

Strategies for Minimizing Material Waste with the Application of Lean Construction in Building Construction Projects

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Abstract

The purpose of this study is to identify the dominant indicators causing material waste in building construction and formulate strategies to minimize material waste by applying lean construction principles in building construction projects. The research sample was 15 small-scale contracting companies in Gianyar with 2 to 3 respondents in each company, namely directors, field managers, and implementers. Data collection used a questionnaire. The data processing technique used was factor analysis. The test results show that there are 10 indicators of the causes of material waste that often occur, namely, the design does not adjust the size of the available material, lack of knowledge about construction implementation techniques, drawings with volume calculations are not well integrated, construction materials cannot be stored for a long period of time, excessive wet material mixtures, remote material storage locations, improper use of conventional formwork, lack of periodic checks related to the results of the work, material specifications installed are not appropriate, lack of attention to material specifications in the field. Strategies to reduce material waste based on the application of lean construction principles are training for workers involved, scheduling good material procurement, using standard components available on the market by paying attention to modules that can be applied, increasing communication with various parties in exchanging information through discussion forums, checking work results and material specifications regularly.

Keywords: Material Waste, Lean Construction, Factor Analysis, Focus Group Discussion

Introduction

Construction projects are said to be successful if the construction can be completed on time, within the cost budget and with good quality (Sufa, 2012). Construction projects are a long process, where in its implementation many obstacles and problems are encountered. common problems that often occur in the implementation of building construction projects include, among others, less effective utilization of materials in the project and the amount of residual material caused so that it can cause cost overruns and have an adverse impact on the environment both in the present and the future. This is more likely to occur in construction projects carried out by small-scale construction service companies, given that generally small-scale construction service companies or contractors have limitations in resources, mastery of technology and management capabilities that are lacking in them, when compared to large-scale construction service companies that have more complete resources and more adequate management capabilities so that prevention and handling of material waste are more calculated or planned (Asnudin, 2005).

Waste is everything that is not in accordance with the needs or all products that are not in accordance with customer desires such as excess material, not according to specifications or

damaged (Julsena et al., 2018). Material as one of the components that has an important role in determining the cost of a project has a contribution of 40 - 60% of project costs, so it indirectly plays a very large role in supporting the success of a construction project, especially in the cost component, the more material that is left or wasted, the more wasteful the development is. Attention in this case can be in the form of a planned action or strategy in overcoming the problem (Botchway et al., 2023; Kabirifar et al., 2020; Nawaz et al., 2023). Strategy is a statement about what the organization must do to act from one reference point to another reference point which is a form of planning that integrates goals and policies (Rusli, 2018), so new strategies and innovations are needed to overcome this problem.

Lean construction is a way to design a production system that can minimize material waste from the use of materials, time, and effort in order to produce maximum value (Putri, 2019). The reason lean construction needs to be implemented in Indonesia is because it offers innovation opportunities that are comprehensive (broad, thorough, thorough and covering many things) and fundamental or fundamental in nature, this concept covers both the fields of construction management, construction engineering and the supporting environment and has been applied in the construction industry.

Methods

This research is quantitative research. The population of this study is a contractor company with small qualifications in Gianyar Regency. Director, Site Manager and Executor in each contractor company so that the total respondents were 40 people. The sampling technique used is purposive sampling by selecting respondents according to certain criteria on the grounds that the selection of respondents is based on experience and strategic positions in a project which in a sense is included in the expert category. The data in this study were obtained by filling out a questionnaire adapted from previous research and adjusted to the research statement, using a Likert scale of 1-5. The data processing method uses factor analysis. The factor analysis used is confirmatory factor analysis with the help of the SPSS 22 program which aims to form factors and to determine factors that have been determined at the beginning or test the factors formed to match the factors that have been determined at the beginning. From the results of these results, the dominant indicators that cause material waste in building construction will be obtained, then after the dominant indicators are found, a Focus Group Discussion (FGD) is conducted with representatives from each contractor regarding the formulation of strategies to minimize building construction material waste combined with applying lean construction principles to building construction projects.

Results and Discussion

Validity and Reliability

The validity test results for variables at the planning stage found 15 valid statements. At the implementation stage variable, 20 statements were declared valid and at the supervision stage, 14 statements were declared valid. In the reliability test of the three stages of the project, the Cronbach alpha value was obtained successively, namely 0.881; 0.946; 0.963, the results show the Cronbach alpha value > 0.70, so it is said to be reliable.

Factor Analysis

The first step in factor analysis is to determine the Kaiser-Mayer-Olkin (KMO) value must be > 0.5 and Bartlett's Test of Sphericity must be < 0.05 (Malhotra & Birks, 2007). The variables at the planning, implementation and supervision stages of the project have KMO results with the lowest significance values of 0.760; 0.745 and 0.784 respectively. Although the significance level of the three variables is 0.000, factor analysis can still be carried out. The

Measures of Sampling Adequacy (MSA) value on the planning stage variable has one statement below 0.5, this value will be excluded from the model for the next step, while the MSA value on implementation and supervision has met the requirements. The collectively obtained value on each variable has also met the requirements, which is greater than 0.5 (50%), meaning that each factor can be explained well. In checking the number of factors, the criteria used are eigenvalue > 1, in the project planning variable there are three components with eigenvalue > 1, in the project implementation variable there are four components with eigenvalue > 1, and in the project supervision variable there are three components with eigenvalue > 1, the Component Transformation Matrix value obtained for each component is also greater than 0.5; this means that each component can be said to be able to summarize all variables. After each factor corresponds to a predetermined group, the dominant indicator can be determined based on the largest correlation value for each component at each project stage shown in Table 1.

Table 1. Loading Factor Value of Indicators at Each Project Stage

Stage	Factor	Dominant Indicators Causing Material Waste	Value
Planning	Design/Planning Document	The design does not adjust to the size of the available materials.	0,900
	Human Resources	Lack of knowledge of construction execution techniques by planners.	0,830
	Working Method	The drawing process with volume calculation is not well integrated.	0,900
Implementation	Material	Construction materials that cannot be stored for a long time	0,918
	Human Resources	Overmixing of wet material	0,890
	Lokasi	Long distance of material storage location	0,933
	Working Method	Using conventional formwork is not effective.	0,968
Surveillance	Working Method	Lack of regular monitoring and checking on the results of work in the field.	0,955
	Material	The specifications of the installed materials do not match.	0,929
	Human Resources	Lack of attention to material specifications on site.	0,902

In this study, after obtaining the dominant or most influential factors from each factor, strategies will be formulated to minimize material waste based on lean construction principles that can be applied to building construction projects through Focus Group Discussions. Focus Group Discussion is carried out only for sub-factors or dominant indicators in a factor in each aspect of the project, including the design does not adjust to the size of the available materials, lack of knowledge about construction implementation techniques by planners, the drawing process with volume calculations is not well integrated, construction materials that cannot be stored for a long time, excessive mixtures in wet materials, long distance of material storage locations, using conventional formwork, lack of regular monitoring and checking related to the results of work in the field, installed material specifications are not appropriate, lack of attention to material specifications on site. After conducting a Focus Group Discussion, a

strategy to minimize material waste with lean construction principles is obtained which is shown in Table 2.

Table 2. Results of Strategy Formulation with the Application of Lean Construction Principles

Subfactors Causing Material Waste	Root Cause	Countermeasure Strategy
The design does not adjust to the size of the available materials.	The use of iron and other components used are designed with non-standard sizes or require several cuts, resulting in waste of pieces of material that cannot be used again.	<ul style="list-style-type: none"> - Early collaboration between designer and material provider, - Continuous feedback from material providers at regular intervals, - Good procurement planning, - Modular customization, - Using standard components available in the market.
Lack of knowledge of construction execution techniques by planners.	The planner lacks knowledge of the techniques and methods of implementation of construction in the field, both from the selection of specifications and implementation methods included in the RAB and technical specifications. Such as the selection of bamboo as scaffolding, conventional formwork and the selection of concrete mix methods that use ready mix concrete or site mix.	<ul style="list-style-type: none"> - Organize or include workers in a periodic training (Team Preparation) - Implement a mentoring program that connects experienced workers with new or less experienced workers (Daily Huddle Meetings).
The drawing process with volume calculation is not well integrated.	The drawing process and volume calculation are done separately, the calculation and drawing activities are not well integrated, done by different people and the software used is not integrated.	<ul style="list-style-type: none"> - Use Building Information Modeling-based software that can integrate design and material volume estimation, such as Revit or Tekla.
Construction materials that cannot be stored for a long time	Construction materials that cannot be stored for a long period of time or need to be used immediately, such as concrete mixes that have been mixed will dry out quickly, iron that rusts quickly, cement that has been exposed or paint mixes that dry out quickly will not be usable.	<ul style="list-style-type: none"> - Just in Time (JIT) organizes the delivery of construction materials to arrive exactly when they are needed at the project site, - Collaboration with Suppliers, - Accurate Planning and Scheduling, - Prefabrication and Modularization, - Storage space management.

Overmixing of wet material	Workers are less competent in producing mixed materials to be installed according to predetermined specifications, so it is possible to require more materials so that the composition and quality produced according to specifications such as when mixing concrete, paint, plastering, acian, etc.	<ul style="list-style-type: none"> - Training and education of workers (Team Preparation), - Regular evaluation of the mixing process (Fail-safe for Quality), - Improve communication and coordination between field teams and management (Daily Huddle Meetings), - Standardize work processes.
Long distance of material storage location	The limited project area resulted in the construction material storage warehouse on the project being quite far from the project, requiring more activity in transporting to the project site so that materials would be scattered during the transportation process.	<ul style="list-style-type: none"> - Reorganization of temporary or mobile storage locations, - Good scheduling of material procurement, - Use of adequate fleet and equipment, - Strict supervision.
Using conventional formwork is not effective.	Using formwork with conventional methods such as plywood, wood, multiplex which after use will be wasted and will result in waste of materials when adjusting the size to the cross section due to waste of unused pieces of material.	<ul style="list-style-type: none"> - Using a modular design, - Selection of the right formwork material, - Worker training, - Strict supervision, - Implementation of precast formwork system.
Lack of regular monitoring and checking on the results of work in the field.	The supervisor did not carry out continuous monitoring and checking of the work results in relation to quality and volume control, allowing inefficient use of materials.	<ul style="list-style-type: none"> - Standardization of Work, - Involve all teams in good communication and coordination through discussions and meetings (Daily Huddle Meetings), - Use software technology or drones or cameras for regular monitoring.
The specifications of the installed materials do not match.	The specifications of construction materials installed in a job are not carried out in accordance with technical specifications and drawings both in terms of quality and planned form.	<ul style="list-style-type: none"> - Worker training (Team Preparation), - Involve all parties in error prevention efforts, - Periodic inspection (Fail Safe for Quality).
Lack of attention to material specifications on site.	The lack of attention of supervisors regarding the specifications of the materials used, especially on the quality of iron that is not in accordance with the plan if the quality of iron used is	<ul style="list-style-type: none"> - Creation of clear standards and documentation, - Checklists and protocols before materials are used on site, - Improved communication and coordination (Daily Huddle Meetings),

	lower than the required calculation, it will increase the amount of iron needed to be installed.	- Participate in regular training (Team Preparation).
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The results obtained in this study differ from previous research studies related to the dominant indicators as the cause of material waste in building construction projects and strategies and efforts to overcome them. A summary of the research results between previous studies where Hastuti et al. (2015) found that the types of material waste produced were dominated by solid waste, liquid waste and relatively little gas. The causes of material waste are grouped into several factors including planning, procurement, handling, implementation and residue factors. The residual factor is the dominant factor as a cause of material waste such as the remaining pieces that cannot be used again. Efforts that can be made are to sell the waste and use it as backfill. Lestari et al. (2022) shows that the causes of material waste are errors in contract documents, purchase of materials not according to specifications, improper material storage, imperfect planning, material cutting errors, lack of knowledge about mixing wet materials and poor material control in the field.

Efforts that can be made to overcome this are good communication, claiming to be asked to replace materials that do not meet specifications, arranging the location of materials, training workers, providing cutting areas, controlling the accuracy of the amount of material sent to the project. Sharma et al. (2022) are some actions or efforts that can overcome a material waste with the application of lean construction obtained from the results of discussions and opinions from the client, experts and also field workers such as the application of legitimate site council strategies, accurate and good determination of materials, the right material capacity on site, buying enough raw materials and reuse of materials. The research also resulted that the most important problem of lean construction implementation is that workers cannot complete tasks successfully. In addition, Srivastava et al. (2023) describes efforts to minimize the generation of industrial waste such as the reuse of residual materials as a blending agent in the cement industry which has been investigated in the red mud process.

This research outlines the sustainable management of industrial waste where industrial waste will become a source of secondary materials and minimize the burden of pollution. The circular economy has created a sustainable pathway between industry and the environment. Tafesse (2021) also describes efforts that can be made to minimize material waste which are compiled or formulated based on the opinions of contractors, consultants and clients, these efforts are hiring waste management officers, using prefabricated or off-site component production, proper site waste management, implementing material waste minimization plan policies. As for this study, reviewing the indicators of the dominant causes of material waste in each of the factors contained in the three stages of the project and the strategies formulated refer to the results of the indicators of the dominant causes of material waste and are based on the actions or principles of lean construction, this study examines the causes of waste that are more specific and more detailed so that they can complement the results of previous studies in terms of different project stages and add insight into the choice of strategies that can be carried out.

Conclusion

The cause of material waste in building construction projects is that the design does not adjust to the size of the available materials. It is necessary to conduct early collaboration between designers and material providers, consider the size of standard materials available in the market and adjust the design made with these materials. Indicators of lack of knowledge about construction implementation techniques by planners need to be carried out worker training on material specifications and construction implementation techniques for planners. Indicators

that the drawing process and volume estimation calculations are not well integrated can be strategized by implementing Building Information Modeling-based collaboration software that can be integrated with other software. Indicators of construction materials that cannot be stored for a long time need to accurately organize the delivery of construction materials and good storage space management. Indicators of over-mixing of wet materials, it is necessary to train workers on material specifications and material handling in order to achieve the planned quality, regularly evaluate the mixing process and improve coordination between stakeholders. Indicators of long distance of material storage locations need to be rearranged storage locations and good scheduling of material procurement. The waste caused by the use of conventional formwork can be overcome by using modular design and proper selection of formwork materials and worker training and strict supervision of formwork installation and dismantling. Indicators of lack of regular monitoring and checking of work results, it is necessary to improve communication by involving all teams through discussions and meetings and use software technology or drones or cameras for regular monitoring. Indicators that the specifications of the installed materials are not appropriate, it is necessary to train workers or recruit competent workers and carry out strict and periodic checks. Indicators of inattention to the specifications of materials available at the site need to be made clear standards and improved documentation and communication as well as checklists before materials are used at the project site. Recommendations for readers, the results of this study are expected to add information about the causes of material waste and strategies to minimize material waste by applying lean construction principles. Contractors are expected to maximize the use of materials to be efficient.

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