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Lean Management Analysis of Major Project Construction Services Southern to Reduce Waste at Pertamina Hulu Sanga Sanga

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ABSTRACT : This Study analyzes the implementation of Lean Management in the flowline construction project at PT Pertamina Hulu Sanga-Sanga (PHSS), with a focus on identifying, evaluating and reducing waste across the value stream. Usinga case study approach, data were collected through questionnaires, field observation and document review. The analysis employed Value Stream Mapping (VSM), Value Stream Analysis Tool (VALSAT), Process Activity Mapping (PAM) and Root Cause Analysis (RCA). The results reveal that waiting is the most dominant waste, caused by material delays, inadequate coordination, access constraints and equipment failures. Defects such as pipe damage and welding errors were also identified, leading to rework and additional costs. Project Risk Management analysis reinforced the need for an integrated material information system, strict quality contro and enhanced coordination. In conclusion Lean Management effectively improves construction efficiency by reducing waste, optimizing cycle time and strengthening risk management. Recommendations include developing a material information system, selecting reliable suppliers, enhancing workforce competencies through Lean training and conducting further research focusing on cost savings and productivity.

KEYWORDS : *Lean Management, Waste, Value Stream Mapping, VALSAT, Process Activity Mapping, Project Risk Management.*

I. INTRODUCTION

The oil and gas industry is a capital-intensive and technologically demanding sector, characterized by high operational and financial risks due to uncertain reserves and complex extraction processes. While the frequency of losses is relatively low, their potential severity can be substantial and often catastrophic (Kassem, 2022). During construction projects various obstacles and failures, although not always directly observable, can significantly impact project completion. Activities that do not add value are considered waste, leading to inefficiencies (Mu'min et al., 2022).

Flowline projects entail high risks and costs, requiring expertise in equipment, operations and process management. Successful implementation depends on leadership and workforce engagement, with Lean management principles integrated into corporate governance to enhance performance, cost efficiency and risk mitigation. (Azis et al., 2021).

Oil and gas are vital to economic sectors, requiring rigorous evaluation of equipment and processes to ensure quality and productivity. In East Kalimantan Pertamina Hulu Sanga-Sanga develops new wells supported by surface facilities such as flowlines and manifolds. Non-contributive activities including rework, overproduction, unnecessary processes, idle movements, delays and non-compliant products are classified as waste (Womack et al., 1997).

The construction industry has adopted Lean Construction principles from manufacturing to enhance value and minimize waste. Lean Construction focuses on resource management, communication efficiency, planning, staffing, supervision and control to optimize quality, time and cost. Inefficient resource use leads to increased costs, extended schedules and suboptimal results (Fitriani et al., 2023)

The Major Project Construction Services Southern PT. Kali Raya Sari provides services for Pertamina Hulu Sanga-Sanga with a contract value of IDR 89,348,037,000 and a project duration of 730 calendar days (June 1, 2022 - May 30, 2024). Effective planning must address schedule changes and resource allocation to improve overall productivity, minimize schedule-related risks and control costs. Lean Construction is recommended to manage workflow efficiently and enhance project performance.

This study focuses on identifying and reducing waste and assessing overall risk during construction executed by PT. Kali Raya Sari. The Flowline construction project applies Lean Construction methods to ensure timely completion, optimize material and information flow and promote continuous improvement.

II. LITERATURE REVIEW

2.1. Introduction

Lean Management initially developed in manufacturing, has been adapted to construction to enhance productivity by minimizing waste. Studies show that Lean Construction improves efficiency, lowers labor costs and supports sustainability through technology integration like BIM (Garcés et al., 2025). Successful implementation depends on leadership, organizational culture and technological readiness (Kadlowec, n.d.)

In large-scale projects such as Pertamina Hulu Sanga-Sanga Flowline, applying Lean principles is essential to identify and reduce waste, optimize resource utilization and ensure timely project completion. This study examines Lean Construction practices to enhance workflow efficiency and minimize non-value-added activities in construction projects.

2.2. Operational Management

Operational management involves planning, organizing, directing and controlling resources, both human and material to achieve organizational goals effectively and efficiently (Purba et al., 2024). It focuses on managing production and service activities to maintain efficiency, effectiveness and quality. This aligns with the emphasis on process integration in the digital era and e-commerce, which demands speed, accuracy and technological adaptability (Pramesti et al., n.d.). Therefore, the success of operational management largely depends on an organization's ability to strategically leverage resources to achieve both short-term and long-term objectives.

2.3. Lean Management

Over the past two decades, Lean Management has evolved from a mere afficiency improvement method to a strategic framework integrated with technological innovation. It is a systematic approach to identify and eliminate waste through continuous improvement, focusing on creating value for customers (Sinha & Matharu, 2019). Lean not only optimizes process flow but also fosters an adaptive and collaborative organizational culture.

Recent developments have led to Lean 4.0, which integrates Lean principles with Industry 4.0 technologies, including IoT, big data analytics and intelligent automation. This integration enhances waste reduction, flexibility, responsiveness and predictive capabilities in dynamic markets (Gil-Vilda et al., 2021). Lean principles are now applied beyond manufacturing, encompassing construction, services, healthcare and education, aiming to achieve more output with fewer resources (H. D. Amri, 2014).

2.4. Concept of Waste in Lean Management

In Lean Management, waste is defined as any activity or process that does not add value to the customer or in unnecessary within the production flow (Setiawan & Rahman, 2021). Such non-value-added activities hinder process flow and can reduce efficiency and output quality. Wasteencompasses all activities that do not directly contribute to the creation of products or services and should be identified and eliminated to improve system performance (Pratiwi et al., 2020).

Waste is typically classified into seven categories: overproduction, waiting, transport, over-processing, inventory, motion and defect (Amri et al., 2025). Lean Thinking emphasizes minimizing or eliminating these forms of waste through continuous improvement. Waste can occur at various stages of operational processes, resulting in increased costs, wasted time and excessive resource usage. Lean views value solely from the customer's perspective, considering any activity that does not directly contribute to delivering desired prducts or services as waste. Identifying and eliminating waste is thus essential for enhancing efficiency and producttivity in any industry.

2.4.1. Types of Waste (Muda, Mura, Muri)

In Lean Management waste is categorized into three main types: Muda, Mura and Muri (Pete, 2014). These concepts help identify various forms of inefficiency in production and operational processes. Muda refers to waste arising from non-value-added activities. Seven common types of Muda, known as the seven wastes, are frequently observed across different processes (Müller et al., 2014).

2.4.2. Big Picture Mapping (BPM)

Big Picture Mapping (BPM) is a method adapted from the Toyota production system to visualize production processes and value streams. It is used to collect information on events within the production system and track material flow. Additionally, BPM helps identify sources of waste and understand the interactions between data and material flows (Phatale, 2020).

2.4.3. Impact of Waste on Construction Projects

Waste in construction projects significantly affects efficiency, costs and project completion time (Sulistio et al., 2021; Beatrix et al., 2020). Key impacts include.

1) Project Delays: Waste such as waiting or excessive transportation extends project duration, disrupting overall schedules and increasing costs (Worximity, 2023).
2) Increased Operational Costs: Overproduction or excess inventory raises expenses due to additional storage and transportation requirements.

3) Reduced Quality: Muri, or overburden, forces workers or machinery to operate beyond capacity, leading to defects, rework and further time and cost escalation.
4) Resource Wastage: Excess motion or overprocessing results in inefficient use of labor, materials and energy, reducing both cost-effectiveness and project sustainability.
5) Decreased Customer Satisfaction: Delays or substandard outputs negatively impact client satisfaction, potentially harming company reputation and future business opportunities.

Understanding these impacts highlights the critical need for Lean Management to identify and eliminate waste, ensuring efficiency, quality and value delivery in construction project.

2.4.4. Value Stream Mapping (VSM)

Value Stream Mapping (VSM) is a Lean Management tool used to map the entire process flow from start to finish, identifying value-added and non-value-added activities. (Morato et al., 2024; Ramani et al., 2021). In construction, VSM enables project teams to visualize the complete construction cycle, from material procurement to project completion and to identify areas of waste, such as slow processes or underutilized resources.

VSM is an effective technique for analyzing and improving business processes. By visualizing the entire value stream from suppliers to customers it helps organizations detect bottlenecks and improvement opportunities, enhancing productivity and customer satisfaction (Vinodh et al., 2010). It is widely applied to visualize workflows and evaluate processes, providing a framework for continuous improvement in construction projects (Mike Rother et al., 2021) In implementation practice, there are seven tools most commonly applied in the detailed analysis of Value Stream Mapping (VSM), namely as follows.

1) Process Activity Mapping (PAM) – used to analyxe value-added (VA) and non-value-added (NVA) activities within processes.
2) Supply Chain Respone Matrix (SCRM) – evaluates material flow and lead time across the supply chain.
3) Production Variety Funnel (PVF) – identifies product variation and its impact on process complexity.
4) Quality Filter Mapping (QFM) - detects defects and quality-related issues within the process flow.
5) Demand Amplification Mapping (DAM) - assesses fluctuations in customer demand and their effect on production.
6) Decision Point Analysis (DPA) - determines critical decision points that influence process flow and efficiency.
7) Overall Supply Chain Mapping (OSCM) - provides a holistic view of supply chain interactions, highlighting inefficiencies and improvement opportunities.

2.4.5. Value Stream Analisys Tool (VALSAT)

The method applied to determine the most appropriate tool in the mapping process is structured through column arrangement. Column A contains the seven categories of waste commonly found in companies, while Column E provides detailed descriptions of each type of waste. The data in this column were obtained through questionnaires on waste, completed by the respective managers and supervisors. Within the framework of Value Stream Mapping, Column B represents the analytical tools employed (Hines et al., 1997).

Table 1. Value Stream Mapping Tool Selection Matrix

Waste	Weight	Tool B
A	B	C
Total Weight		E

Column C represents the relationship between Columns A and B with three levels of correlation: high correlation weighted 9, medium correlation weighted 3 and low correlation weighted 1. The calculated results are then summed and placed in Column E, where the highest value is determined as the primary choice. However, selecting more than one tool is considered more effective in assisting companies to minimize waste.

2.4.6. Waste Identification

The concept of waste in this study refers to the original categorization of waste introduced by Ohno as an integral part of the Toyota Production System (TPS), which later became widely known as Lean Manufacturing (Ohno, 2019). In this research, the term waste is defined as follows (Hibatullah et al., 2022).

1) Overproduction – producing more than what is required or earlier than needed leading to exess inventory.
2) Waiting – idle time caused by delays in material delivery, equipment readiness or information flow.
3) Transportation – unnecessary movement of materials or product that does not add value.
4) Overprocessing -performing process or activities beyond what is nescessary to meet customer requirement.

5) Inventory – excessive stock of raw materials, work in progress or finished good that ties up resources.
6) Motion – inefficient movements of workers or equipment that do not contribute to value creation.
7) Defect – errors or quality issues requiring rework or scrap, resulting in wasted time and resources.

2.4.7. Waste Analysis

According to (Hines et al., 2000), the concept of waste in the Lean approach is not limited to the seven commonly recognized types of waste, but can be analyzed more comprehensively by classifying them into three main categories. These categories provide a deeper understanding of process activities and serve as the foundation for effectively identifying and reducing waste, namely.

1) Value-Adding Activity (VA). Activities that directly contribute value to the product or service in accordance with customer or client needs and expectation.
2) Non-Value-Adding Activity (NVA). Activities that do not add any value and can be eliminated without affecting customer or client requirement. This category of waste is the primary focus improvement in Lean Management.
3) Necessary but Non-Value-Adding Activity (NNVA). Activities that do not create value for the customer butare still required in the process due to certain constraints, such as regulatory compliance, technical limitations or system restrictions.

2.4.8. Root Cause Analysis (RCA)

Root Cause Analysis (RCA) is a systematic method used to identify underlying causes of problems and prevent their recurrence, thereby enhancing process reliability and audit quality (Groot, 2021). RCA examines contributing factors commonly categorized into the 5M framework: man, machine, material, method and management system. Its primary aim is to gain a deep understanding of failures, develop effective corrective actions and support continuous improvement (Sologic Company Materials, 2023).

If the root cause of a problem is not identifiedn only the symptoms will be visible and the issue will persist. Therefore, Root Cause Analysis (RCA) is highly effective in uncovering the true sources of problems that may pose risks in production operations. According to (Rooney et al., 2004), the RCA process involves six key stages.

1) Problem Identification: The initial stage involves a detailed determination of the issue, including what occurred, where and when it happened and the stakeholders involved.
2) Data Collection: A systematic process of gathering relevant information from various sources such as operational records, field observations and supporting documents.
3) Causal Factor Identification: The development of a list of possible contributing factors to the problem, which may stem from human, work method, machine, material or environmental conditions.
4) Root Cause Analysis: The application of specific analytical techniques, such as the Five Whys or the Ishikawa (Fishbone) Diagram to trace and identify the fundamental causes of a problem.
5) Solution Development and Implementation: The design and execution of corrective actions or improvement strategies aimed at eliminating the root cause rather than merely addressing visible symptoms.
6) Evaluation and Monitoring: The assessment of the effectiveness of implemented solutions, accompanied by continuous monitoring mechanisms to ensure that similar issues do not recur in the future.

2.4.9. Project Risk Management

Project risk is defined as a state of uncertainty that can influence project outcomes either positively or negatively (Garcés et al., 2025). Each risk has underlying causes and once it occurs, it inevitably affects the project. Risk management is therefore applied to identify and control potential hazards during project execution. Its primary objectives are to estimate the likelihood of risks, mitigate their impact before project initiation and provide effective responses when they materialize.

2.5. Selection of Lean Construction Tools

2.5.1. Last Planner System

(Ballard, 2000) introdused the Last Planner System (LPS) is a Lean Construction based production management freamwork designed to control workflow. The system consists of sequential stages, including the master schedule, Reverse Phase Scheduling (RPS), medium-term planning six-week lookahead, Weekly Work Plan (WWP) and performance evaluation through Percent Plan Complete (PPC). It also incorporates constraint analysis and variance analysis between planned and actual outcomes.

Using a pull-based approach, LPS establishes workflow, pacing and task sequencing by aligning tasks with available capacity, while fostering collaboration across roles. Workflow improvements are achieved through team communication, training, early problem analysis, evaluation of deviations and planner contributions. Unlike traditional approaches that assume enforced work improves performance, LPS replaces optimistic planning with realistic commitments by evaluating performance against workers' actual capabilities.

2.5.2. Increased Visualization

Visual management as a Lean tool, emphasizes the effective communication of critical information to workers through the use of visual cues. By visualizing elements such as workflow, performance and specific tasks, information retention becomes more effective. In construction visual efforts are primarily applied to safety, scheduling and quality assurance (Salem et al., 2005).

2.5.3. Tool-box Meeting

Effective communication in daily stand-up meetings or tool-box meetings, is essential for enhancing employee engagement and project understanding. These brief sessions support planning, facilitate rapid problem-solving and enable progress reporting as part of continuous improvement efforts (Stray et al., 2012).

2.5.4. First Run Studies

First Run Studies focus on efficiency assessment and work evaluation by restructuring and simplifying involved functions. These studies often use videos, images or diagrams to illustrate procedures and provide work guidance. The initial stage of the selected process is examined in detail to generate recommendations ("Industrial Engineering and Management: A Comprehensive Introduction," 2023)

III. METODOLOGY

This study employs a quantitative approach to assess the impact of Lean Management on waste reduction and efficiency improvement in large-scale construction projects at Pertamina Hulu Sanga-Sanga, by analyzing pre- and post-implementation data.

3.1. Operational Definitions

To clarify the research variables, the following operational definitions are applied.

1) Lean Management: A management approach aimed at enhancing efficiency and reducing waste through process optimization and effective resource utilization.
2) Waste: Non–value-adding activities in construction projects, including waiting time, inefficient transportation, excessive use of materials or human resources and rework.
3) Project Efficiency: The project's ability to achieve its objectives in terms of time, cost and quality while utilizing minimal resources.
4) Barriers to Lean Implementation: Factors hindering the adoption of Lean Management, such as resistance to change, lack of understanding or challenges in cross-team collaboration.

3.2. Population and Sample

The number of sample members is generally expressed as the sample size, which is expected to adequately represent the overall population. In studies with large populations, only a subset is selected as the sample with the expectation that it reflects the characteristics of the population.

The population of this study comprises all construction workers involved in the ongoing project at Pertamina Hulu Sanga-Sanga, namely the Major Project Construction Services Southern. Based on data obtained from PT Pertamina the project involves 50 workers from PT Pertamina and 179 workers from PT Kaliraya Sari. The research sample is determined using purposive sampling, selecting participants relevant to the implementation of Lean Management and those who have applied or have the potential to apply Lean principles.

3.3. Research Instruments

The instruments employed in this study include:

1) Structured Questionnaire: Designed to collect quantitative data regarding respondents' perceptions of Lean implementation, waste reduction and project efficiency before and after Lean adoption. The questionnaire was adapted from (Yame, 2020) developed based on an extensive literature review focusing on technical and cultural Lean requirements, critical success factors (CSFs) and types of waste targeted for elimination. It covers the entire Lean value chain from suppliers, through internal processes and procedures, to customers. The questionnaire also assesses organizational practices in supplier and customer engagement, process flow, scientific tool usage, management commitment and employee-related aspects such as involvement, empowerment, reward systems and training. It consists of seven constructs with 21 items designed to identify waste. Responses are measured using a Likert scale to evaluate organizational readiness and preparedness for Lean adoption.
2) Field Observation: Conducted to directly observe construction processes and identify activities with potential to generate waste.
3) Project Documentation: Includes project reports, schedules and completion time records, used to analyze the impact of Lean implementation on efficiency.

3.4. Data Collection Techniques

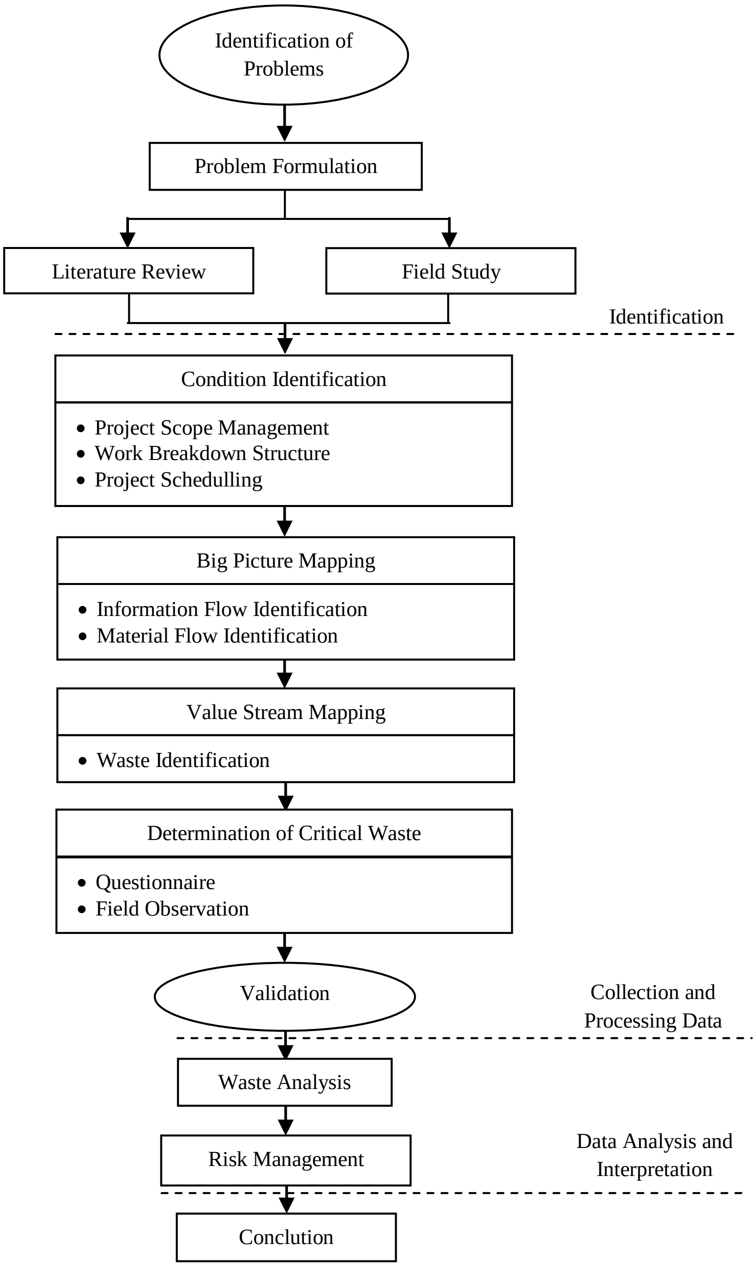
Data for this study will be collected using the following techniques.

1) Questionnaire: Distributed to relevant participants (project managers, field coordinators, team leaders and workers) to capture perceptions regarding waste and efficiency. The questionnaire is adapted from (Yame, 2020) with modifications to align with the research objectives.
2) Field Observation: Conducted directly at the project site to record activities related to waste generation and the application of Lean principles.
3) Documentary Study: Involves collecting data from available project documents to analyze work duration, resource utilization and cost expenditures.

3.5. Data Analysis Technique

The data analysis aims to identify and evaluate waste in project implementation through a quantitative approach. Root Cause Analysis (RCA) is applied to determine underlying causes and guide preventive actions, while project risks are assessed based on impact severity and likelihood. Questionnaire responses are analyzed using descriptive statistics to compare project performance before and after Lean Management implementation.

Fig 1. Flowchart



IV. FIGURES AND TABLES

4.1. Waste Identification

Following the mapping of information and material flows, waste was identified and categorized into the seven established types. Questionnaires, supported by researcher guidance, were distributed to workers to score and describe observed waste activities. The weighted results were ranked to determine the dominant categories and the Value Stream Mapping Toll (VALSAT) was applied to select the three most relevant tools for waste identification and elimination.

Table 2. Score Waste

No.	Waste	Score
1	Overproduction	1.35
2	Waiting	1.53
3	Transportation	1.46
4	Inappropriate process	1.38
5	Inventory	1.36
6	Unnecessary motion	1.43
7	Defect	1.50

4.2. Value Stream Analysis Tool

At this stage, the selection of Value Stream Mapping (VSM) tools was carried out using the Value Stream Analysis Tool (VALSAT) approach. VALSAT provides seven tools that enable in-depth analysis of various forms of waste within production processes. The suitability level was determined by multiplying the average score of each waste category with the VSM suitability matrix, as shown in Table 3. The VSM tool with the highest total score was selected as the primary mapping method, as it is assumed to best represent and comprehensively identify waste across the value stream. The VALSAT results are presented in Table 4.

Table 3. Calculation Valsat

No.	Waste	Process Activity Mapping	Supply Chain Respone Matrix	Product Variety Funnel	Quality Filter Mapping	Demand Amplification Mapping	Decision Point Analysis	Phisycal Structure
1	Overproduction	1.35	4.04		1.35	4.04	4.04	
2	Waiting	13.78	13.78	1.53		4.59	4.59	
3	Transport	13.15		4.38				1.46
4	Inappropriate process	12.40		4.13	1.38		1.38	
5	Inventory	4.07	12.22	4.07		12.22	4.07	1.36
6	Unnecessary motion	12.87	1.43					
7	Defect	1.50			13.48			
	TOTAL	59.10	31.47	14.12	16.20	20.85	14.08	2.82

Table 4. Score Valsat

No	Value Stream Mapping	Total Score
1	Process Activity Mapping	59.10
2	Supply Chain Response Matrix	31.47
3	Demand Amplification Mapping	20.85
4	Quality Filter Mapping	16.20
5	Product Variety Funnel	14.12
6	Decision Point Analysis	14.08
7	Phisycal Structure	2.28

4.3. Process Activity Mapping (PAM)

Process Activity Mapping (PAM) is a method that visualizes processes in a step-by-step sequence using specific symbols to represent different activities. O for operation, T for transportation, I for inspection, D for delay and S for storage. The primary objective of PAM is todetermine the proportion of activities categorized as value-adding (VA), non-value-adding (NVA) and necessary but non-value-adding (NNVA).

The result of Process Activity Mapping (PAM), provide information on the total number of identified activities and the percentage contributtion of each. This data is then used to classify activities into value-adding (VA) and non-value-adding (NVA) ategories.

Table 5. Total Activity in Process Activity Mapping

No.	Type Of Activity	Total Actuvity	Percentage (%)
1	Operation	846	39.1
2	Transportation	470	21.7
3	Inspection	329	15.2
4	Storage	94	4.3
5	Delay	423	19.6
	TOTAL	2162	100

Based on Table 4 operational activities classified as value-added account for 39.1%. In contrast, non-value-adding activities consist of transportation (21.7%), inspection (15.2%), storage (4.3%) and delay (19.6%). Therefore, to enhance efficiency and ensure smooth project execution, non-value-adding activities must be minimized to the greatest extent possible.

Table 6. Total Time Activity in Process Activity Mapping

No.	Type Of Activity	Time (day)	Percentage (%)
1	Operation	1931	62.8
2	Transportation	311	10.1
3	Inspection	179	5.8
4	Storage	218	7.1
5	Delay	437	14.2
	TOTAL	3076	100

Table 6 shows that the total duration recorded in the Process Activity Mapping (PAM) is 3,076 days. Of this, operational activities classified as value-added require 1,931 days, representing 62.8% of the total. The analysis further reveals that non-value-adding activities consist of transportation (10.1%), inspection (5.8%), storage (7.1%) and delay (14.2%). This considerable proportion highlights the need for corrective measures to reduce both the duration and frequency of such activities, thereby enabling more efficient project execution with shorter cycle times.

4.4. Supply Chain Respone Matrix (SCRM)

The Supply Chain Respone Matrix (SCRM) is a graphical representation ilustrating the relationship between lead time and inventory, designed to identify and evaluate fluctuation in stock levels and distribution times across different segments of the supply chain. This toool aims toenhance inventory management efficiency and minimize distribution time, thereby achieving service level targets at lower costs.

The mapping approach is visualized through a simple diagram that plots cumulative lead times for both company and supplier distribution. The horizontal axis represents material lead times from internal and external sources, while the vertical axis indicates the average inventory level (in days) at specific points in the supply chain. Such visualization facilitates the identification of lead times and inventory levels that can subsequently serve as focal points for improvement.

After obtaining the calculation results, the next step is to construct the Supply Chain Response Matrix (SCRM), with detailed procedures outlined as follows.

1) Material Retrieval Stage. The warehouse procures pipeline materials from Pertamina, consisting of 3,000 pipes of 2-inch diameter, 9,000 pipes of 4-inch diameter and 3,000 pipes of 6-inch diameter for flowline construction. In addition, support pipes are collected, including 3,000 pipes of 3.5-inch diameter, 1,200 pipes of 4-inch diameter and 500 pipes of 6-inch diameter, each with a length of 6 meters. The total number of pipes used in the project amounts to 9,996 units. Each construction mobilization allows the transportation of 40 pipes. With 1,844 effective project days, warehouse stock (days physical stock) is estimated to support construction activities for 249.9 days.

2) Construction Stage. During implementation, the project achieves an average pipe installation rate of 15 pipes per day. Given the retrieval rate of 40 pipes per mobilization, the available daily physical stock is estimated to sustain operations for 666.4 days

Table 7. Pipe Supply Chain Respone Matrix

No	Detail	Line Up (Inch)			Pipe Support (Inch)		
		2"	4"	6"	3-1/2"	4"	6"
1	Stock	3000	9000	3000	3000	1200	500
2	Used	1342	6003	1016	917	596	54
3	Scrap	6.7	30	12.2	11	7.2	0.6
4	Total Pipe Used	1348.7	6033	1028.2	928	603.2	54.6
5	Remaining Pipe	1651	2967	1972	2072	597	445

Fig 2. Graph of Supply Chain Respone Matrix

4.5. Waste Analisys Using Process Activity Mapping (PAM)

In the development of the PAM, all observed activities were clasified into five categories: Operation, transportation, inspection, storage and delay. The analysis presented in Chapter 4 illustrates the percentage distribution of each category.

Operations accounted for 62.8%, transportation 10.1%, inspection 5.8%, storage 7.1% and delay 14.2%. From this PAM analysis, the proportion of value-adding and non-value-adding activities can be clearly identified. Operations represent the main value-adding activities, while transportation, inspection, storage and delay fall under the Non-Value-Added (NVA) category. These results are summarized in the Table 8 below.

Table 8. Total Activity Value Added and Non-Value Added

Activity	Total	Percentage
Operatio (O)	846	39.1
Transportation (T)	470	21.7
Inspection (I)	329	15.2
Storage (S)	94	4.3
Delay (D)	423	19.6
Total	2162	100.0
Percentage VA	39.1 %	
Percentage NVA	60.9 %	

Based on Table 8 value-adding (VA) activities account for 39.1%, while non-value-adding (NVA) activities represent 60.9%. The high proportion of NVA activities highlights the need for their reduction to shorten cycle time and minimize project delays.

4.6. Analysis Supply Chain Response Matrix (SCRM)

Based on the Supply Chain Response Matrix (SCRM) analysis, inventory fluctuations and lead times across supply chain sectors were evaluated to assess efficiency and effectiveness in resource management. The findings indicate that the total duration required to complete the flowline pipeline project was 3,076 days, with an average daily physical stock of 249.9 days, representing the time materials remained in the system either under processing or awaiting further use. The construction area recorded the longest physical stock duration at 249.9 days, producing an average of 15 pipes per day against a material usage of 40 pipes. The SCRM also shows that construction experienced the longest distribution lead time at 666.4 days, primarily due to delays in material delivery from suppliers, pending work instructions and the issuance of work orders.

4.7. Demand Amplification Mapping Analysis

Demand Amplification Mapping highlights the emergence of inventory issues, particularly related to batch orders from suppliers. One of the largest inventory sources is scrap material from pipe cutting during construction. Since Pertamina cannot reuse these off-cuts in subsequent projects and pipes are only available in standard lengths, the leftover material is classified as inventory. Pipe scraps are categorized into two types: pieces longer than one meter, which are stored for potential reuse in future projects requiring shorter lengths and smaller pieces, which remain unused. The main challenge lies in managing the accumulation of these materials efficiently, as only a fraction can be reused in future projects, while most requirements must still be met through new material orders. This contractual limitation results in continued procurement and further accumulation of scrap inventory.

4.8. Root Causes of Waste and Improvement Proposals

The analysis of the seven wastes identifies three primary causes of inefficiency. First, waiting, mainly due to delays in material delivery, which stem from inefficiencies in both internal information systems and external communication with suppliers. Improvement strategies should focus on reducing lead time to enhance material distribution. Second, defects, occurring during material handling and welding, often require rework such as cutting and re-welding. Third, excessive transportation, where unnecessary material movements increase time and resource consumption.

4.9. Proposed Improvements through Process Activity Mapping (PAM)

Process Activity Mapping (PAM) was applied to structure improvement initiatives and identify opportunities for reducing process duration. The results Table 9 show a reduction of non-value-added activities from 1,316 to 1,128, with value-adding operations increasing from 39.1% to 42.9%. While transportation, inspection and storage activities remained constant, their durations were compressed. Delays decreased significantly from 423 to 235 activities, lowering the percentage from 19.6% to 11.9%.

Table 9. Improvements Activity in Process Activity Mapping (PAM)

No	Type Of Activity	Total	Percentage (%)
1	Operation	846	42.9
2	Transportation	470	23.8
3	Inspection	329	16.7
4	Storage	94	4.8
5	Delay	235	11.9
	TOTAL	1974	100

In the proposed improvements, the number of activities remained unchanged, but cycle times for inefficient processes were reduced. As shown in Table 10, the total cycle time decreased from 3,076 to 2,383 days, a 23% reduction. Operational activities dropped from 1,931 to 1,646 days, increasing their share from 62.8% to 69.1%. Transportation time declined from 311 to 263 days, with a slight percentage rise from 10.1% to 11%, while inspection duration remained constant but increased proportionally from 5.8% to 7.5%. Storage time was reduced from 218 to 140 days (7.1% to 5.9%) and delays showed the most significant improvement, decreasing from 437 to 155 days, reducing their share from 14.2% to 6.5%.

Table 10. Improvements Time Activity in Process Activity Mapping (PAM)

No	Type Of Activity	Total	Percentage (%)
1	Operation	1646	69.1
2	Transportation	263	11.0
3	Inspection	179	7.5
4	Storage	140	5.9
5	Delay	155	6.5
	TOTAL	2383	100

V. CONCLUSION

The final stage of this research presents conclusions derived from the previous analyses to address the proposed research questions. In addition, recommendations are provided as practical guidance for the company and as a reference for future studies.

5.1. Conclusion

Based on the research findings the main conclusions are as follows

1) Analysis of the seven categories of waste identified the dominant factor causing delays in the flowline pipeline construction project. The highest-ranking waste type represents the most critical aspect hindering project performance.
   a. Waiting - Waste in the form of waiting primarily results from material delays, suboptimal field coordination, access and weather constraints and equipment failures, all of which reduce productivity and extend project duration. Mitigation efforts include reliable supplier selection, enforcement of delay penalties, improved coordination and training and incentives for workers.
   b. Defect - Defect-related waste arises from supplier material flaws and construction errors. Pipe damages, such as dents from poor handling and welding defects (e.g., transverse cracks) lead to costly rework and delays. Minimization requires competent welders, strict supervision and consistent application of Welding Procedure Specifications (WPS).
   c. Excessive Transportation - Transportation waste occurs due to time, labor and cost intensive material movements. In this project, pipe handling using mobile cranes and trailer trucks created inefficiencies due to slow loading and handling complexity. More over, long distribution distances between project sites (Badak, Nilam, Sambera) and challenging road conditions further delayed material delivery.
2) Value-added activities accounted for 62.8%, while non-value-added activities reached 37.2%. After improvements using Process Activity Mapping (PAM), the proportion of value-added activities increased to 69.1%, with non-value-added reduced to 30.9%.
3) Supply Chain Response Matrix (SCRM) analysis revealed a cumulative inventory of 667 days and a cumulative lead time of 250 days, resulting in a total inventory of 917 days.
4) Improvements can be achieved by optimizing information systems between the company and suppliers, enhancing interdepartmental communication and reducing cycle times in activities identified as waste to improve overall process efficiency.

5.2. Recommendations

The proposed recommendations for the company and directions for future research are formulated as strategic initiatives aimed at enhancing project management effectiveness, minimizing waste and enriching scholarly contributions in construction management

1) Optimization of Material Information Systems

   The company should develop an integrated material information system to monitor procurement, distribution and utilization in real time, thereby minimizing delays.
2) Enhanced Team Coordination and Collaboration

   More effective communication mechanisms are required between procurement, engineering, construction and suppliers to ensure synchronized flows of information and materials.
3) Further Research Development

   Future studies are encouraged to incorporate cost analysis, enabling the company to calculate and evaluate potential cost savings derived from activities with reduced cycle times.

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