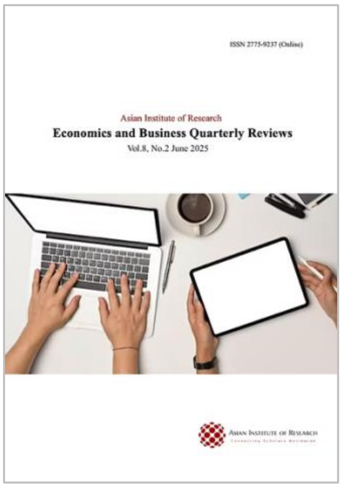

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Identifying Causes of Project Delays and Management Recommendations in Paper Machine Installation

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Abstract

This study investigates the causes of project delays and develops management recommendations for PT Tuntas Lugas Cemerlang (TLC) paper machine installation project in Purwakarta, Indonesia. Using a sequential exploratory mixed-methods approach, the research systematically identified delay factors through the analysis of Work Breakdown Structures (WBS), Gantt charts, meeting minutes, stakeholder interviews, and quantitative surveys. The study revealed that Schedule Management emerged as the most critical knowledge area, with 15 occurrences of delay-related issues, followed by Communication Management and Procurement Management (10 occurrences each) and Scope Management (9 occurrences). Key findings indicated that decision-making delays (problem score 4.44), schedule adaptation to field conditions (4.11), and resource shortages (3.56) were the primary contributors to project delays. The existing project management tools demonstrated significant structural weaknesses, including a lack of hierarchical Work Breakdown Structure (WBS) structure, the absence of critical path dependencies, and insufficient integration of commissioning activities. In response, comprehensive improvements were developed, including a four-tiered hierarchical Work Breakdown Structure (WBS) with formalized numbering and deliverable definitions, an enhanced Critical Path Method that incorporates end-to-end commissioning activities, and optimized Gantt charts with parallel scheduling and weekly time scales. The integrated solutions address the technical, communication, and managerial factors identified in the conceptual framework, aligning with the PMBOK knowledge areas. The implementation of these improvements is projected to reduce project completion delays and enhance coordination efficiency, enabling PT TLC to meet the critical July 2025 tender deadline, valued at 22 billion rupiah.

Keywords: Project Delays, Paper Machine Installation, PMBOK, Critical Path Method, Work Breakdown Structure, Industrial Project Management

1. Introduction

The global paper industry remains a cornerstone of manufacturing excellence, demonstrating remarkable resilience and adaptability in the modern digital era. Despite initial predictions of a decline in traditional paper products such as writing and printing materials, the industry has successfully diversified into emerging markets, including specialty papers, eco-friendly packaging solutions, and hygiene products. According to the Global Paper and Pulp Industry Outlook (2022), the global paper industry market is projected to expand at a compound annual growth rate (CAGR) of 1.8%, growing from $351.5 billion in 2021 to an estimated $370.1 billion by 2025. This sustained growth trajectory highlights the industry's ability to adapt and meet evolving consumer demands while maintaining its fundamental importance to global economic activities.

Indonesia has strategically positioned itself as a significant force in the global paper production landscape, leveraging its natural resources and manufacturing capabilities to become a significant industry player. The paper industry serves as one of the primary drivers of Indonesia's GDP and represents a crucial sector within the country's economic framework. In 2020, the manufacturing sector contributed 19.87% to Indonesia's GDP, making it the largest economic sector (Ministry of Industry, 2020). Within this substantial manufacturing contribution, the pulp and paper industry specifically accounted for 3.9% of GDP, supported by robust export performance totaling US$6.83 billion in the same year. The sector's economic significance extends beyond direct financial contributions, employing approximately 260,000 individuals directly and creating an additional 1.1 million indirect employment opportunities (Bank Mandiri, 2018).

The expansion trajectory of Indonesia's pulp and paper sector reflects both national economic priorities and international market demands. Statistical data from Statista (2023) demonstrates consistent growth in Indonesia's manufacturing sector over the past decade, with an increasing percentage contribution to the country's overall GDP. The pulp and paper industry has emerged as one of the fastest-growing manufacturing subsectors, driven primarily by escalating global demand for paper products and Indonesia's competitive positioning in raw material access and production capabilities. FAO (2023) reports that Indonesia generated 8.98 million metric tonnes of pulp, confirming its critical role in the global supply chain and highlighting the country's substantial production capacity.

However, Indonesia's paper industry confronts multiple complex challenges that threaten its continued expansion and competitiveness. Regional competition from countries such as China, Vietnam, and Thailand, which are also developing their paper production capabilities simultaneously, creates intense market pressure (ResourceWise, 2023). Additionally, growing sustainability concerns have intensified global scrutiny of forest management practices and environmental impacts associated with Indonesian paper mills (Mongabay, 2024). Infrastructure limitations, particularly suboptimal logistics networks in certain regions, lead to increased distribution costs that impact overall competitiveness (Fleetx, 2023). Furthermore, the sector's dependence on imported raw materials and sophisticated machinery creates vulnerability to fluctuations in exchange rates and disruptions to the global supply chain. At the same time, the limited availability of human resources with advanced technical expertise constrains the effective operation of modern pulp and paper technology (CRIF Asia, 2024).

PT TLC represents a significant new entrant in Indonesia's specialty paper manufacturing landscape, embodying both the opportunities and challenges characteristic of the sector's current development phase. As a newly established company in the paper manufacturing industry, PT TLC is currently constructing a factory in Purwakarta, Indonesia, with ambitious plans to produce specialty and security paper products that command higher profit margins compared to commodity paper products. The company decided to acquire a used paper machine from a UK or European papermaking company, demonstrating that they were prudent with their finances and opted for a proven technology. It aligns with the main industry trends, which focus on producing more valuable goods and utilizing new technologies in developing countries.

The implementation of PT TLC's paper machine installation project illustrates the complex technical and managerial challenges facing modern industrial construction in Indonesia's manufacturing sector. Nearly one year into the Paper Machine Installation Project in Purwakarta, the company continues to work toward operational targets while managing intricate coordination between multiple stakeholder groups, including production teams, finishing specialists, engineering units, machine installation contractors, and civil construction teams. The project is managed by the Head of Manufacturing, who serves as the Project Manager at the site office and is overseen by the Board of Directors in Jakarta, Indonesia. The latest project report (March 2025) indicates that the machine installation is running approximately 4 weeks behind schedule, which could impact the goal for the plant's operation.

A review of the project's current performance reveals significant discrepancies between the planned and actual outcomes, which should be addressed promptly. According to the data, 66% of the planned installation activities have been finished, even though 91.08% of the given schedule has passed—additionally, 38% of the completed tasks required correction due to errors in the original work. As a result of these inefficiencies, about 2.8 billion rupiahs have been wasted, and the commissioning could be delayed until the end of December 2025, which might cause PT TLC to miss a key tender deadline worth 22 billion rupiahs in July 2025. Because these delays are systematic, it is clear that the project's execution methodology needs significant changes, so urgent action is required.

To address these critical issues and prevent further harm to the project, this research aims to achieve three primary objectives. First, to identify and analyze the specific technical, coordination, and management factors causing delays in PT TLC's paper machine installation project through a systematic investigation of current practices and bottlenecks. Second, assess the project schedule by using the Gantt Chart and Critical Path analyses to find out which actions are causing the delay and set the most important points for intervention. Third, to put in place new methods for project management, such as better planning and communication, which help reduce delays and increase how well projects are carried out. If these objectives are met, PT TLC can fulfill its operations and also establish best practices that can be applied to similar projects, thereby helping to improve Indonesia's paper industry.

2. Literature Review

2.1 Project Management Theory (PMBOK)

The Project Management Body of Knowledge (PMBOK) serves as the foundational framework for understanding and implementing effective project management practices across diverse industries and organizational contexts (Project Management Institute, 2021). Developed and maintained by the Project Management Institute (PMI), PMBOK provides a comprehensive guide that standardizes project management terminology, processes, and best practices based on decades of collective industry experience and academic research (Kerzner, 2022). PMI has set up the project lifecycle management framework with five groups that direct the project: Initiating, Planning, Executing, Monitoring and Controlling, and Closing (PMI, 2021). All of these process groups are brought together with ten different knowledge areas, such as Project Integration Management, Scope Management, Schedule Management, Cost Management, Quality Management, Resource Management, Communications Management, Risk Management, Procurement Management, and Stakeholder Management (Larson & Gray, 2021). Research by Turner (2020) demonstrates that organizations implementing comprehensive PMBOK methodologies achieve 28% higher project success rates compared to those using ad-hoc project management approaches.

Within the context of industrial construction projects such as paper machine installations, PMBOK's emphasis on schedule management and risk management becomes particularly critical for successful project delivery (Meredith & Mantel, 2019). The framework advocates for the development of detailed Work Breakdown Structures (WBS) that decompose complex projects into manageable components, enabling more accurate estimation, resource allocation, and progress monitoring (Schwalbe, 2021). Critical Path Method (CPM) and Gantt chart methodologies, as endorsed by PMBOK guidelines, provide essential tools for identifying project dependencies, optimizing resource utilization, and maintaining schedule adherence (Burke, 2020). Based on Kezner's study (2022), projects with a complete Work Breakdown Structure (WBS) framework experience 42% fewer delays in their schedules than projects with incomplete decomposition. The framework helps address the coordination issues that arise in multidisciplinary projects involving international contractors, local technical teams, and various organizational levels (Harrison & Lock, 2021). Furthermore, PMBOK's risk management processes establish proactive methodologies for identifying, analyzing, and mitigating potential project delays before they impact critical milestones, with empirical evidence showing a 35% reduction in cost overruns when properly implemented (Wysocki, 2020).

2.2 Prior Studies on Project Delays and Industrial Project Management

Extensive research in construction and industrial project management has consistently identified recurring patterns of delay factors that transcend geographic boundaries and industry sectors. In 2006, Assaf and Al-Hejji looked into construction delays in Saudi Arabia and found 73 possible reasons for delays grouped into eight main areas: project-related, owner-related, contractor-related, consultant-related, design-related, materials-related, equipment-related, and external factors. It was found that the main reasons for project delays were insufficient planning, poor teamwork among the parties, and delays in getting the needed materials. In the same way, Sambasivan and Soon (2007) studied delays in Malaysian construction projects, stating that poor coordination among contractors, lack of good project management skills, and lack of technical talent in the project teams were the main reasons for delays.

Recent studies have examined industrial manufacturing projects and found that there are extra challenges related to bringing in technology and installing special equipment. Pourrostam and Ismail (2012) examined delays in industrial construction projects in Malaysia and found that those involving imported machines and international experts encounter unique issues, such as customs delays and difficulties in sharing technical knowledge and coordinating between international consultants and local workers. Their research highlighted the importance of comprehensive project planning that accounts for cross-cultural communication barriers and technical competency gaps. Furthermore, Marzouk and El-Rasas (2014) applied statistical analysis to identify critical delay factors in industrial projects, demonstrating that projects with inadequate Work Breakdown Structure implementation experienced 34% longer completion times compared to projects with comprehensive WBS frameworks. These empirical findings support the theoretical foundation that systematic project management methodologies, when properly implemented, can significantly reduce delay occurrences and improve overall project performance in complex industrial environments.

2.3 Conceptual Framework

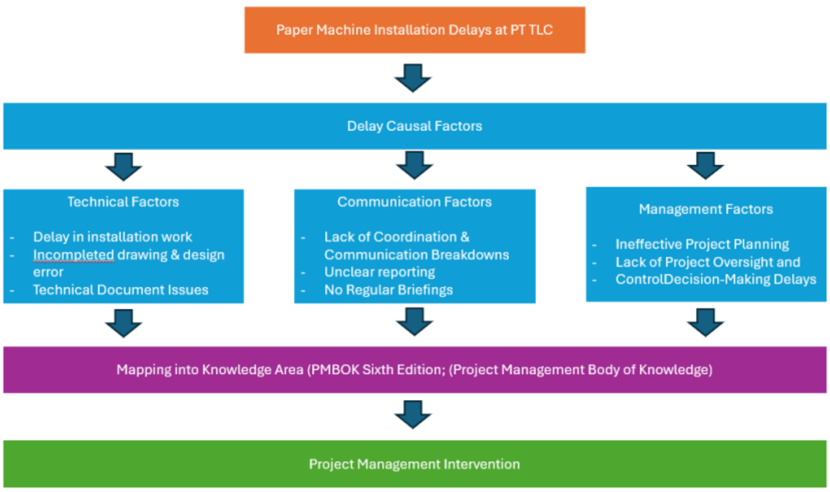


Figure 1: Conceptual Framework

The conceptual framework (Figure 1) for this study establishes a systematic approach to identify, analyze, and address the factors contributing to delays in PT TLC's paper machine installation project through a comprehensive project management intervention strategy. The framework begins with the identification of three primary delay causal factor categories: technical factors encompassing delays in installation work, incomplete or incorrect engineering drawings, and technical document issues; communication factors including lack of coordination between teams, communication breakdowns, unclear reporting protocols, and absence of regular briefings; and management factors involving ineffective project planning, insufficient project oversight and control, and delays in critical decision-making processes. These empirically identified delay factors are then systematically mapped into the internationally recognized PMBOK (Project Management Body of Knowledge) sixth edition knowledge areas, creating a theoretical bridge between field observations and established project management standards, including Project Integration Management, Project Scope Management, Project Schedule Management, Project Communications Management, and Project Risk Management. This mapping process enables the development of evidence-based project management interventions that directly target the root causes of delays through structured process improvements, enhanced coordination mechanisms, strengthened monitoring systems, and optimized decision-making protocols, ultimately providing a practical roadmap for improving project execution efficiency and ensuring timely completion of the paper machine installation project.

3. Methodology

This study adopts a Sequential Exploratory Mixed Methods approach, which systematically combines qualitative and quantitative methodologies to provide a comprehensive understanding of the factors contributing to project delays in PT TLC's paper machine installation project (Figure 2). The study starts by gathering and studying qualitative data to understand the problem and then moves on to collect and analyze quantitative data to confirm, measure, and determine the importance of the first findings about delay factors (Creswell & Plano Clark, 2018). First, the researcher investigates the project execution challenges qualitatively and then confirms and measures these findings with standard instruments. The mixed-methods approach was specifically chosen to address the multi-dimensional nature of industrial project delays, which encompass technical, managerial, and coordination factors that require both contextual understanding and empirical validation to develop effective interventions.

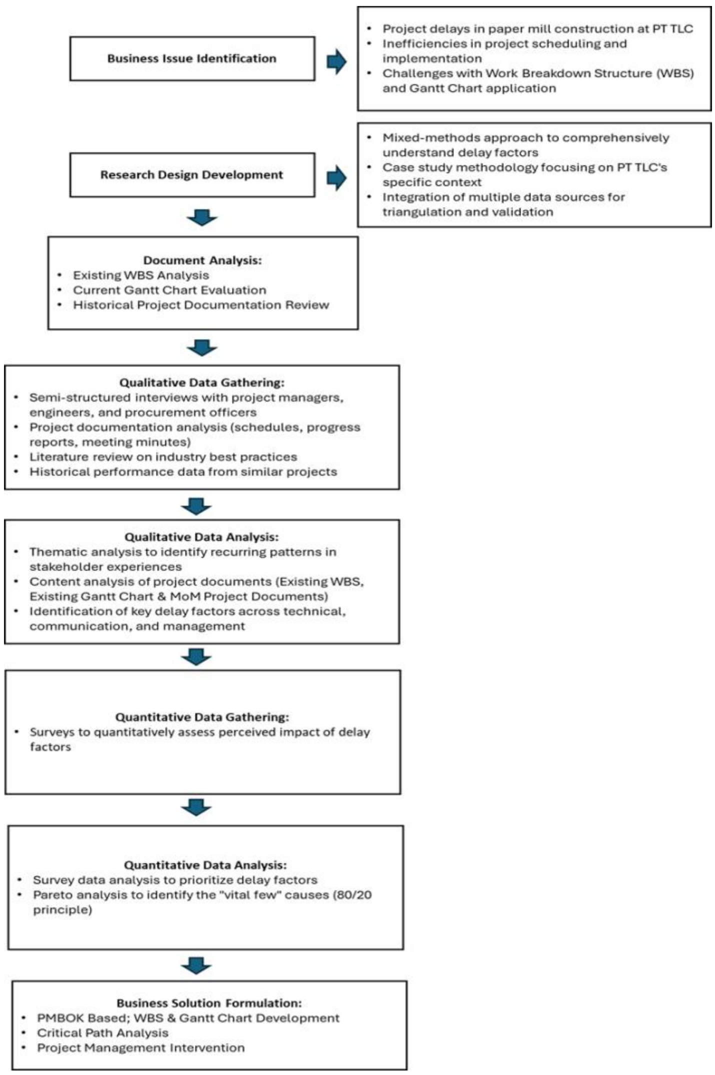


Figure 2: Research Design

In the qualitative phase, researchers employ various methods to collect data and thoroughly explore the reasons for delays. Interviews are used as the main way to collect qualitative data, involving project managers, installation engineers, and procurement officers to learn about challenges and gaps during implementation seen by different members of the organization. Secondary data analysis focuses on critical project documentation, including Work Breakdown Structure (WBS) documents, baseline and updated Gantt Charts, Minutes of Meetings (MoM) from project coordination forums, installation logs, progress reports, and internal correspondence. The qualitative data are analyzed using thematic analysis following Braun and Clarke's (2006) six-phase framework to identify recurring patterns and dominant causes of delays, which are then categorized into technical, communication, and managerial factors. Additionally, content analysis is conducted on project documents to identify structural weaknesses in scheduling and task sequencing, while visual and structural analysis of the Gantt Chart and WBS reveals deviations from baseline plans and coordination inefficiencies.

The quantitative phase builds directly upon qualitative findings to validate and prioritize identified delay factors through empirical measurement and statistical analysis. A structured survey questionnaire utilizing Likert-scale items is developed based on themes emerging from the qualitative analysis, targeting individuals directly involved in project execution to capture stakeholder perceptions regarding the frequency and severity of each delay factor. The quantitative data are analyzed using descriptive statistics to rank the influence of each factor, followed by a Pareto analysis to isolate the "vital few" causes that contribute most significantly to project delays, applying the 80/20 principle to focus intervention efforts on high-impact areas. Besides, Critical Path Analysis (CPA) is performed on both the baseline and actual Gantt Chart to spot tasks that are most important for finishing the project quickly and suggest actions to speed up the project. By using this design, the research combines different types of data, which helps validate and strengthen the findings and offers valuable solutions for PT TLC’s industry (Johnson & Onwuegbuzie, 2004).

3.1 Data Collection

This study employed a comprehensive mixed-methods data collection strategy encompassing both secondary and primary data sources to ensure a thorough investigation of delay factors in PT TLC's paper machine installation project. Secondary data collection focused on a systematic analysis of critical project documentation, including Work Breakdown Structure (WBS) documents, baseline and updated Gantt Charts, Minutes of Meetings (MoM) from project coordination forums, installation logs, progress reports, and internal correspondence. The WBS analysis evaluated task hierarchy clarity and completeness according to PMBOK Guide standards, while the Gantt Chart analysis involved a retrospective comparison between original baseline plans and actual progress to identify scheduling deviations, critical path disruptions, and resource misalignments. By analyzing MoM and internal coordination notes, it was found that delays were caused by miscommunication, late choices, unsure vendor actions, and unresolved technical issues (Bowen, 2009). A thorough review of the documents allowed me to understand the places where scheduling, technical, and managerial issues occurred during the project.

In line with the mixed-methods approach, the first stage was conducting interviews, and the second stage was administering the Survey. Project managers, engineers, and procurement officers responsible for various tasks within the project were interviewed using semi-structured interviews. Every interview session ran for 20-40 minutes and was based on questions that fit the role, so project managers discussed planning issues and stakeholder cooperation, engineers talked about technical problems and workflow problems, and procurement officers discussed issues with service coordination and timeline integration. After studying the interview transcripts, a questionnaire was created and sent to many project stakeholders to confirm and measure how often and how seriously each delay factor occurred. Five main areas were covered in the Survey by using a 5-point Likert scale: planning and scheduling the project, coordinating internally, working with contractors and vendors, decision-making and leadership, and using resources effectively (Fowler, 2014). This sequential approach ensured that quantitative measurement was grounded in qualitative insights while enabling methodological triangulation to enhance research validity.

3.2 Data Analysis

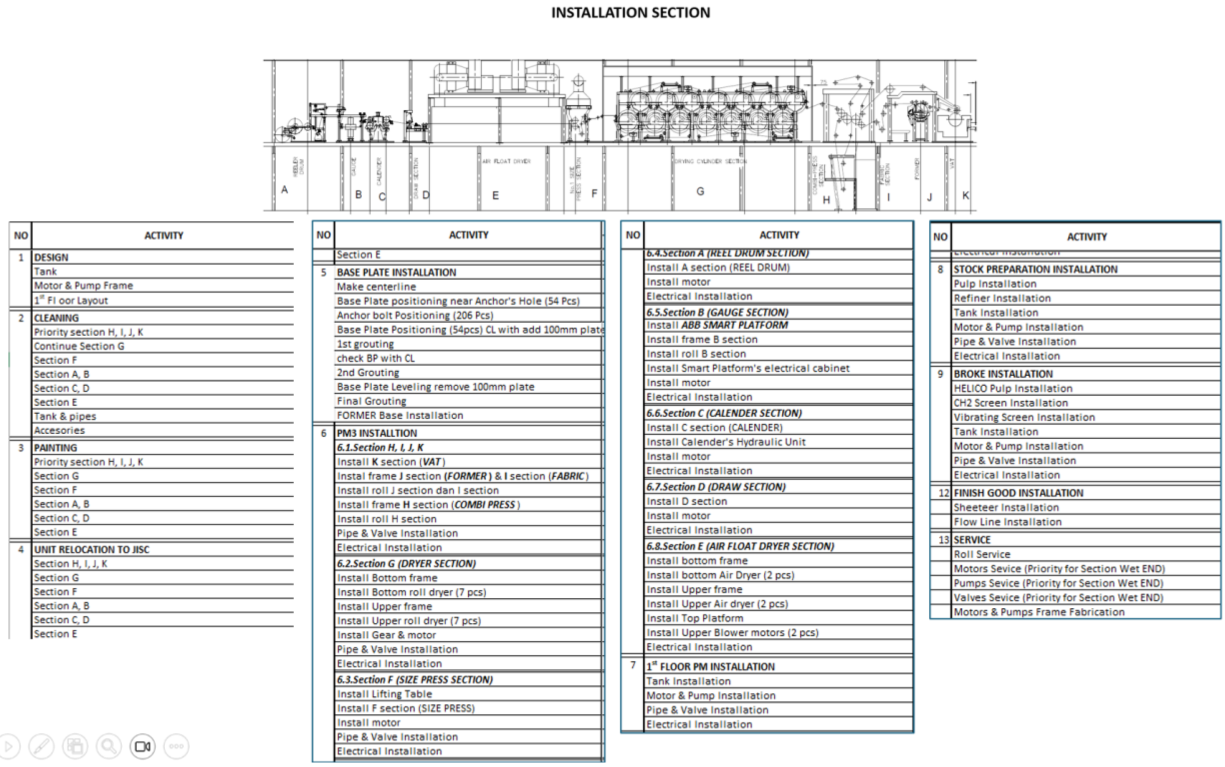
Qualitative data analysis employed multiple complementary analytical approaches to extract comprehensive insights from interview transcripts and project documentation. Thematic analysis served as the primary analytical framework, following Braun and Clarke's (2006) six-phase model encompassing transcript familiarization, initial coding, theme development, theme review, theme definition, and report generation to identify recurring patterns related to project delays, including communication bottlenecks, coordination breakdowns, and technical execution challenges. This analysis utilized both deductive approaches based on established delay taxonomies and inductive approaches, allowing emergent patterns from field data to surface organically. Simultaneously, integrated document analysis combined content analysis of textual materials (MoM, internal communications) to extract delay-related issues, visual analysis of Gantt Charts to identify baseline deviations and scheduling inconsistencies, and structural analysis of WBS documents to assess task hierarchy clarity and alignment with PMBOK standards. These qualitative analytical methods were systematically cross-referenced and triangulated to ensure consistency and strengthen the reliability of identified delay factors, with findings serving as the foundation for developing the quantitative survey instrument.

Quantitative data analysis focuses on validating and prioritizing qualitative findings through statistical measurement and strategic analytical techniques. Descriptive statistical analysis was conducted on survey responses from nine project participants, beginning with data preparation procedures including reverse coding of positively framed items to create a unified problem severity scale using the formula: Problem Score = 6 - Average Score. Average scores were calculated for each survey item and categorized using established thresholds, where scores above 3.5 indicated critical concerns requiring immediate attention, scores between 2.0 and 3.5 represented moderate concerns, and scores below 2.0 suggested minor issues (Vagias, 2006; Dawes, 2008). To further prioritize intervention strategies, Pareto analysis was applied, following the 80/20 principle, to identify the "vital few" delay factors that contribute disproportionately to project timeline disruptions (Craft & Leake, 2002). The Pareto analysis involved the systematic categorization of delay factors, frequency tabulation based on both qualitative and quantitative evidence, ranking, and percentage conversion to assess relative contributions, as well as cumulative percentage calculation to determine factor combinations accounting for approximately 80% of project delays. Additionally, Critical Path Analysis (CPA) was conducted on baseline and actual Gantt Chart data to identify task sequences with the highest time sensitivity and map potential interventions for accelerating project completion, ensuring that analytical findings directly informed practical recommendations for schedule recovery and future project optimization.

4. Result

4.1 Existing WBS Analysis

The evaluation of the existing Work Breakdown Structure (WBS) at PT TLC revealed significant deviations from standardized project management practices through a comprehensive analysis that identified ten distinct weaknesses within the current implementation (Figure 3, Table 1). These issues encompassed fundamental structural problems, including the absence of clear deliverables per level, lack of hierarchical numbering systems, inappropriate work package sizing, missing duration, and resource allocations, activity redundancy and overlap, inconsistent terminology usage, undefined outputs or deliverables, exclusion of critical testing and commissioning phases, poor integration with other project areas, and absence of defining milestones or gates. The analysis demonstrated that the existing WBS functioned merely as an activity list rather than a proper hierarchical structure showing the progression from project goals to phases, deliverables, and specific tasks, thereby undermining the effectiveness of project planning, monitoring, and control processes.



NO	ACTIVITY
1	**DESIGN**
	Tank
	Motor & Pump Frame
	1st Fl oor Layout
2	**CLEANING**
	Priority section H, I, J, K
	Continue Section G
	Section F
	Section A, B
	Section C, D
	Section E
	Tank & pipes
	Accesories
3	**PAINTING**
	Priority section H, I, J, K
	Section G
	Section F
	Section A, B
	Section C, D
	Section E
4	**UNIT RELOCATION TO JISC**
	Section H, I, J, K
	Section G
	Section F
	Section A, B
	Section C, D
	Section E

NO	ACTIVITY
	Section E
5	**BASE PLATE INSTALLATION**
	Make centerline
	Base Plate positioning near Anchor's Hole (54 Pcs)
	Anchor bolt Positioning (206 Pcs)
	Base Plate Positioning (54pcs) CL with add 100mm plate
	1st grouting
	check BP with CL
	2nd Grouting
	Base Plate Leveling remove 100mm plate
	Final Grouting
	FORMER Base Installation
6	**PM3 INSTALLTION**
	6.1.Section H, I, J, K
	Install **K** section (***VAT***)
	Instal frame **J** section ***(FORMER)*** & **I** section (***FABRIC***)
	Install roll J section dan I section
	Install frame **H** section (***COMBI PRESS***)
	Install roll H section
	Pipe & Valve Installation
	Electrical Installation
	6.2.Section G (DRYER SECTION)
	Install Bottom frame
	Install Bottom roll dryer (7 pcs)
	Install Upper frame
	Install Upper roll dryer (7 pcs)
	Install Gear & motor
	Pipe & Valve Installation
	Electrical Installation
	6.3.Section F (SIZE PRESS SECTION)
	Install Lifting Table
	Install F section (SIZE PRESS)
	Install motor
	Pipe & Valve Installation
	Electrical Installation

NO	ACTIVITY
	6.4.Section A (REEL DRUM SECTION)
	Install A section (REEL DRUM)
	Install motor
	Electrical Installation
	6.5.Section B (GAUGE SECTION)
	Install ***ABB SMART PLATFORM***
	Install frame B section
	Install roll B section
	Install Smart Platform's electrical cabinet
	Install motor
	Electrical Installation
	6.6.Section C (CALENDER SECTION)
	Install C section (CALENDER)
	Install Calender's Hydraulic Unit
	Install motor
	Electrical Installation
	6.7.Section D (DRAW SECTION)
	Install D section
	Install motor
	Electrical Installation
	6.8.Section E (AIR FLOAT DRYER SECTION)
	Install bottom frame
	Install bottom Air Dryer (2 pcs)
	Install Upper frame
	Install Upper Air dryer (2 pcs)
	Install Top Platform
	Install Upper Blower motors (2 pcs)
	Electrical Installation
7	**1st FLOOR PM INSTALLATION**
	Tank Installation
	Motor & Pump Installation
	Pipe & Valve Installation
	Electrical Installation

NO	ACTIVITY
	Electrical Installation
8	**STOCK PREPARATION INSTALLATION**
	Pulp Installation
	Refiner Installation
	Tank Installation
	Motor & Pump Installation
	Pipe & Valve Installation
	Electrical Installation
9	**BROKE INSTALLATION**
	HELICO Pulp Installation
	CH2 Screen Installation
	Vibrating Screen Installation
	Tank Installation
	Motor & Pump Installation
	Pipe & Valve Installation
	Electrical Installation
12	**FINISH GOOD INSTALLATION**
	Sheeteer Installation
	Flow Line Installation
13	**SERVICE**
	Roll Service
	Motors Sevice (Priority for Section Wet END)
	Pumps Sevice (Priority for Section Wet END)
	Valves Sevice (Priority for Section Wet END)
	Motors & Pumps Frame Fabrication

Figure 3: Existing WBS Installation Section

The systematic mapping of these identified weaknesses to relevant PMBOK Knowledge Areas (Table 1) revealed that Scope Management and Schedule Management were the most frequently impacted areas, each appearing three times in the frequency analysis (Table IV.3), indicating concentrated weaknesses in project scope definition and time planning. Integration Management followed with two occurrences, reflecting poor alignment between WBS structure and overall project control, while Communication Management and Procurement Management each appeared once, highlighting specific but important coordination and communication gaps. This mapping process facilitated the development of targeted intervention strategies, such as assigning durations and resources to activities, clarifying deliverables at each WBS level, implementing hierarchical numbering systems, standardizing terminology, and aligning procurement schedules with installation timelines. The findings emphasized the critical need to strengthen WBS development by applying structured project management standards to ensure better project execution and control.

Table 1: Existing WBS Identification based on PMBOK concept

No.	PMBOK Categories	Issue	Detail
1	Scope Definition	WBS does not have clear deliverables per level	WBS is just an activity; it does not show the hierarchy of goals (project → phase → deliverable → task)
2	WBS Numbering	There is no hierarchical numbering (example: 1.0, 1.1, 1.1.1)	It makes tracking activities difficult, does not conform to standard level-based WBS structure
3	Work Package Clarity	There are activities that are too large or too small to be called a work package	Example: “Install Refiner” (too general), “Install Dryer (2 pcs)” (too narrow without sub-tasks)
4	Lack of Duration & Resource	No mention is made of estimated duration, resources, or dependencies between activities	It cannot be used for scheduling or monitoring
5	Redundancy or Overlap	Some activities appear to overlap between sections	Example: "Motor & Pump Installation" appears in several sections without clarity as to

			whether it refers to the same or different items.
6	Inconsistent Terminology	There are differences in writing style between sections (some use technical details, some are general)	Example: "Install Section A" vs. "Install Refiner Motor & Pump"
7	Lack of Deliverables or Outcomes	The output of each activity is not listed (for example, components completed, installed, tested, handed over)	It is challenging to determine whether activities are completed to the required standards.
8	No Work Package for Testing & Commissioning	Focus only on installation; does not include testing and commissioning	An important step for the final validation of unit performance before going live
9	Lack of Integration with Other Areas	It does not cover communication, quality, or vendor coordination	Not by the integration principle between PMBOK Knowledge Areas
10	There is no defining milestone (Gate)	There are no critical milestones such as: "Baseplate Completed," "Mechanical Completion," and "Ready for Commissioning."	It is not easy to evaluate progress based on key targets.

4.2 Existing Gantt Chart Analysis

The evaluation of the existing Gantt chart used in the machine installation project at PT TLC (Figure 3) revealed significant structural and functional weaknesses that compromise the project's ability to manage time, resources, and scope effectively according to PMBOK-based project scheduling best practices. The analysis identified ten critical findings (Table IV.3), including the absence of activity dependencies that prevent critical path determination, lack of visible estimation methods for durations despite their presence in the chart, missing essential project control features such as float calculations and milestone definitions, absence of baseline and progress indicators that hinder objective performance tracking, poor integration with the Work Breakdown Structure (WBS), and insufficient visibility of resource allocations per task. Additionally, while technical activities were detailed across sections such as cleaning, painting, and base plate installation, the chart failed to include crucial commissioning activities necessary for project closure. Furthermore, the existing "Service" activity at the end lacked proper detailing for industrial project requirements.

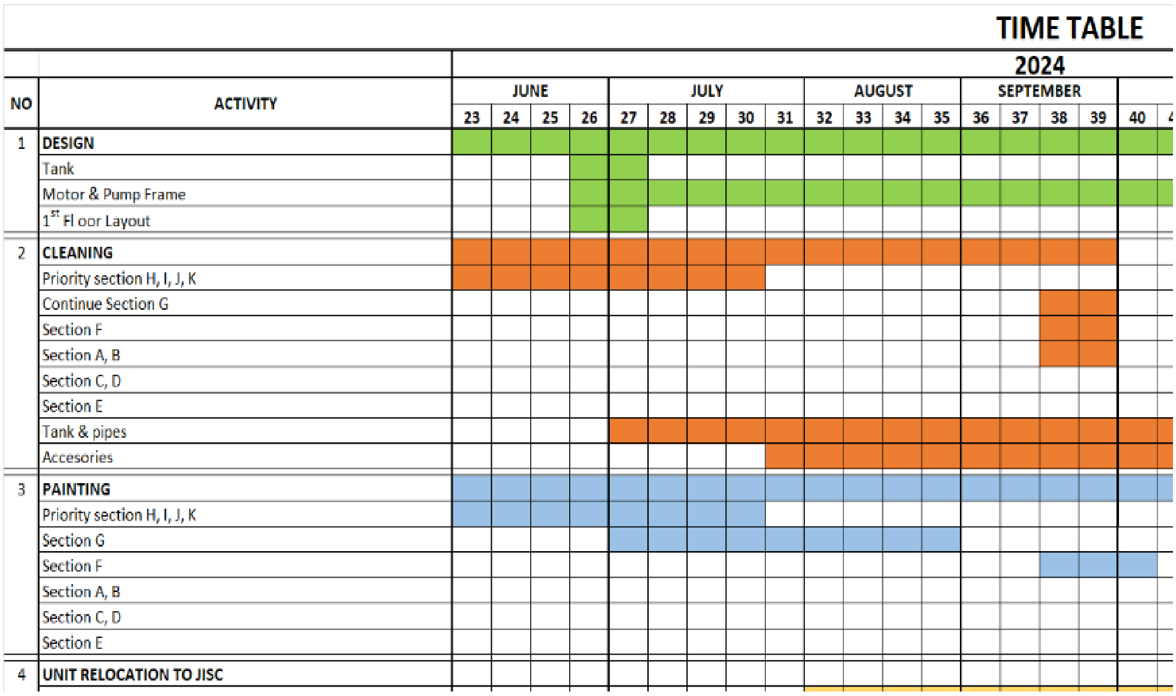


Figure 3: Existing Gantt Chart

The systematic mapping of these identified weaknesses to corresponding PMBOK Knowledge Areas (Table 2) demonstrated that Schedule Management was the most significantly impacted area, covering four of the eight identified issues, including problems in activity sequencing, estimation methods, milestone definition, and overall schedule development. Integration Management appeared in two instances, reflecting poor alignment between the Gantt chart and the project's WBS structure as well as missing control baselines, while Resource Management and Scope Management each appeared once, highlighting the absence of resource details and missing commissioning activities, respectively. These findings emphasized the critical need to enhance the Gantt chart by incorporating essential project control elements such as logical activity dependencies to establish critical path analysis, proper duration estimation methods, float calculations, key project milestones, resource allocation details, and comprehensive commissioning stages to ensure improved clarity, coordination, and schedule accuracy in alignment with PMBOK standards.

Table 2: Existing Gantt Chart Identification based on PMBOK concept

No.	Initial Code	Theme	Mapped PMBOK Knowledge Area	Freq	Recommended Intervention
1	No duration/resource assignment	Schedule Integration Problem	Schedule Management	3	Assign durations and resources to each activity for effective planning.
2	Overlap between activities	Structural & Control Weakness			Rearrange the activity sequence to eliminate overlapping tasks.
3	Lack of commissioning milestone	Execution Incompleteness			Include commissioning stages in the project schedule baseline.
4	No clear deliverables per level	WBS Structural Deficiency	Scope Management	3	Clarify deliverables at each WBS level by providing detailed scope definitions.
5	Overly general/narrow task definition	Work Package Clarity			Refine the work package definitions to match the actual work scope better.
6	Undefined output or deliverables	Work Control Problem			Clearly define expected outputs and quality criteria for each task.
7	No numbering hierarchy	WBS Structural Deficiency	Integration Management	2	Implement a hierarchical numbering system to support integration and project control.
8	No milestone (Gate) defined	Execution Monitoring Gap			Set major project milestones (Gates) as checkpoints for performance tracking.
9	Inconsistent terminology	Communication Gap	Communication Management	1	Standardize terminology and provide a project glossary for common understanding.
10	Not integrated with procurement/vendor	Integration Deficiency	Procurement Management	1	Align procurement schedule with equipment installation timelines.

4.3 Pareto Analysis

The Pareto analysis conducted to validate and quantify the seven significant delay categories factors identified through thematic analysis of PT TLC's paper mill project demonstrated a precise distribution of issues across

PMBOK Knowledge Areas, with the results visualized in Figure 4. showing the relative frequency and cumulative impact of project delays by knowledge area. This quantitative validation, derived from structured survey questionnaires administered to key stakeholders, effectively bridged the gap between qualitative thematic findings and statistical evidence by mapping each identified delay factor to specific survey items, thereby enabling comprehensive coverage of project issues while providing empirical support for the prevalence and significance of various delay categories. The Pareto chart revealed the concentration of delay factors within specific knowledge areas, following the 80/20 principle where a minority of knowledge areas contributed to the majority of project delays, thus providing project management with clear prioritization guidance for intervention strategies and resource allocation to address the most critical delay-causing factors in the paper machine installation project.

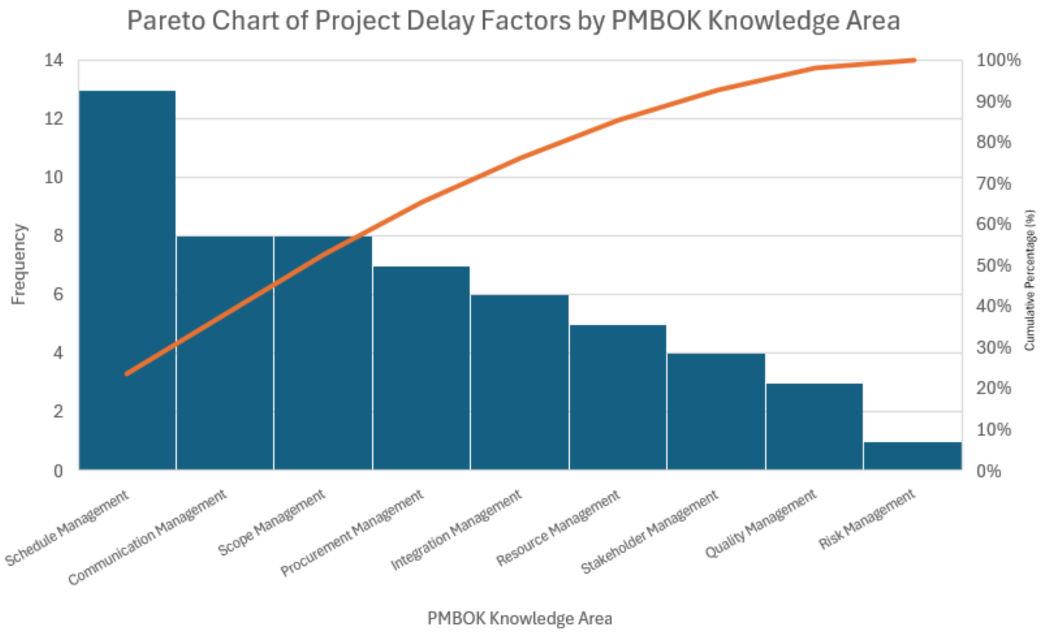


Figure 4: Pareto Analysis of PMBOK Knowledge Area

4.4 Integrated Master Delay Factor

The construction of a comprehensive understanding of dominant project delay factors was achieved through an integrated master delay factor analysis that systematically aggregated findings from five key data sources including Work Breakdown Structure (WBS) analysis, Gantt Chart evaluation, Minutes of Meeting (MoM) document review, thematic analysis of stakeholder interviews, and quantitative survey results, with each identified issue being thematically coded and mapped into the ten PMBOK knowledge areas for structured classification (Table 3). The integrated analysis revealed that Schedule Management emerged as the most frequently cited knowledge area associated with project delays with 15 total occurrences across all data sources, followed by Communication Management and Procurement Management each recording 10 occurrences, and Scope Management with 9 occurrences, indicating that the most pressing challenges were rooted in ineffective scheduling practices, coordination breakdowns, and vendor-related obstacles. This cross-functional integration approach captured both technical deficiencies and organizational governance weaknesses while reducing bias from any single dataset, thereby supporting a triangulated understanding of systemic delay drivers where Resource Management (8 occurrences), Integration Management, and Stakeholder Management (7 occurrences each), Quality Management and Risk Management (2 occurrences each) represented additional but less critical areas of concern. The aggregated frequency data provided a robust foundation for subsequent prioritization analysis using Pareto principles to determine the most impactful areas for project improvement interventions, ensuring that improvement strategies would address the root causes of delays rather than merely treating symptoms (Table 3).

Table 3: Integrated Master Delay Factor Frequency by PMBOK

No.	PMBOK Knowledge Area	Delay Source					Total
		WBS	Gantt Chart	MoM	Interview	Survey	
1	Schedule Management	3	4	2	4	2	15
2	Communication Management	1	0	5	2	2	10
3	Scope Management	3	1	2	2	1	9
4	Procurement Management	1	0	2	4	3	10
5	Integration Management	2	2	0	2	1	7
6	Resource Management	0	1	2	2	3	8
7	Stakeholder Management	0	0	0	4	3	7
8	Quality Management	0	0	1	1	0	2
9	Risk Management	0	0	2	0	0	2

4.5 Proposed Solution

This subchapter presents a structured set of proposed improvements for PT TLC's machine installation project by adopting a comparative approach that systematically evaluates deficiencies in the original project planning documents, specifically the Work Breakdown Structure (WBS), Critical Path Method (CPM), and Gantt chart including resource visibility, and contrasts them with revised tools developed in response to findings from the integrated analysis conducted. The proposed solutions address six major identified problems as summarized in Table 4, including designing a hierarchical WBS with defined outputs and numbering to resolve scope and integration issues, recalculating CPM with proper dependencies, float calculations, and milestone definitions to enhance schedule and integration management, adding resource columns for workforce, vendor, and equipment visibility to strengthen resource management, improving RFI response SOPs with assigned communication focal points to eliminate communication bottlenecks, synchronizing delivery plans with WBS milestone checkpoints to address procurement management challenges, and aligning terminology across WBS and MoM documents while defining clear deliverables per task to enhance scope and quality management. The subchapter is systematically organized into three main components that provide evaluation of the existing WBS and its improvement, comparison between original and improved CPM and Gantt Chart structures, and a comprehensive summary of key improvements with detailed explanations of their impact on project clarity, timing, and resource management, thereby ensuring that each proposed solution directly addresses the root causes identified through multiple evidence sources including WBS analysis, Gantt chart evaluation, MoM reviews, thematic interviews, and survey data.

Table 4: Summary of Delay Issues and Improvement Focus Areas

Identified Problem	Evidence Source	PMBOK Area	Proposed Improvement
WBS lacks hierarchy, deliverables, and numbering	WBS analysis, Interview	Scope & Integration	Design hierarchical WBS with defined output numbering
Activities unlinked to milestones and float not calculated	Gantt Chart & MoM	Schedule & Integration	Recalculate CPM, define dependencies, float, and milestone
No resource visibility per task	Gantt Chart & Survey	Resource Management	Add resource columns in the schedule for workforce/vendor/equipment

Communication & and RFI bottlenecks	Thematic interviews, Survey	Communication Management	Improve RFI response SOP, assign communication focal points
Vendor schedule mismatch delivery delays	Interview & MoM	Procurement Management	Synchronize delivery plan with WBS milestone checkpoints
Inconsistent terminology & and unclear output	WBS, MoM, Interviews	Scope/Quality Management	Align language in WBS & MoM; define deliverables per task

4.6 Improved WBS design

To address the structural and clarity issues identified in the evaluation of the existing WBS, an improved Work Breakdown Structure was developed based on hierarchical formatting aligned with PMBOK best practices and incorporating findings from delay analysis conducted through interviews, Gantt chart review, and survey data. The revised WBS introduces a comprehensive four-tiered structure consisting of Level 1 (Overall project - Paper Machine Installation at PT TLC), Level 2 (Project phases including Project Management, Engineering & Design, Construction & Installation, and Commissioning), Level 3 (Major deliverables), and Level 4 (Sub-deliverables or activities), which enables better task traceability, more explicit deliverable definitions, embedded milestone integration, and accurate resource and duration estimates to support enhanced scheduling and progress control. The enhanced WBS design directly resolves the previously identified deficiencies by establishing clear hierarchical relationships, eliminating redundancy and overlap, providing consistent terminology throughout all levels, defining specific deliverables and outcomes for each work package, and ensuring proper integration with scheduling and resource management systems, thereby creating a robust foundation for effective project planning, monitoring, and control.

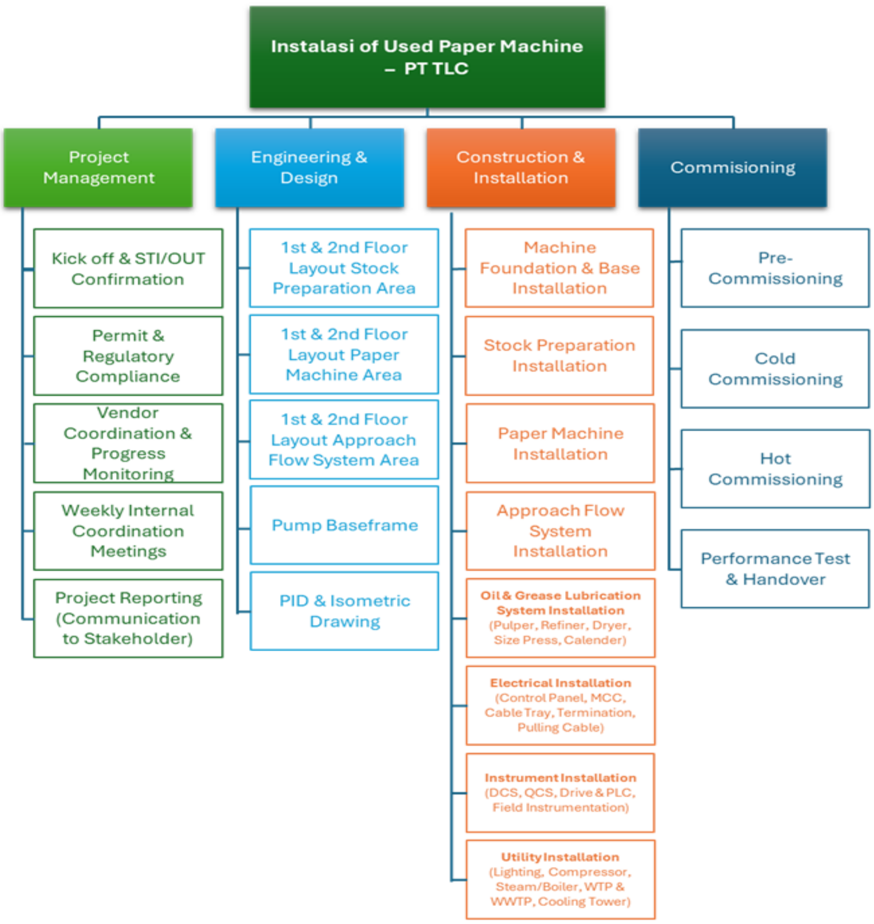


Figure 5: Improved WBS Overview by Project Phases

4.7 Critical Path Method

As part of the project improvement strategy, a comprehensively revised Critical Path Method (CPM) was developed in full alignment with the enhanced hierarchical WBS, featuring complete activity mapping from Engineering and design through Construction and installation to Commissioning and handover phases (Table 5). The improved CPM significantly expanded the critical path to include essential downstream commissioning stages such as Cold and hot Commissioning, Pre-Commissioning, and Final Acceptance and handover, with activities including Hot Commissioning (M), Performance Testing (N), and Final Acceptance (O) now correctly identified as critical with zero float values, ensuring that any delays in these areas would directly impact project completion dates. The dependency logic underwent substantial revision, exemplified by Pre-Commissioning (K) now being linked to a comprehensive set of predecessors (E, F, G, H, I, and J) representing physical readiness and functional verification requirements before testing commences, thereby ensuring the updated CPM accurately reflects real-world sequencing and interdependencies. The detailed comparison presented in Table IV.14 demonstrates key improvements, including the transformation from a technical section-based structure to a hierarchical phase-based organization, full inclusion of commissioning activities end-to-end rather than partial coverage, defined durations for all tasks, eliminating previous scheduling gaps, expanded delay risk coverage beyond installation to include end-phase and handover risks, and enhanced critical path visibility extending through final acceptance rather than terminating at installation. Through this improved structure, the CPM evolves into a strategic management tool capable of highlighting critical risks throughout the entire project lifecycle, enabling the project team to identify latent risks in downstream activities and implement early interventions such as resource reallocation or schedule compression to avoid delays and successfully meet the July 2025 deadline.

Table 5: Improved Critical Path Method (After Improvement)

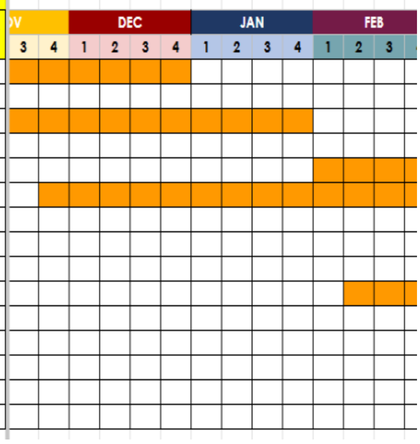
Machine Installation - Project Activity Plan											
No.	Activity	Start	Finish	Duration (Days)	Predecessors	ES	EF	LS	LF	FLOAT	CRITICAL
A	Layout Drawings	4/1/2024	12/31/2024	274	-	0	274	0	0	0	YES
B	Pump Baseframe Drawings	10/1/2024	10/31/2024	30	A	274	304	274	304	0	YES
C	PID & Isometric Drawings	10/31/2024	1/31/2025	92	A	274	366	274	366	0	YES
D	Machine Foundation & Base Constructed	8/20/2024	10/31/2024	72	B	274	346	274	346	0	YES
E	Stock Preparation System Installed	2/10/2025	6/20/2025	131	D	346	477	427	558	81	NO
F	Paper Machine Installed	11/30/2024	6/30/2025	212	D	346	558	346	558	0	YES
G	Approach Flow System Installed	4/1/2025	6/30/2025	91	D	346	437	467	558	121	NO
H	Electrical System Installed	4/25/2025	6/18/2025	54	E, F, G	558	612	558	612	0	YES
I	Instrumentation Systems Installed	5/1/2025	7/31/2025	92	H	612	704	647	739	35	NO
J	Utility Systems Installed	2/11/2025	7/15/2025	127	A	612	739	612	739	0	YES
K	Pre-Commissioning Checklist Completed	5/20/2025	6/30/2025	41	E, F, G, H , I, J	739	780	739	780	0	YES
L	Cold Commissioning Report	6/2/2025	6/20/2025	1	K	780	781	780	781	0	YES
M	Hot Commissioning	6/30/2025	7/24/2025	25	L	781	806	781	806	0	YES
N	Performance Testing (Performance Commissioning)	7/2/2025	7/24/2025	23	M	806	829	806	829	0	YES
O	Final Acceptance & Handover	7/13/2025	7/31/2025	1	N	829	830	829	830	0	YES

4.8 Gantt Chart

The evaluation of the initial Gantt Chart (Figure 6) used in PT TLC's paper machine installation project revealed significant structural weaknesses including predominantly linear activity scheduling with minimal overlapping that reduced time compression opportunities, treatment of critical activities such as relocation, PM3 installation, and baseplate installation as standalone sequences rather than integrated phases, absence of clear linkage between design completion and early site execution resulting in time gaps and underutilized resources, and lack of indicators for deliverables, responsible parties, or resource alignment that hindered cross-functional coordination. In response to comprehensive delay analysis findings from Sections 4.3 and 4.4, an improved Gantt Chart was developed (Figure IV.11) that directly integrates WBS hierarchy into scheduling logic, enables parallel scheduling of installation phases with foundation work and layout drawing co-occurring, introduces strategic overlap between machine installation and utility work including electrical, instrumentation, and piping to reduce idle periods, and incorporates commissioning stages and performance testing as visible milestones for enhanced preparation and handover readiness control. The improved Gantt Chart delivers superior visual logic, enhanced activity sequencing, and better alignment with actual field practices and engineering workflow, transforming the scheduling tool from a basic linear timeline into a sophisticated project management instrument that optimizes resource utilization, minimizes project duration through strategic activity overlapping, and provides clear visibility into critical dependencies and milestone achievements throughout the entire project lifecycle.

Table 6: Gantt Chart (After Improvement)

PROJECT TIMELINE					
No.	Activity	PIC	Start	Finish	Duration (Days)
A	Layout Drawings	Arif	4/1/2024	12/31/2024	274
B	Pump Baseframe Drawings	Dudung	10/1/2024	10/31/2024	30
C	PID & Isometric Drawings	Wida	10/31/2024	1/31/2025	92
D	Machine Foundation & Base Constructed	Eri	8/20/2024	10/31/2024	72
E	Stock Preparation System Installed	Lantip	2/10/2025	6/20/2025	131
F	Paper Machine Installed	Lantip	11/30/2024	6/30/2025	212
G	Approach Flow System Installed	Soni	4/1/2025	6/30/2025	91
H	Electrical System Installed	Feri	4/25/2025	6/18/2025	54
I	Instrumentation Systems Installed	Dwi	5/1/2025	7/31/2025	92
J	Utility Systems Installed	Rifky	2/11/2025	7/15/2025	127
K	Pre-Commissioning Checklist Completed	Cikal	5/20/2025	6/30/2025	41
L	Cold Commissioning Report	Cikal	6/2/2025	6/20/2025	1
M	Hot Commissioning	Cikal	6/30/2025	7/24/2025	25
N	Performance Testing (Performance Commiss	Cikal	7/2/2025	7/24/2025	23
O	Final Acceptance & Handover	Cikal	7/31/2025	7/31/2025	1



4.9 Discussion

The comprehensive comparison of project management tools at PT TLC reveals fundamental transformations that align with established PMBOK framework principles and address the technical, communication, and managerial factors identified in the conceptual framework. The WBS enhancement represents a significant evolution from a list-based sectional format to a hierarchical structure that incorporates PMBOK-compliant scope management practices (PMI, 2017). According to Turner (2014), effective WBS design requires a clear decomposition of project scope into manageable work packages, which the improved structure achieves through its four-tiered hierarchy and formalized numbering systems. The integration of explicit deliverables and Person-in-charge (PIC) assignments reflects what Kerzner (2017) identifies as essential accountability structures in project management while addressing gaps noted by Crawford (2002) regarding scope control deficiencies. However, unlike previous studies that focus primarily on WBS structure (Haugan, 2002), this research highlights the critical importance of integrating WBS improvements with downstream scheduling and resource management tools, which many existing studies overlook.

Table 7: Before vs. After Improvement

Tool	Evaluation Aspect	Before Improvement	After Improvement
WBS	Structure Format	List-based by section	Hierarchical (Project → Phase → Task)
WBS	Hierarchy Levels	2 levels (main/sub-activity)	3–4 levels (e.g., 1.2.1.1)
WBS	Numbering System	No formal numbering	Formalized (e.g., 3.2.1.2)
WBS	Scope Clarity	Generic/overlapping tasks	Clear, specific deliverables
WBS	Deliverables Defined	Not clearly stated	Key deliverables defined per task
WBS	Resource Allocation	Absent	PIC listed per task
WBS	Duration Estimation	Missing	Included per task (in days)
WBS	Milestone Integration	Absent	Milestones embedded (e.g., commissioning)
WBS	Traceability to Schedule	Not linked to schedule tools	Fully traceable to Gantt Chart and CPM
WBS	Responsibility (PIC)	Not explicit	Named PICs per task

WBS	Issue Mapping	Not present	Linked to MoM/interview issues in the remarks column
CPM	WBS Structure	Technical section-based only	Hierarchical, phase-based
CPM	Commissioning Activities	Partially or not included	Fully included end-to-end
CPM	Duration Definition	Some tasks are missing durations/schedules	Defined duration for all tasks
CPM	Delay Risk Coverage	Focused on installation delays only	Includes end-phase and handover risks
CPM	Critical Path Visibility	Limited (ends at installation)	Full timeline through to final acceptance
Gantt Chart	Activity Structure	Integrated across all phases but not modular	Modular breakdown: Design → Cleaning → Painting → Move
Gantt Chart	Unit Relocation	Not Included	Explicitly listed as the final task
Gantt Chart	Preparation Tasks	Missing (no cleaning or painting shown)	Included and logically sequenced
Gantt Chart	Activity Dependencies	Not Visible	Implied through phased and section-based layout
Gantt Chart	Time Scale	Monthly	Weekly
Gantt Chart	Execution Logic	Less visible, less field-friendly	Better suited for actual on-site coordination
Gantt Chart	Activity Scheduling	Linear with minimal overlapping	Parallel scheduling with strategic overlaps
Gantt Chart	Cross-functional Coordination	Limited indicators for deliverables/resources	Enhanced with deliverables, PICs, and milestones
Gantt Chart	Commissioning Integration	Partial or missing	Fully integrated with visible milestones

The CPM improvements demonstrate significant advancement beyond traditional approaches documented in project management literature. While Meredith and Mantel (2017) emphasize the importance of activity identification and dependency mapping, their focus remains primarily on construction phases, neglecting what Burke (2013) identifies as critical commissioning and handover activities. This research addresses this limitation by transitioning from a technically focused approach to a comprehensive lifecycle perspective that includes end-to-end commissioning activities. The enhanced delay risk coverage reflects modern risk management principles outlined in PMBOK's Project Risk Management knowledge area (PMI, 2017). However, it extends beyond what Hillson (2009) describes as traditional risk identification by incorporating systematic bottleneck analysis throughout the entire project system. Previous CPM studies by Kelley and Walker (1959) and subsequent research by Larson and Gray (2021) have not adequately addressed the integration challenges between the installation and commissioning phases that this study specifically targets.

The Gantt chart optimization represents a significant advancement in visual project communication that addresses limitations identified in current project scheduling literature. While Verzuh (2015) advocates for parallel scheduling techniques, most existing research fails to address the practical field implementation challenges that this study tackles explicitly through weekly time scales and field-friendly execution logic. The shift from monthly to weekly time scales enhances schedule control capabilities, as defined by PMBOK's Project Schedule Management (PMI, 2017), but goes beyond what Lewis (2007) suggests by integrating preparation tasks and explicit resource coordination, which previous studies have treated as separate concerns. Unlike Cleland and Ireland's (2007) emphasis on communication tools as standalone elements, this research demonstrates how integrated Gantt chart improvements can simultaneously address resource management, stakeholder communication, and schedule control, filling a significant gap in the literature where these elements are typically studied in isolation.

The comprehensive improvements demonstrate the successful application of PMBOK knowledge areas in ways that address critical limitations in existing project management research. While PMI (2017) provides the theoretical framework for Project Integration Management, most empirical studies fail to demonstrate how WBS, CPM, and Gantt charts can be systematically integrated to create cohesive project management systems. This research addresses the gap between project management theory and practice, as identified by Shenhar and Dvir (2007), by embedding issue mapping and lessons learned integration that serves the dual purposes of current project control and future improvement. The systematic approach supports PMBOK's emphasis on continuous improvement (PMI, 2017). However, it extends beyond what Kerzner (2017) describes by directly linking identified delay factors to specific tool improvements, which previous studies have not systematically demonstrated. Furthermore, while Morris and Pinto (2007) emphasize the importance of considering the project lifecycle, their research does not provide practical methodologies for integrating commissioning and handover activities into critical path analysis, as this study accomplishes.

The demonstrated improvements provide significant implications that challenge existing project management practice assumptions and address gaps in the current literature. While most studies focus on individual tool improvements (Haugan, 2002; Lewis, 2007), this research demonstrates that systematic application of integrated PMBOK principles delivers superior results compared to isolated tool implementation approaches commonly advocated in existing literature. The emphasis on end-to-end project lifecycle consideration, particularly the inclusion of commissioning and handover activities in critical path analysis, addresses a significant research gap identified by Nicholas and Steyn (2017), where transition phases are inadequately studied despite their high failure rates. Unlike previous research that treats technical, communication, and managerial factors as separate domains (Turner, 2014; Burke, 2013), this study demonstrates how comprehensive tool integration can simultaneously address all three-factor categories, providing a more holistic approach to project delay mitigation than currently available in the literature. The transformation from fragmented, technically focused tools to integrated, lifecycle-oriented instruments challenges the conventional wisdom in project management literature, which suggests that incremental improvements are sufficient. Instead, it supports the need for comprehensive, systematic transformation to achieve superior project outcomes.

5. Conclusion

This research successfully identified and analyzed the specific factors causing delays in PT TLC's paper machine installation project and developed comprehensive project management interventions to address these challenges. The integrated master delay factor analysis revealed that Schedule Management, Communication Management, and Procurement Management were the most critical knowledge areas requiring immediate intervention, with systematic weaknesses identified across Work Breakdown Structure design, Critical Path Method implementation, and Gantt chart functionality.

The study's key findings demonstrate that the existing project management framework suffers from fundamental structural deficiencies, including the absence of hierarchical task decomposition, lack of critical path dependencies, insufficient integration of commissioning activities, and inadequate resource visibility. These deficiencies directly contributed to decision-making delays (4.44 problem score), schedule adaptation challenges (4.11), and resource shortage impacts (3.56), collectively accounting for the 4-week project delay and potential loss of the 22 billion rupiah tender opportunity.

The comprehensive improvement solutions developed through this research provide a systematic response to identified delay factors by implementing a four-tiered hierarchical WBS with formalized numbering and clear deliverable definitions, enhanced Critical Path Method incorporating end-to-end commissioning activities with proper dependency mapping, and optimized Gantt charts featuring parallel scheduling, weekly time scales, and field-friendly execution logic. These integrated improvements address the technical, communication, and managerial factors identified in the conceptual framework, ensuring complete alignment with the PMBOK knowledge area principles.

The practical implications of this research extend beyond PT TLC's immediate project needs to provide valuable insights for similar industrial construction projects in Indonesia's manufacturing sector. The systematic application of PMBOK-based project management principles, combined with integrated tool improvements, offers a replicable framework for addressing project delays in complex industrial environments. The study demonstrates that comprehensive tool integration delivers superior results compared to isolated improvement approaches, challenging conventional project management practices that treat scheduling, scope, and resource management as separate domains.

For future research, this study establishes a foundation for investigating the long-term effectiveness of integrated project management interventions and their impact on organizational project management maturity. The methodological framework developed through this research can be adapted for similar studies in other industrial sectors. At the same time, the specific findings provide benchmarks for project performance improvement in Indonesia's paper industry. The research contributes to both a theoretical understanding of project delay mechanisms and practical knowledge for implementing effective project management solutions in emerging market industrial contexts.

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Declaration of Generative AI and AI-assisted Technologies: This study has not used any generative AI tools or technologies in the preparation of this manuscript.

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