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The Application of Lean Construction uses the Borda Method and the Root Cause Analysis Method (Case Study: Sunrise Mall 2 Construction)

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Abstract: The purpose of this study is to find the root causeof critical problems that occurred in the construction of Sunrise Mall 2 in Mojokerto City. The Borda method was used to obtain the sequence of waste that occurred at the project site, the pareto principle to determine the most critical to non-critical parameters, focus group discussions to obtain the perspectivesof the expert team, and root cause analysis using the 5 why's approach to obtain the root causes of the waste that occurred. From the results of theanalysis, five critical parameters were found to contribute to the biggest problems. The RCA analysis identified the root causes of each critical waste parameter identified, overprocessing with the sub-parameter "The existence of repair"; overproduction with the sub-parameter "There are design change"; motion with the sub-parameter "No dedicated storage for workers"; defects with the sub-parameter "Suitability/adequacy of heavy equipment used" waiting with the sub-parameter "Delay in material arriving at project site". The results of the analysis will be visualized in the form of a fishbone diagram to obtain a comprehensive overview of all waste generated during the construction of Sunrise Mall 2 in Mojokerto City.

Keywords: waste, lean construction, borda

Introduction

Construction projects are complex and dynamic projects. This complexity creates its own challenges in predicting and controlling the course of a project effectively. In each stage of development, there are many variables that must be carefully managed, from the initial planning to the final completion stage(Xia & Chan, 2012). Various internal factors, such as design changes that may occur due to owner demand or market needs, can result in significant adjustments in the project schedule. In addition, underskilled human resources and an inadequate number of workers can also slow down the progress of the project (Oktaviani, 2018).

One of the main problems in construction projects is the existence of activities that do not provide added value, or more often referred to as waste non-added value activities (Yarbrough et al, 2022). Waste non-added value activity or can be abbreviated as NVA includes various processes and activities that use resources, be it time, human labor or materials, but do not make a significant contribution to the function of the product, or in the case of a development project, do not provide progress on the project (Koskela et al., 2013). The main advantages of the implementation of lean construction are reduced labor requirements, faster job completion, increased safety and cleaner project sites (Dara et al, 2024).

The application of lean construction is a strategic approach that is commonly used in the construction world, more precisely aiming to minimize and eliminate NVA or more often referred to as waste (Shaqour, 2022). Focusing on eliminating activities that do not add value, lean construction helps optimize the use of time, materials, and labor, so that projects can be completed at a lower cost. Thus, the implementation of lean construction creates financial benefits for companies and creates sustainability in the construction world (Andika et al, 2022).

Multiple decision making with borda method is one of the strategies in lean construction research, especially when the research involves the assessment and selection of alternatives by a number of parties or experts with different preferences (Pamungkas et al, 2024). Through this method, each respondent can rank a number of alternatives, the combined results of the rankings are processed to get the most objective priority order and acceptable to all stakeholders. The borda method able to bridge diverse viewpoints, increase transparency in the selection process and effective in making final decisions that have a positive impact on overall project improvement (Resti et al, 2024).

The Pareto principle is an important foundation in finding critical parameters in lean construction implementation (Ali & Nugraheni, 2024). The concept of few causes resulting in most impacts can be applied to identify the main factors that should be prioritised in an effort to improve project efficiency. The pareto principle can map that about 80% of problems usually come from 20% of causes (Prameswari et al, 2025). This approach helps stakeholders to focus resources, actions and improvement strategies on those aspects that have the greatest impact on overall project performance. The application of the pareto principle not only accelerates the decision-making process and prioritises corrective actions, but also contributes to achieving the lean construction goals of minimising waste and optimising added value throughout the construction phase (Irfanto & Charolin, 2024).

Root cause analysis plays a central role in finding the root cause of problems after conducting a series of borda and pareto analyses (Aisyah et al., 2023). Through the systematic approach of RCA, each identified waste can be analysed in depth until the underlying cause of the problem is found, not just the surface symptoms (Nabilah et al., 2025). This process provides an opportunity for stakeholders to develop more accurate and long-term improvement solutions due to direct intervention at the actual source of the problem. RCA makes an important contribution to lean construction practices in an effort to increase efficiency, minimise waste and create optimal added value at every stage of a construction project (Wibowo et al, 2018).

Focus group discussion (FGD) is a qualitative research method involving a small group of people, typically around 6 to 12 participants (Moretti et al., 2011). The participants share common characteristics or experiences relevant to a particular topic (Shabina et al., 2024). Guided by a moderator, the group engages in an interactive and structured conversation to understand more about their perceptions, attitudes and opinions. The main goal is to gain deeper insights through group dynamics where participants exchange ideas, give feedback to other opinions and generate a new perspective to the following subjects (Ning et al, 2024).

The fishbone diagram serves as an effective visualisation tool in summarising and mapping the series of analyses that have been conducted (Coccia, 2018). From various causal factors, root causes to identified wastes, fishbone diagrams are able to illustrate the cause-and-effect relationship of each major problem in a comprehensive and structured manner (Lestari & Adhirajasa, 2024). This approach not only facilitates the identification of the root causes of critical waste, but also helps present the results of the analysis in a transparent and easy-to-understand manner so that all project stakeholders can see the big picture and focus on the improvement priorities that have the most impact on project performance (Arif & Gunawan, 2023).

Methodology

The methods used in this study include qualitative and quantitative analysis, quantitative methods will be used to identify activities that do not provide added value and the application of lean construction principles at the project site. Data will be collected to analyze how lean construction can be applied in the context of mall construction that is experiencing delays. In addition, qualitative methods will use RCA to understand more deeply about the causes of delays that occur (Worster et al, 2006).

This research was conducted on the construction project of Sunrise Mall 2 Mojokerto City located on Jalan Benteng Pancasila, Mojokerto City, East Java, Indonesia (Figure 1).

Figure 1. Site plan for the construction of Sunrise Mall 2 in Mojokerto City (https://earth.google.com, 2025)

The flowchart in Figure 2 below will be a reference in conducting this research.

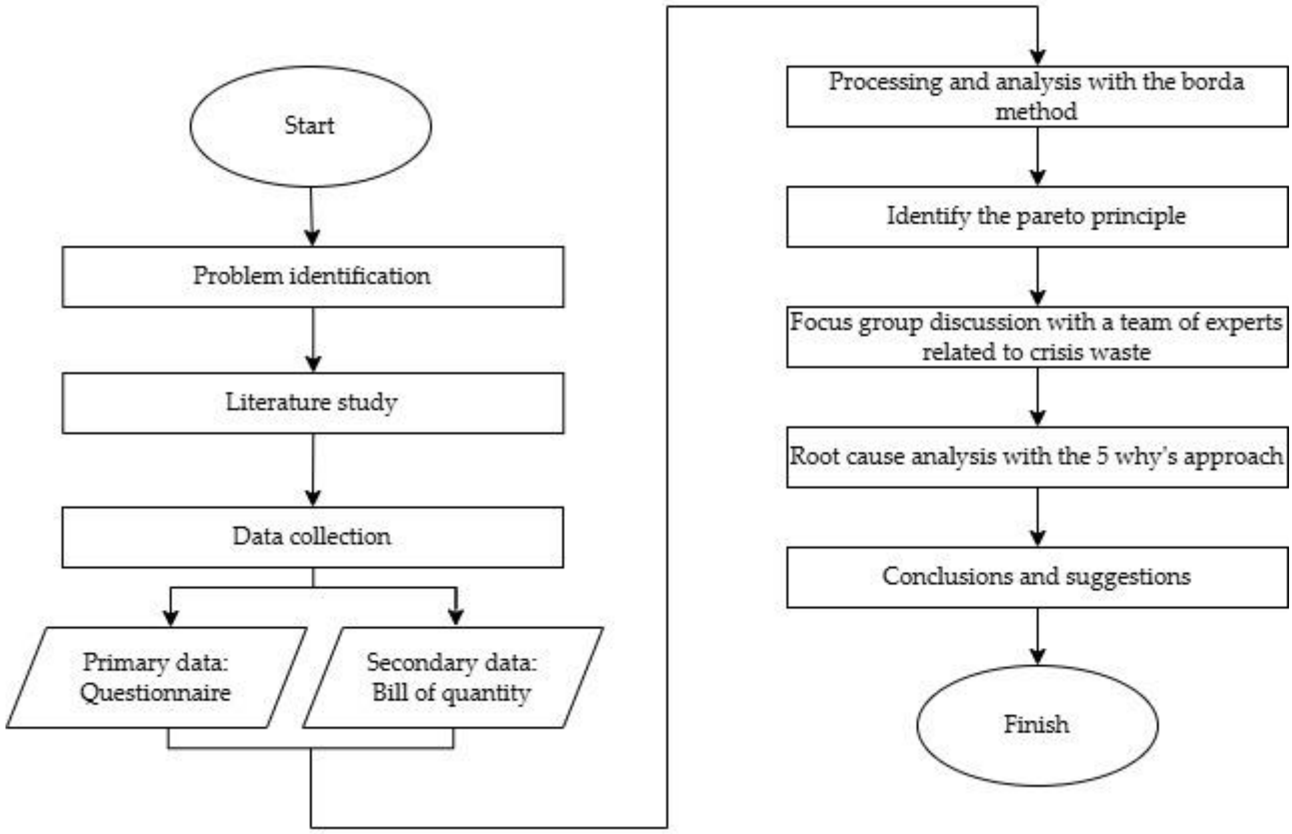

Figure 2. Flowchart

Based on Figure 2 the research procedures in this study include:

1. Identify problems and conduct literature studies on lean construction, boring methods, pareto methods, focus group discussions, root cause analysis (RCA) and fishbone diagrams in order to determine the research objectives.
2. Data collection, there are 2 types of data used in this study, primary data in the form of surveys and questionnaires from respondents and secondary data in the form of literature from previous research in the form of books, journals and other research results.
3. After collecting waste parameter data through the distribution of questionnaires, then a recapitulation of the questionnaires that have been collected is carried out. The borda method is used in order to get representative results from the respondents. The calculation of the number of points on each variable is formulated with the following equation (Pamungkas et al, 2024):

   $$bi = \Sigma k \times rik\text{-}1$$

   BI = Adjusted borda value on a scale of 1-5

   rik= Rank from the likert scale
4. The results of the borda calculation will then be sorted from the most dominant to the non-dominant, the 20/80 pareto method is used to determine the critical and non-critical

variables. If the results of the pareto calculation cannot reach 20/80, then the coverage of pareto will be expanded to get a cumulative problem of 75%.

5. RCA will be used to get the root of the problem from the critical variables of each parameter. The focus group discussion (FGD) method was used in the interview process with workers involved in the construction process of Sunrise Mall 2 Mojokerto City. The recapitulation of the FGD is the author's reference in determining the root of the problem of each critical variable.
6. The results of the series of analyses in the form of the root of the problem from critical parameters, will then be visualized in the form of a fishbone diagram to get an overview of the research from beginning to end.

Result and Discussion

Recapitulation of Questionnaire Distribution

There were 18 respondents used in this study. The selected respondents are workers involved in the Sunrise Mall 2 construction project in Mojokerto City. The data that has been obtained through the distribution of the questionnaire will then be calculated using the borda method in order to get the highest waste parameter and variable cause of waste (Allo & Bhaskara, 2022). Recapitulation of the results from the borda method calculation are presented in Table 1.

1. Rank 1 : Strongly Disagree
2. Rank 2 : Disagree
3. Rank 3 : Neutral
4. Rank 4 : Agree
5. Rank 5 : Strongly Agree

Table 1. Recapitulation of Questionnaire Distribution

No.	Waste parameter		Waste sub-parameter	Influence Level				
				1	**2**	**3**	**4**	**5**
1.	Overproduction	a.	Materials ordered beyond requirements	1	7	5	4	1
		b.	There are design changes	0	0	3	8	7
		c.	Loss of materials at the project site	3	4	3	8	0
		d.	Compatibility of field progress with schedule/planning is not on target	1	3	4	7	3
		e.	Lack of control over material use	2	2	3	9	2
2.	Waiting	a.	Delay in material arriving at the project site	0	1	4	10	3
		b.	Weather not supportive	2	5	3	7	1
		c.	The previous stage of work is still in the completion stage	1	5	0	12	0
		d.	Length of approval waiting time	0	4	6	4	4
		e.	There is a force majeure (natural disaster)	10	2	6	0	0

No.	Waste parameter		Waste sub-parameter	Influence Level				
				1	2	3	4	5
3.	Transport	a.	Ordered materials do not go directly to the project site	3	7	6	1	1
		b.	Material ordering location is too far away	1	3	11	3	0
		c.	Ineffective jobsite layout	2	6	7	3	0
		d.	Material delivery schedule does not match	1	2	4	10	1
		e.	Limitations of access	3	8	6	1	0
4.	Overprocessing	a.	Incompatibility of work procedures	0	3	8	6	1
		b.	The existence of repair	0	0	4	9	5
		c.	The existence of rework	0	0	4	11	3
		d.	Lack of supervision	1	3	3	8	3
		e.	Presence of unnecessary work/activities	1	5	9	3	0
5.	Inventory	a.	Storage exceeds warehouse capacity	2	6	6	3	1
		b.	Materials damaged during storage	1	8	7	1	1
		c.	Poor material arrangement	0	4	7	7	0
		d.	Poor planning and scheduling	0	3	5	7	3
		e.	Delay in material arriving at the project site	0	4	9	5	0
6.	Motion	a.	Workers perform unnecessary movements	0	4	6	8	0
		b.	No dedicated storage (for worker work tools)	0	4	6	7	1
		c.	No disposal area	0	3	8	7	0
		d.	Inconsistent working methods	0	4	6	8	0
		e.	Blocking of work areas	1	4	8	5	0
7.	Defects	a.	Incompatibility of the process	0	5	6	7	0
		b.	Material not up to specification	3	3	4	7	1
		c.	Poor material storage	2	4	6	5	1
		d.	Suitability/adequacy of the heavy equipment used (according to capacity)	0	3	3	10	2
		e.	Low worker skills	1	5	8	2	2

Data Processing Using the Borda Method

The borda method is used to process the data that has been obtained through the distribution of questionnaires by giving a weight of points to each ranking position given by the respondents to the waste sub-parameters (Pratistha et al., 2018). The fifth rank is given the highest value weight (n-1), the fourth rank is given the value weight (n-2), the third rank is given the value weight (n-3), the fourth rank is given the value weight (n-4) and the fifth rank is given the value weight (n-5) or equal to 0. After calculating each level of influence on the likert scale, the scores obtained from the respondents are accumulated to obtain the final waste rating based on total points, which will be used for the pareto principle. This method is effective in accommodating the group's opinion objectively in determining the most critical waste priority. The recapitulation from the results of the borda calculation can be seen in Table 2.

Table 2. Recapitulation of Borda Method

No.	Waste parameter		Waste sub-parameter	Influence Level					Total value	Cumulative value
				1	2	3	4	5		
1.	Overproduction	a.	Materials ordered beyond requirements	1	7	5	4	1	33	212
		b.	There are design changes	0	0	3	8	7	58	
		c.	Loss of materials at the project site	3	4	3	8	0	34	
		d.	Compatibility of field progress with schedule/planning is not on target	1	3	4	7	3	44	
		e.	Lack of control over material use	2	2	3	9	2	43	
2.	Waiting	a.	Delay in material arriving at the project site	0	1	4	10	3	51	186
		b.	Weather not supportive	2	5	3	7	1	36	
		c.	The previous stage of work is still in the completion stage	1	5	0	12	0	41	
		d.	Length of approval waiting time	0	4	6	4	4	44	
		e.	There is a force majeure (natural disaster)	10	2	6	0	0	14	
3.	Transport	a.	Ordered materials do not go directly to the project site	3	7	6	1	1	26	156
		b.	Material ordering location is too far away	1	3	11	3	0	34	
		c.	Ineffective jobsite layout	2	6	7	3	0	29	
		d.	Material delivery schedule does not match	1	2	4	10	1	44	
		e.	Limitations of access	3	8	6	1	0	23	
4.	Overprocessing	a.	Incompatibility of work procedures	0	3	8	6	1	41	226
		b.	The existence of repair	0	0	4	9	5	55	
		c.	The existence of rework	0	0	4	11	3	53	
		d.	Lack of supervision	1	3	3	8	3	45	
		e.	Presence of unnecessary work/activities	1	5	9	3	0	32	

No.	Waste parameter		Waste sub-parameter	Influence Level					Total value	Cumulative value
				1	2	3	4	5		
5.	Inventory	a.	Storage exceeds warehouse capacity	2	6	6	3	1	31	182
		b.	Materials damaged during storage	1	8	7	1	1	29	
		c.	Poor material arrangement	0	4	7	7	0	39	
		d.	Poor planning and scheduling	0	3	5	7	3	46	
		e.	Delay in material arriving at the project site	0	4	9	5	0	37	
6.	Motion	a.	Workers perform unnecessary movements	0	4	6	8	0	40	196
		b.	No dedicated storage (for worker work tools)	0	4	6	7	1	41	
		c.	No disposal area	0	3	8	7	0	40	
		d.	Inconsistent working methods	0	4	6	8	0	40	
		e.	Blocking of work areas	1	4	8	5	0	35	
7.	Defects	a.	Incompatibility of the process	0	5	6	7	0	38	191
		b.	Material not up to specification	3	3	4	7	1	36	
		c.	Poor material storage	2	4	6	5	1	35	
		d.	Suitability/adequacy of the heavy equipment used (according to capacity)	0	3	3	10	2	47	
		e.	Low worker skills	1	5	8	2	2	35	

Implementation of the Pareto principle

After obtaining the waste rating from the calculation through the boring method, the pareto method is used to visualize and identify the waste that contributes the most to the problems that occurred in the Sunrise Mall 2 construction project. The Pareto principle helps to focus the analysis on waste that has a significant cumulative impact, so that the root of the problem can be analyzed on the most critical sub-parameters (Arif & Gunawan, 2023). The priority waste parameters of the borda method calculation can be strengthened by sequencing the parameters using the pareto method. The following is the cumulative value of each waste parameter that has been calculated using the borda method and ranked from the most critical to least critical (Table 3).

Table 3. Cumulative Waste Value

No	Parameter waste	Value	Cumulative value	Cumulative percentages
1	Overprocessing	226	226	17%
2	Overproduction	212	438	32%
3	Motion	196	634	47%
4	Defects	191	825	61%
5	Waiting	186	1011	75%
6	Inventory	182	1193	88%
7	Transport	156	1349	100%
	Total Value	1349		

Table 3 lists the cumulative value of the waste parameters that have been calculated using the borda method. The results from the calculation above will be a reference for the pareto principle in determining the critical parameters of the identified waste.

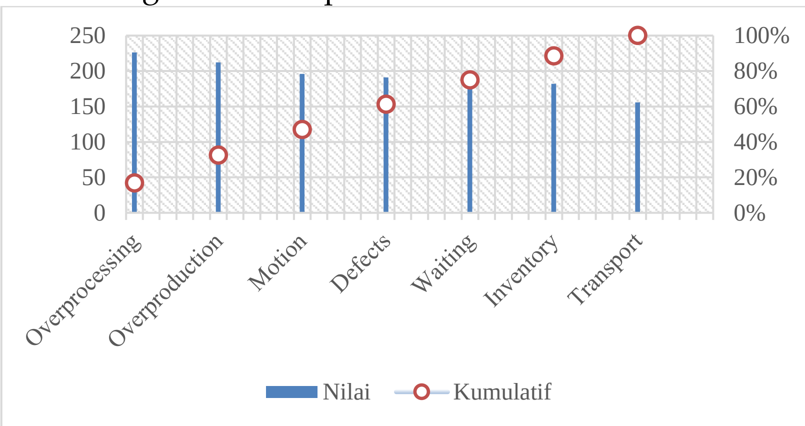

Figure 3. Pareto Diagram

Figure 3 shown that after being processed using the pareto method, it can be found that the 20/80 principle cannot be used in this study, because the results of each parameters are adjacent, so the coverage of the cumulative value of the parameters will be expanded to 75% (Irfanto & Charolin, 2024). 75% of the cumulative value includes 5 critical waste parameters, including: overprocessing with the sub-parameter "The existence of repair"; overproduction with the sub-parameter "There are design change"; motion with the sub-parameter "No dedicated storage"; defects with the sub-parameter "Suitability/sufficiency of the heavy equipment used" waiting with the sub-parameter "Delay in material arrival at the project site". From the five critical waste parameters, the root of the problem of each parameter will be sought using the RCA method with the 5 why's approach. The results of the RCA were obtained through the author's observation and interviews with a team of experts using FGD.

Focus Group Discussion

After obtaining the critical waste parameters, the most critical sub-parameters of each critical parameters will be analyze for the root of the problem. The FGD was carried out to get a perspective from a team of experts related to the problems that occurred (Nyumba et al, 2018). The following is a recap of the FGD from each critical parameters:

Table 4. Recapitulation of Overprocessing FGD Results

	Analysis of the 5 why's	**Support for FGD results with Project managers, Site engineers, Field implementers**
Why 1	There is damage to the work item	Project manager: "Repairs often occur due to a lack of quality control in the early stages" - confirms that the damage does occur due to a lack of control over the work items that are already installed
Why 2	The work done is not in accordance with procedures	Implementer: "Repairs are usually caused by unclear instructions" - support that procedural inconsistencies stem from poor communication
Why 3	No maintenance/maintenance is carried out on the work items that have been installed	Site engineer: "Repairs can be minimized with periodic inspections and a more detailed quality checklist" - reinforces the importance of periodic maintenance
Why 4	The ability of workers is still lacking	Project manager: "Worker training needs to be improved to reduce errors" - in line with the identification of worker skills shortages
Why 5	Lack of effective supervision of workers	Project manager: "Repairs often occur due to the rush to get the job done, better time management is needed" – supports that less effective supervision causes workers to work in a hurry

Based on Table 4 the results of the FGD related to the overprocessing parameters, it was found that the first root of the problem occurred because there was damage to the work item caused by a lack of control over the work item that had been completed. According to the executive, the lack of control over the items that have been worked on is caused by unclear instructions. The potential for damage can be minimized if periodic maintenance, lack of ability from workers and lack of supervision contribute to damage to work items.

Table 5. Recapitulation of Overproduction FGD Results

	Analysis of the 5 why's	**Support for FGD results with project managers; Site Engineer**
Why 1	The owner requested a design revision after construction began	Project manager: "Design changes often occur due to immature initial planning" - reinforces that revisions occur due to immature planning
Why 2	The needs of the owner are not clearly defined from the beginning	Project manager: "Design changes should be clearly communicated to all teams to avoid misunderstandings" - supports the importance of clearly defining the owner's needs/wants
Why 3	Communication between owners and planners is less efficient	Site engineer: "Design changes cause purchased materials to become unused" - reinforcing the impact of poor communication

	Analysis of the 5 why's	Support for FGD results with project managers; Site Engineer
Why 4	There are no contract documents governing design revisions	Project manager: "Design changes affect the project schedule and budget significantly. Need stricter approvals" - in line with the need for clear contract documentation
Why 5	-	-

The results from the Table 5 above explains that the FGD regarding the waste overproduction parameter, with the sub-parameter "There are design changes", it can be known that the owner requested a design revision after the construction process began. According to the project manager, the lack in the planning process also contributes to this waste, the needs of the owner who are not clearly defined from the beginning are also one of the reasons why design revisions can occur when the project is already running. Communication between the planner and the owner and the absence of a contract that regulates design revision are the root of the main problem.

Table 6. Recapitulation of Motion FGD Results

	Analysis of the 5 why's	Support for FGD results with Project managers; Site engineer; Field implementer
Why 1	Unplanned work area with adequate storage space	Project manager: "The storage layout needs to be well planned" - reinforces that the problem stems from the planning of the work area
Why 2	Project layout planning pays less attention to tool storage needs	Implementer: "Need toolboxes in every work area" - supports that layout planning doesn't consider storing work tools for workers
Why 3	Lack of coordination between planners and implementers regarding operational needs	Site engineer: "What can be done now is to provide empty tenant slots as temporary storage for workers' work tools" – reinforcing that coordination at the planning stage is still not good
Why 4	-	-
Why 5	-	-

Table 6 above explains that motion parameters with the sub-parameter "There is no storage space for workers" can occur because during the planning process, operational needs such as storage space are not considered. According to the site engineer, because the project is already running, tenant slots that have not yet been worked on or occupied by tenants will be used as a storage place for workers' tools. The lack of coordination between planners and implementers is the root of the main problem why this waste can occur.

Table 7. Recapitulation of Defects FGD Results

	Analysis of the 5 why's	Support for FGD results with Project managers; Site engineer
Why 1	Heavy equipment is provided directly by the owner, without considering the specific needs of the work in the field	Site engineer: "The heavy equipment used on the project is mostly owned by the owner, only a few are rented" – confirming that the provision of heavy equipment does not take into account the specific needs of the project
Why 2	Heavy equipment selection based on the availability of heavy equipment owned by the owner	Project manager: "Most of the heavy equipment is owned by the owner, but in some jobs such as during structural work, we still have to rent suitable heavy equipment, such as tower cranes at the beginning of the work" – supporting that even though most of the heavy equipment used belongs to the owner, we still have to rent heavy equipment that is suitable for the work required.
Why 3	Lack of coordination between contractors and owners regarding the optimal need for heavy equipment for each type of work	Project manager: "Need a proper machine needs analysis" - reinforces that the provision of tools does not take into account the specific needs of the project
Why 4	The responsibility for the procurement of heavy equipment is entirely on the owner	Project manager: "As long as the existing equipment can be used properly, there is no need to rent other heavy equipment" – confirms that the heavy equipment used is limited to what the owner has
Why 5	-	-

The results from the FGD in Table 7, regarding the defects parameter with the sub-parameter "Suitability of the heavy equipment used" can occur because the heavy equipment used in the project is the property of the owner without considering the specific needs in the field. The lack of coordination related to the specific needs that occur in the field and the responsibility for the procurement of heavy equipment that is entirely on the owner is the root of the problem of this waste.

Table 8. Recapitulation of Waiting FGD Results

	Analysis of the 5 why's	Support for FGD results with Project managers, Site engineers, Quantity surveyors;
Why 1	Delivery of materials by suppliers is not on time	Project manager: "The process of ordering materials is often hampered due to the late approval process from the owner" – confirming that delays can be caused by internal parties
Why 2	The supplier does not have a sufficient amount of material	Quantity surveyor: "Some materials already have a subscription place by the owner, so if the material is not finished production, we have to wait first" - supports that supplier limitations are a problem
Why 3	Ordering materials to suppliers too close to the work installation schedule	Quantity surveyor: "There are often delays in material arrival, it can be due to long approvals, or there may be obstacles from the supplier" - reinforces that the timing of orders and contracts needs to be improved

	Analysis of the 5 why's	Support for FGD results with Project managers, Site engineers, Quantity surveyors;
Why 4	The design of the owner is still undetermined	Site engineer: "If there is still a design that has not been dropped, we must report it to the Project manager so that it can be forwarded to the owner and planner" - in line with the impact of design uncertainty
Why 5	-	-

Table 8 above shows that delays in the delivery of materials are the most critical sub-parameter of the waiting parameters. Based on the results of the discussion, it can be seen that the delay in material arrival is due to the supplier not having a sufficient amount of material. Design revisions from the owner that are still undetermined and the installation schedule of the materials to be used are too close together resulting in delays in the delivery of materials.

RCA The 5 Why's

The results of this series of research analyses produced final results in the form of the root of the problem of each critical waste.The table below is a recapitulation of the root from the problem of critical waste (Table 9).

Table 9. Recapitulation of The 5 Why's

Waste parameter	Waste Sub-parameter	Why 1	Why 2	Why 3	Why 4	Why 5
Overprocessing	The existence of repair	There is damage to the work item	The work done is not in accordance with procedures	No maintenance/maintenance is carried out on the work items that have been installed	Abilities/skills of workers that are still lacking	Lack of strict supervision of workers
Overproduction	There are design changes	The owner requested a design revision after construction began	The needs of the owner are not clearly defined from the beginning	Communication between owners and planners is less efficient	There are no contract documents governing design revisions	
Motion	No dedicated storage for worker work tools)	Unplanned work area with adequate storage space	Project layout planning pays less attention to tool storage needs	Lack of coordination between planners and implementers regarding operational needs		

Waste parameter	Waste Sub-parameter	Why 1	Why 2	Why 3	Why 4	Why 5
Defects	Suitability/adequacy of the heavy equipment used (according to capacity)	Heavy equipment is provided directly by the owner, without considering the specific needs of the work in the field	Heavy equipment selection based on the availability of heavy equipment owned by the owner	Lack of coordination between contractors and owners regarding the optimal need for heavy equipment for each type of work	The responsibility for the procurement of heavy equipment is entirely on the owner	
Waiting	Delay in material arriving at the project site	Delivery of materials by suppliers is not on time	The supplier does not have a sufficient amount of material	Ordering materials to suppliers too close to the work installation schedule	The design of the owner is still undetermined	

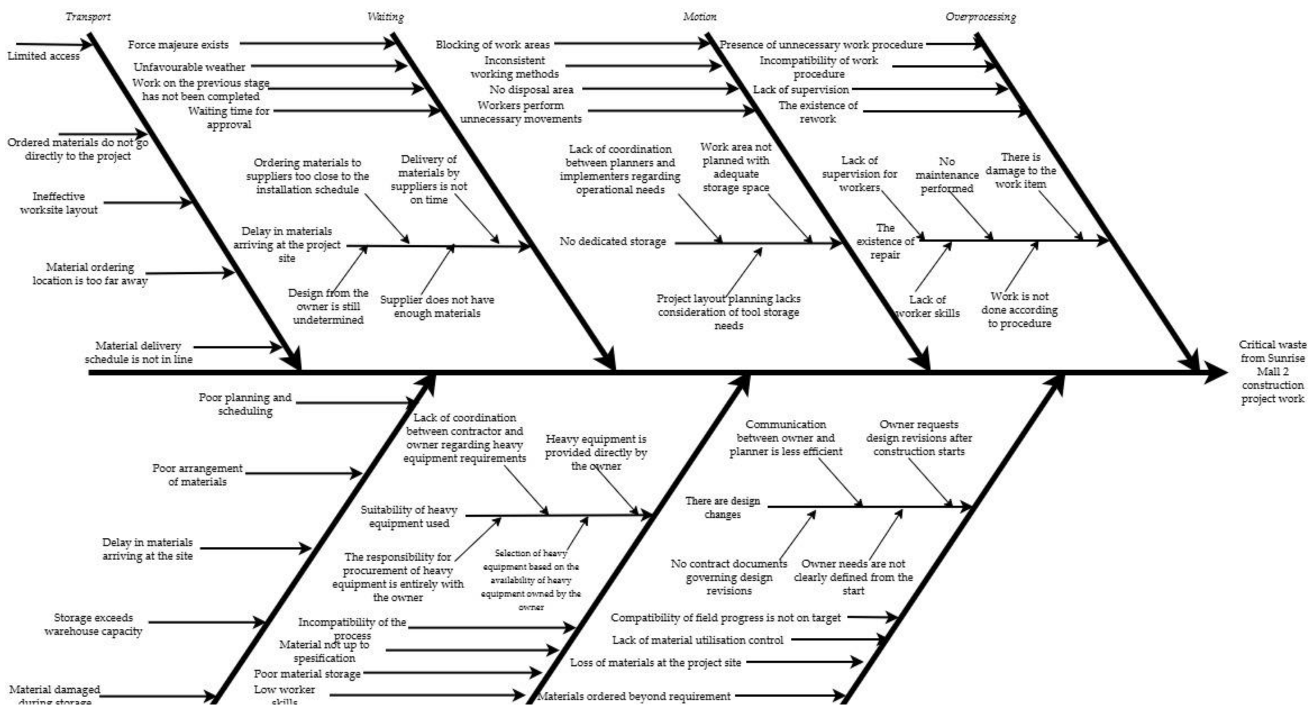

Figure 4. Fishbone Diagram

Based on Figure 4 observations while at the project site and discussions with Project managers, Engineers, Quantity surveyors and Field implementers involved in the Sunrise Mall 2 construction project. It can be concluded that:

The results of a series of analyses related to the sub-parameter "The existence of repair" showing that there is damage to the work item that has been installed, the root of this problem starts from the work not being done in accordance with the procedure. The root of this problem develops into a chain of causes and effect where the lack of maintenance on the finished work item causes damage that requires repair. This problem is rooted in the limited skills of workers which is ultimately caused by a lack of supervision of workers. The root of the problem from the critical parameter of overprocessing with the sub-parameter "The existence of repair" is a system that is not have a strict supervision of the competence and performance of workers.

The critical sub-parameter of the overproduction parameter is "There are design changes" that occurs due to design changes made by the owner after the construction project has started. The root of this problem occurs because what the owner wants is not clearly defined before the start of construction. This can be caused by inefficient communication between the owner and the planner. This problem is compounded by the absence of a contract document that governs the design revision mechanism. The root of the problem of this sub-parameter waste is the absence of a contract system that clearly regulates the mechanism of design change and less structured communication.

The critical sub-parameter of the motion parameter is "There is no special storage for workers", based on the results of the analysis it can be seen that the work area is not planned with adequate storage space. Deeper observations were made after finding the first why, the results of the observation found that the project layout planning did not consider the location for special storage for worker tools, in the absence of a dedicated storage space, workers needed more time to carry the tools when they arrived and when they were going home. The root of the problem in this waste is "Lack of coordination between planners and implementers related to operational needs".

Based on the defects parameter, the most critical sub-parameter is "Suitability of the machine used". Based on the results of the analysis, it was found that there was a discrepancy in the heavy equipment used in the project, the heavy equipment used in the project mostly belonged to the owner himself. The selection of heavy equipment to be used in the project also depends on what the owner has. The lack of coordination between the owner and the planner is also one of the reasons why there is a mismatch between the heavy equipment used in the project. The root of the problem with this waste is "The responsibility for the procurement of heavy equipment is entirely on the owner".

Waste in the waiting parameter with the sub-parameter "Delay in material arrival at the project site" occurs because the supplier is not on time in delivering materials. The results of the discussion between the quantity surveyor and the supplier were found that the supplier did not have a sufficient amount of material with what was ordered by the contractor. After further investigation, it was found that the schedule for ordering materials by the contractor was too close to the schedule for the installation of related materials. From the results of the analysis, it can be concluded that the design that has not been determined by the owner caused the ordering of materials to be too close to the installation schedule. The root of the problem of this waste is "The design of the owner is still undetermined".

Conclussion

Based on the series of analyses that have been conducted, it can be determined that the parameters studied are: overproduction, overprocessing, motion, defects, waiting, inventory, and transportation. There are five critical parameters obtained through the pareto principle: overprocessing is “The existence of repair,” overproduction is “There are design changes,” motion is “No dedicated storage for workers,” defects are “Suitability of heavy equipment used,” and waiting is “Delay in material arriving at the project site.” The application of lean construction can narrow down various problems into waste parameters. Using the borda and pareto principles, the sequence of problems that occur can be identified, and critical and non-critical parameters can be obtained. Root cause analysis identifies the root cause of the identified waste. Fishbone diagram to obtain a comprehensive overview of all waste generated during the construction. Further research can be conducted by providing recommendations for improvements based on the identified critical waste through the concept of lean construction.

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