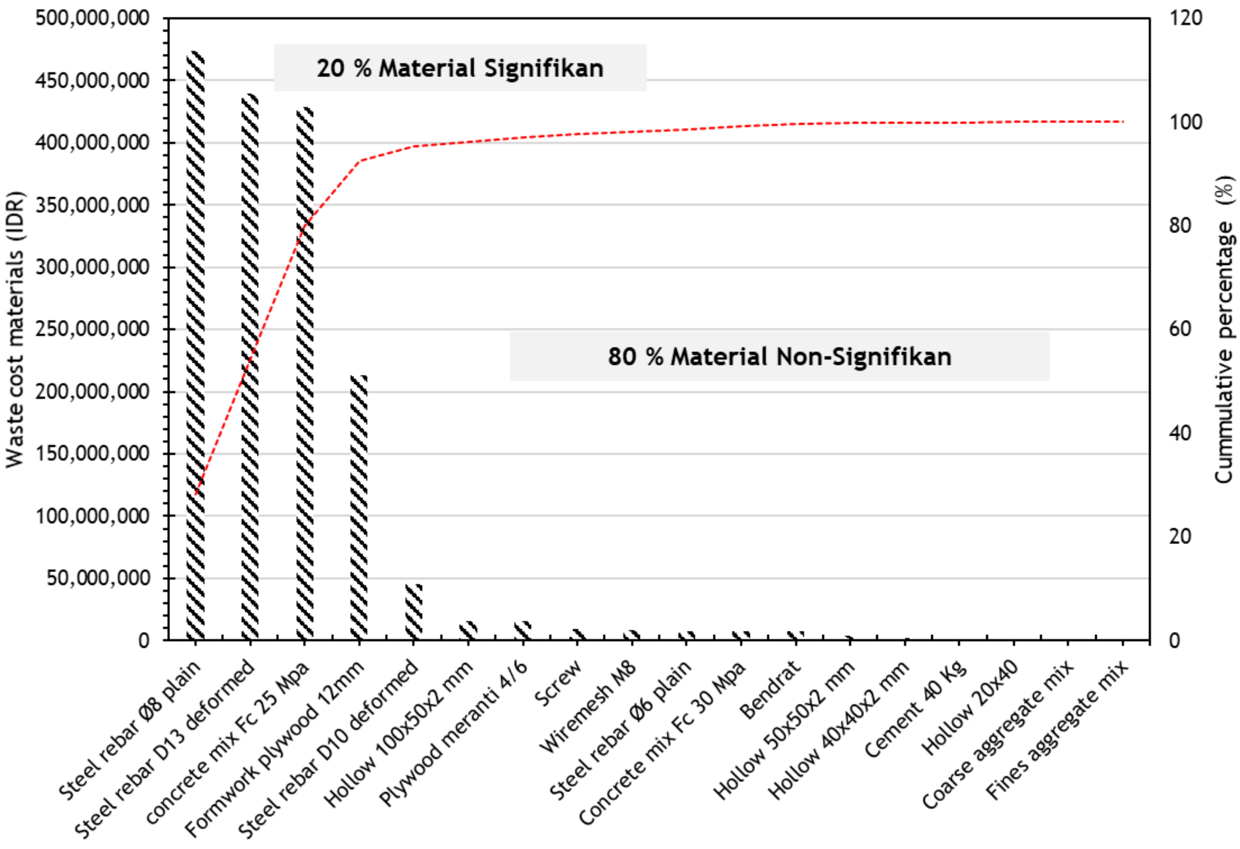

Figure 3. Pareto analysis diagram of waste materials

This section demonstrates how the contribution rates derived in this study can be used to estimate the cost of material wastes in building projects. Although some residual level of construction waste is unavoidable, the correlation between waste and cost minimisation is substantial and provides an incentive for participants in construction projects to pursue them. The total cost of waste is the sum of its materials and disposal costs.

Rates of contribution basically based on waste levels which are calculated to find out the volume of waste of each material that has previously been determined using pareto analysis. Below is the example of calculation of waste level in the material attached to the steel rebar Ø8-plainaccording to Indonesian Standard . Normally, a single steel rebar Ø8-plain is having 12 m long which equivalent to 4.74 kg and then easily determined by ;

Used Volume	= 1,062 rods (obtained from warehouse reports) equivalent to 5,033.88 kg
Installed Volume	= 4,277.57 kg
Volume Waste	= Used Volume – Installed Volume
Volume Waste	= 5,033.88 kg – 4,277.57 kg = 756.31 kg
Waste Level	= (Volume Waste) / (Used Volume) x 100%
	= 756.31/5,033.88 x 100% = 15.02 %

Extent to the contribution, waste cost calculation then followed by the waste cost analysis. The following calculation of waste cost in the material obtained by the considering contract obtained from secondary data of some companies which valued by Rp 3,250,336,000. Following calculation can be identified as informed below;

Workload	= (Amount of Material Price)/(Total Contract Value) x 100%
Material Price	= Vol Used x Unit Price
Material Price Amount	= 5,033.88 x Rp 12,000 = Rp 60,406,560
Workload	= (Amount of Material Price)/(Total Contract Value) x 100%
Workload	= (Rp 60,406,560)/(Rp 3,250,336,000) x 100% = 1.86%
Waste Cost	= Waste Level x Workload x Total Contract Value
	= 0.1502 x 0.0186 x Rp 3,250,336,000 = Rp 9,075,717.50

Conclusion

This research has produced an analytical approach for calculating the cost of construction trash. Reliable calculation of the cost of construction waste prior to the start of construction activities would help decision makers better comprehend the financial implications of waste generation and improve their decision-making in designing an effective waste-mitigation plan. Knowing the extent of contribution and the cost implications of misplacement, for example, can aid in decision-making regarding the adoption of information and communication technology-based tracking systems such as radio frequency identification devices, which can mitigate misplacement and abandonment of materials on large construction sites. Furthermore, as a result of the study's findings, waste can be reduced by, for example, design by factoring in standard dimensions of materials, labour by careful handling of materials during construction, adequate storage to avoid damage, and so on. Based on the investigation study, steel rebar become a big problem of waste materials and become a greatly waste cost contribution especially of Ø8-plain and D13-deformed.

Furthermore, the outcomes of this study suggest that waste is a significant contributor to building costs. The overall cost of trash is projected to be 20% of the material cost, where 80% implied in un significant issues. Furthermore, the rates of contribution and corresponding ranking of waste sources will improve prioritization of the sources that could be mitigated in the face of budgetary challenges of mitigation measures. Residual (off-cuts of materials to design dimensions), design change, and material handling are the first, second, and third largest contributors of construction waste, respectively. Using the method used in this study, important project stakeholders will be able to estimate the expected volume and cost of waste in the future.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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