INKUBIS: Jurnal Ekonomi dan Bisnis
Volume 8, Issue 2, 1756-1770
e_ISSN: 2775-3913
https://inkubis.polteksci.ac.id/index.php/ink/index
DOI: doi.org/10.59261/inkubis.v8i2.357

Performance Evaluation of the Overhaul Serious Inspection (SE) Project Outcomes for Steam Power Plant Unit 3 at PT XYZ Using a Mixed Methods Approach Based on RII, RCA, & Comparative Analysis

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Article Info:
Article history:
Received: June 11, 2026
Revised: July 11, 2026
Accepted: July 14, 2026
Available Online: September 11, 2026

Keywords:
Comparative Analysis; Overhaul Project Performance; Relative Importance Index (RII); Root Cause Analysis (RCA); Unit Availability and Reliability (EAF/EFOR)

Abstract

Background: Power plant overhaul projects play a critical role in maintaining project performance targets (quality, cost, and schedule) and operational reliability indicators, including efficiency, Equivalent Availability Factor (EAF), and Equivalent Forced Outage Rate (EFOR). However, many overhaul projects still experience difficulties in achieving planned targets due to ineffective project management practices.
Objective: This study aims to identify the dominant causal factors contributing to the failure of overhaul performance targets and develop managerial improvement strategies.
Methods: A mixed-method approach was applied through a questionnaire survey involving 100 respondents (50 owners and 50 contractors), Relative Importance Index (RII) analysis for factor prioritization, tree diagram-based Root Cause Analysis (RCA), comparative analysis of actual project performance data, and Focus Group Discussion (FGD) validation.
Results: The *Serious Inspection (SI)* overhaul project of *Steam Power Plant Unit 3 at PT XYZ* failed to achieve five of six established performance indicators. The findings revealed that performance failures were caused by systemic interactions among planning, inventory management, resource management, and team execution management. Planning and inventory management were identified as the most dominant factors, resulting in schedule delays, cost overruns, incomplete work before unit return-to-service, and suboptimal operational performance, reflected by an EAF of 88.5% and EFOR of 11.5%.
Conclusion: This study recommends risk-based integrated planning, criticality-based inventory optimization, competency improvement, and stronger team coordination to enhance the effectiveness and reliability of future power plant overhaul projects.

To cite this article: Amdriadi, R. S., & Silvianita. (2026). *Performance Evaluation of the Overhaul Serious Inspection (SE) Project Outcomes for Steam Power Plant Unit 3 at PT XYZ Using a Mixed Methods Approach Based on RII, RCA, & Comparative Analysis. INKUBIS: Jurnal Ekonomi dan Bisnis, 8*(2), 1756-1770. https://doi.org/10.59261/inkubis.v8i2.357

INTRODUCTION

The increasing demand for electrical energy in various countries has encouraged power generation companies to ensure the reliability and continuity of power generation unit operations in a sustainable manner (Liu et al., 2023; Strielkowski et al., 2021). In the global context, power plants are not only required to produce energy efficiently but also to maintain a high level of availability and reliability to meet the needs of society and industry (Abdelkader et al., 2024; Gidiagba et al., 2023). One of the primary strategies used to maintain plant performance is the implementation of periodic overhaul projects. An overhaul project is a comprehensive maintenance activity aimed at restoring equipment conditions to a state close to their original performance levels, enabling them to operate optimally again. Nevertheless, various studies indicate that achieving successful overhaul projects remains a significant challenge across multiple industries.

Nazarychev et al. (2025) Approximately 70% of equipment failures in the power generation and industrial maintenance sectors are associated with inaccurate maintenance practices, while the Institute (2021) emphasizes that project success is strongly influenced by an organization's ability to effectively manage the entire project life cycle. This condition demonstrates that evaluating the performance outcomes of overhaul projects is a globally relevant issue, particularly in the power generation industry, which has a high level of operational complexity.

The failure to achieve optimal overhaul project performance is generally influenced by various interconnected factors. The literature indicates that planning factors are among the primary determinants of project success because they are associated with defining the work scope, allocating resources, estimating costs, and controlling project risks (Herath & Chong, 2021). In addition, ineffective inventory management can lead to delays in material procurement, inconsistencies in component specifications, and disruptions in the work execution process (Jusoh & Kasim, 2017).

Another influencing factor is resource management, which includes workforce competency, equipment availability, and sufficient organizational support throughout the overhaul implementation process (Parsa & Torfi, 2017). Furthermore, suboptimal team execution management may create various obstacles, including weak coordination, reduced work quality, and an increased risk of technical errors during the overhaul process. Therefore, the success of an overhaul project is not determined by a single factor but by the interaction among various managerial aspects that influence one another.

These factors ultimately have a direct impact on the achievement of project performance indicators. Deficiencies in planning may result in cost overruns, schedule delays, and inconsistencies between the planned work scope and actual field conditions. Meanwhile, inventory-related problems can hinder the availability of critical materials required during the overhaul process, thereby increasing the risk of rework and plant downtime. Limited resources and inadequate workforce competency may also reduce work quality and increase the likelihood of equipment failures following the completion of the overhaul. Broader impacts can be observed through decreased power plant availability, reflected in the Equivalent Availability Factor (EAF), increased Equivalent Forced Outage Rate (EFOR), and reduced overall operational efficiency of the plant (Devi & Putu, 2020). If these conditions are not properly managed, they will not only affect company performance but may also disrupt the reliability of electricity supply to the community.

Within the power generation industry, the performance outcomes of overhaul projects represent important indicators for assessing the success of power plant maintenance activities (Oprea et al., 2019). Rahadi et al. (2021) explained that the success of an overhaul project should not only be measured based on quality, cost, and time, as represented by the traditional project management iron triangle, but should also consider efficiency, availability, and reliability aspects of the unit after the overhaul. Quality reflects the degree to which the completed work complies with established technical specifications.

Cost represents the project's ability to achieve the predetermined budget target. Time indicates the accuracy of project completion according to the planned schedule. Efficiency relates to the unit's capability to generate electrical energy optimally with minimal resource consumption. Meanwhile, availability (EAF) and reliability (EFOR) are key indicators demonstrating the ability of a power generation unit to continuously supply electricity after the completion of the overhaul. Therefore, evaluating these six indicators is essential to ensure that the objectives of the overhaul project are fully achieved.

This research introduces a novelty that distinguishes it from previous studies. Most previous research has focused only on identifying project success factors, improving plant performance, or applying specific approaches in overhaul management without comprehensively examining the root causes behind the failure to achieve optimal overhaul performance outcomes (Devi & Putu, 2020).

This study integrates a mixed-methods approach combining the Relative Importance Index (RII), Root Cause Analysis (RCA), and Comparative Analysis to identify the dominant factors contributing to unsuccessful overhaul outcomes based on both respondent perceptions and actual project data. Furthermore, this study does not merely evaluate general project management aspects but also connects the evaluation results with operational performance indicators of the power plant, including EAF and EFOR. The integration of perception analysis, root cause analysis, and actual quantitative project data represents a scientific contribution that has rarely been explored in power plant overhaul research in Indonesia.

The integration of these three methods provides analytical advantages compared with single-method approaches: RII quantifies the relative importance of causal factors based on the perceptions of 100 respondents, RCA systematically identifies underlying failure mechanisms, and Comparative Analysis validates perception-based findings against objective project data, including actual costs, schedules, EAF, and EFOR values. No previous study on Indonesian power plant overhaul projects has simultaneously applied these three analytical approaches, making this methodological integration the primary scientific contribution of this research. Table 1 below presents a comparative synthesis of previous studies.

Table 1

Synthesis of Previous Research: Similarities, Differences, and Limitations

No	Author(s) & Year	Similarities with This Study	Differences	Limitation Addressed by This Study
1	(Rahadi et al., 2021)	Evaluates overhaul project performance in power generation	Uses Theory of Constraints; no RII or RCA applied	Does not trace root causes; limited to quality/cost/time indicators
2	(Parsa & Torfi, 2017)	Identifies success factors of power plant overhaul using perception data	Uses ANP and DEMATEL; no Comparative Analysis with actual data	Does not link factors to EAF/EFOR operational indicators
3	(Zahedi et al., 2021)	Investigates material management impact on power project performance	Single-factor framing; no RCA or ranking	No perception-based quantitative cross-validation
4	(Devi & Putu, 2020)	Evaluates overhaul improvement using actual plant performance data	Uses Lean Thinking/LCA; no respondent perception analysis	No causal factor ranking; limited to process level
5	(Ferguson, 2017)	Links overhaul effectiveness to EAF and reliability outcomes	Focuses on South African plants; no RII or RCA applied	No perception-based factor ranking
6	(Firdausy, 2023)	Uses RII+RCA; validates via FGD; evaluates project performance	Applied to EPC projects, not power plant overhaul specifically	Does not evaluate EAF/EFOR post-project operational indicators
7	This Study (2025)	Integrates RII + RCA + Comparative Analysis; evaluates all 6 indicators incl. EAF & EFOR; FGD validation with SMEs	Novel three-method integration applied to SE-type overhaul in Indonesia	Single object; future research: multi-unit comparison

Source: Synthesized by authors from literature review

The urgency of this research is further emphasized by the Serious Inspection (SE) project of Steam Power Plant Unit 3 at PT XYZ, which is scheduled to be carried out in 2025 and has shown several non-achievement performance indicators from previous overhaul results. Despite daily monitoring, coordination between the owner and contractors, and routine evaluations throughout project implementation, several issues were still identified after the unit resumed operation. This condition indicates that the existing control mechanisms have not been fully effective in eliminating the factors causing the failure to achieve the targeted overhaul performance. Considering that PLTU Unit 3 has a capacity of 200 MW and plays a critical role in the Java–Bali electricity system, failure to meet overhaul performance targets may affect power supply reliability and the company's operational efficiency. Therefore, research is required to comprehensively identify the root causes of performance deficiencies, providing a basis for more effective managerial decision-making in future overhaul activities.

Historical data indicate that performance shortfalls in Serious Inspection (SE)-type overhauls are not isolated occurrences. Across multiple steam power plant units within the Java–Bali system, the average Equivalent Availability Factor (EAF) values from 2022 to 2024 ranged from 82% to 88%, remaining below the industry benchmark of >90% for base-load power plants. Similarly, Equivalent Forced Outage Rate (EFOR) values exceeding 10% have been recorded in several SE-type overhaul cycles, indicating a systemic challenge rather than an isolated issue in overhaul project management (Sheikhalishahi et al., 2017).

Based on these problems, this study aims to analyze the achievement level of performance indicators resulting from the Serious Inspection (SE) overhaul project of Steam Power Plant Unit 3 at PT XYZ, including quality, cost, schedule, efficiency, availability, and unit reliability aspects. In addition, this study aims to identify the dominant factors contributing to the failure to achieve overhaul performance targets based on planning, inventory management, overhaul resource management, and team execution management aspects. Furthermore, this study seeks to develop recommendations for effective managerial strategies to improve the success of future overhaul projects through a systematic and data-driven evaluation approach.

The results of this study are expected to provide both theoretical and practical contributions. Theoretically, this study may enrich the literature on power plant overhaul project management, particularly regarding project performance evaluation using a Mixed Methods approach incorporating Relative Importance Index (RII), Root Cause Analysis (RCA), and Comparative Analysis. Practically, this research is expected to serve as a reference for power generation companies in improving the effectiveness of planning, inventory management, resource management, and overhaul team implementation. Furthermore, the proposed recommendations can be utilized as lessons learned to minimize project failure risks, enhance power plant availability and reliability, and support the establishment of a more effective, efficient, and sustainable overhaul management system in the future.

METHOD

This study employed a mixed-methods approach designed to provide a comprehensive understanding of the factors causing the non-achievement of overhaul project performance targets in power generation units. This approach was selected because the problems investigated were not only related to quantitative data in the form of project performance achievements but also involved the perceptions, experiences, and assessments of project personnel who were directly involved in the overhaul process. Through the integration of multiple data sources, this study aimed to produce a comprehensive understanding of the relationships among causal factors, impacts, and alternative solutions that could be applied to improve the success of future overhaul projects.

This study was designed as an evaluative study focusing on identifying the primary causes of the non-achievement of performance indicators in overhaul project outcomes. The research strategy was not only directed toward identifying existing conditions but also toward exploring the relationships among factors influencing the quality, cost, schedule, efficiency, availability, and reliability of the power plant unit after the overhaul was completed. Therefore, the results of this study were expected to generate applicable recommendations that could be used as organizational learning materials for subsequent overhaul activities (Institute, 2021).

The research was conducted on the Overhaul Serious Inspection (SE) project of Steam Power Plant Unit 3 at PT XYZ. The research location was selected based on the phenomenon of several unachieved performance indicators following the overhaul project, which required an in-depth evaluation to identify the dominant factors contributing to these outcomes. PLTU Unit 3 is one of the strategic power generation units with a capacity of 200 MW that plays an important role in maintaining the reliability of the Java–Bali electricity system. Therefore, the success of overhaul activities was considered a critical aspect in ensuring the continuity and reliability of electrical energy supply.

The research activities were conducted following the completion of the Serious Inspection

(SE) overhaul, which was carried out from July 28 to September 10, 2025. Data collection and processing were performed during the post-overhaul period, when actual performance data from the generating unit were available and could be used as the basis for evaluation. The selection of this research period enabled the researchers to obtain a comprehensive overview of the overhaul implementation process and its impact on unit performance after the unit returned to operation.

This research focused on evaluating the performance of overhaul project outcomes through six main indicators: quality, cost, time, efficiency, unit availability, and power plant reliability. These six indicators were selected because they represent the primary parameters used to measure the success of overhaul projects in the power generation industry. In addition to evaluating the achievement level of each indicator, this study also examined the factors contributing to the failure to achieve the targeted performance outcomes (Rahadi et al., 2021).

The aspects examined in this study included project planning, inventory management, overhaul resource management, and team execution management. These four aspects were selected based on previous literature indicating that the success of an overhaul project is strongly influenced by an organization's ability to plan activities, manage materials and spare parts, provide adequate resources, and ensure effective coordination during project execution (Jusoh & Kasim, 2017). By examining these four aspects simultaneously, this study was expected to identify the causal relationships affecting overhaul performance outcomes in greater depth.

The research population consisted of all personnel directly involved in the Serious Inspection (SE) overhaul project of Steam Power Plant Unit 3 at PT XYZ. The population included personnel from both the owner and contractor organizations who were involved in the planning, implementation, supervision, and evaluation stages of the project. The involvement of respondents from various organizational groups was necessary to obtain diverse perspectives regarding the factors influencing the success and failure of overhaul projects (Lemon & Hayes, 2020).

The research sample consisted of 100 respondents, comprising 50 respondents from the owner's organization and 50 respondents from the contractor's organization. The respondents were selected based on their level of involvement in the overhaul project implementation to ensure that the information obtained came from individuals with sufficient knowledge of actual field conditions. The respondents represented various professional levels, including managers, engineers, supervisors, technicians, and project staff. This diversity enabled the study to obtain more objective and representative information regarding the overall project conditions.

This research utilized primary instruments in the form of questionnaires, group discussion guidelines, and project-related documents associated with overhaul implementation. The questionnaire was used to collect respondents' perceptions regarding factors influencing project performance outcomes. The instrument was developed based on a literature review and input from Subject Matter Experts (SMEs) with experience in managing power plant overhaul projects (Parsa & Torfi, 2017).

In addition to respondent perception data, this study utilized secondary data obtained from the company. The data included the Work Breakdown Structure (WBS), Cost Breakdown Structure (CBS), project S-curve, actual cost data, implementation schedule data, unit efficiency data, as well as post-overhaul plant availability and reliability indicators. The utilization of multiple data sources was conducted to strengthen the depth of analysis and ensure that the research findings were not dependent on a single source of information (Cerezo-Narváez et al., 2020).

Data collection was conducted through several complementary stages. The first stage involved distributing questionnaires to respondents involved in the overhaul project. This stage aimed to obtain information regarding respondents' perceptions of various factors potentially contributing to the non-achievement of project performance targets. Subsequently, project documents were collected to obtain actual performance data that could be used as a basis for evaluation and comparison with respondents' perceptions.

The next stage involved conducting group discussions with management representatives and Subject Matter Experts who possessed extensive knowledge of the overhaul process. This activity aimed to enrich the information obtained, clarify research findings, and gather input regarding alternative improvement strategies applicable to future overhaul activities. This approach enabled the evaluation process to be conducted more comprehensively by incorporating the perspectives of practitioners and decision-makers directly involved in the project (Lemon & Hayes, 2020).

To ensure the credibility of the research findings, a validation process was conducted through source triangulation and method triangulation. Data obtained from respondents were compared with actual project data to identify the consistency between perceptions and actual field conditions. Furthermore, the analytical results were reviewed with Subject Matter Experts who had experience in overhaul project management to ensure that the interpretations generated were aligned with the operational conditions of the power plant (Lemon & Hayes, 2020).

This validation process was essential because the research aimed to produce recommendations applicable to real-world conditions within the power generation industry. By integrating multiple data sources and perspectives, this study was expected to generate findings that were objective, reliable, and relevant to organizational needs.

RESULTS AND DISCUSSION

Results

Research Study Profile

This research was conducted on the Overhaul Serious Inspection (SE) project of Steam Power Plant Unit 3 at PT XYZ, which has an installed capacity of 200 MW. Overhaul activities are periodic maintenance programs designed to restore the condition of power generation equipment to ensure optimal operation after reaching a specified operating interval. A Serious Inspection (SE) overhaul represents the most extensive type of overhaul compared with Simple Inspection (SI) and Medium Inspection (ME) because it involves comprehensive inspections, replacement of critical components, repair activities, testing, and verification of post-overhaul unit performance.

This overhaul project is scheduled to be conducted over 45 days, from July 28 to September 10, 2025. The scope of work encompasses various engineering disciplines, including boiler systems, turbines, generators, balance of plant (balance of plant / BOP) systems, electrical systems, instrumentation and control systems, and other supporting activities. The complexity of the project means that the success of the overhaul is highly dependent on effective planning, material availability, resource preparedness, and the quality of coordination among all involved parties (Kerzner, 2021).

This study involved 100 respondents, comprising 50 respondents from the owner’s side and 50 respondents from the contractor’s side. The respondents represented various organizational levels and positions with direct involvement in the planning, execution, supervision, and evaluation processes of the overhaul project. The participation of both groups aimed to obtain a more objective representation of the factors influencing the performance outcomes of the overhaul project.

Overview of Research Variables

This study evaluates six main performance indicators of overhaul project outcomes, consisting of quality, cost, schedule, efficiency, unit availability (Equivalent Availability Factor / EAF), and unit reliability (Equivalent Forced Outage Rate / EFOR). These six indicators were selected because they represent key measures of overhaul project success commonly applied in the power generation industry (Rahadi et al., 2021).

In addition to assessing performance achievement and project outcomes, this study examines four groups of factors suspected to contribute to unsuccessful project performance, namely planning aspects, inventory management, overhaul resource management, and team execution management. These four aspects were developed based on a literature review and validated by Subject Matter Experts (SMEs) from PT XYZ (Parsa & Torfi, 2017).

Table 2

Research Variables

Variable	Indicator
Performance of Overhaul Results	Quality, Cost, Time, Efficiency, EAF, EFOR
Causal Factors	Planning
Causal Factors	Inventory Management
Causal Factors	Resource Management

Causal Factors	Team Execution Management

Source: Processed from Chapter 2 and Chapter 3 of the research.

Characteristics of Research Data

The research data consisted of both qualitative and quantitative data. Qualitative data were obtained through the distribution of questionnaires to respondents, including the owner and contractors. Quantitative data were obtained from the company's actual documents, which included the Work Breakdown Structure (WBS), Cost Breakdown Structure (CBS), project S-curve, project cost realization, unit efficiency data, plant availability data, and post-overhaul unit reliability data (Institute, 2021).

The use of these two types of data enabled the research to obtain a more comprehensive understanding of the factors contributing to the non-achievement of project performance targets. Respondents' perception data were used to identify dominant factors based on field experience, while actual project data were used to verify and strengthen the findings obtained from the survey results (Lemon & Hayes, 2020).

Table 3

Summary of Research Data

Data Type	Source
Owner Questionnaire	50 respondents
Contractor Questionnaire	50 respondents
Data WBS	Project documents
Data CBS	Project documents
S-Curve Data	Project documents
Data EAF & EFOR	Unit operational data
Actual Cost Data	Company data

Performance Achievement Rate of Overhaul Results

The results show that only one performance indicator has been optimally achieved, while the other five indicators have not met the targets established by the company. These findings indicate that the overhaul project has encountered various obstacles that have affected the achievement of the overall project objectives.

Based on the actual project data and respondents' evaluations, the relative quality indicators of the work were achieved because most of the overhaul activities met the established inspection and testing standards. However, several rework activities still indicated inconsistencies during the implementation stage. This condition suggests that the quality of the work results was not entirely consistent throughout the overall scope of work (Parsa & Torfi, 2017).

Regarding cost performance, the study found an increase in material costs due to additional work requirements and changes in the scope of work during the overhaul implementation. This condition affected the increase in actual cost realization compared with the previously established budget plan (Kerzner, 2021).

For the time performance indicator, the project experienced delays in completion due to additional work, material delivery delays, and various technical obstacles encountered during the implementation process. These delays resulted in several work items remaining incomplete when the unit resumed operation (Gray & Larson, 2011).

Meanwhile, the unit availability indicator showed an Equivalent Availability Factor (EAF) value of 88.5%, while the reliability indicator showed an Equivalent Forced Outage Rate (EFOR) value of 11.5%. These results indicate that the post-overhaul unit performance remained below the company's expected targets. These findings demonstrate that the overhaul project had not fully restored the unit condition to its optimal performance level (Devi & Putu, 2020).

Table 4

Summary of Performance Achievements of Overhaul Results

Indicator	Results
Quality	Partially achieved

Cost	Not reached
Time	Not reached
Efficiency	Reached
EAF	88,5% (Not reached)
EFOR	11,5% (Not reached)

Source: Actual data of overhaul projects.

Dominant Factors Causing Performance Failure

The identification results show that the failure to achieve overhaul performance targets is not caused by a single factor but rather by the interaction of multiple factors that influence one another. Based on the survey results and project data evaluation, the planning and inventory management aspects are identified as the most dominant factors compared with other aspects.

Table 5

Relative Importance Index (RII) Analysis – Ranked Causal Factors

No	Causal Factor / Indicator	Aspect	RII Score	Rank
1	**EOH/operating hours exceed the plan**	**Planning**	**0,868**	**1**
2	**Urgent procurement due to emergent work**	**Inventory Mgmt**	**0,868**	**2**
3	**Overlapping overhaul schedules**	**Planning**	**0,852**	**3**
4	**Incomplete overhaul scope**	**Planning**	**0,840**	**4**
5	**Inaccurate material/spare-part planning**	**Inventory Mgmt**	**0,808**	**5**
6	Ineffective working-time utilization	Resource Mgmt	0,796	6
7	Inaccurate cost estimates for emergent work	Planning	0,792	7
8	Insufficient overhaul personnel	Resource Mgmt	0,792	8
9	Scope changes during overhaul execution	Planning	0,784	9
10	Long procurement lead times	Inventory Mgmt	0,784	10
11	Uneven workload distribution	Resource Mgmt	0,784	11
12	Inadequate personnel requirement analysis	Resource Mgmt	0,776	12
13	Delayed material/service delivery	Inventory Mgmt	0,772	13
14	Non-conforming materials/services	Inventory Mgmt	0,772	14
15	Rework due to poor contractor/third-party work quality	Team Execution	0,772	15
16	Tool failures during overhaul	Resource Mgmt	0,768	16
17	Insufficient CBS detail	Planning	0,756	17
18	Incomplete execution of standard overhaul scope	Team Execution	0,744	18
19	Ineffective critical-material safety stock	Inventory Mgmt	0,744	19
20	Underutilization of direct procurement	Inventory Mgmt	0,744	20
21	Material specifications not aligned with OEM standards	Planning	0,732	21
22	Non-compliance with emergent-work procurement schedules	Inventory Mgmt	0,724	22
23	Outdated standard overhaul scope	Planning	0,716	23

Note: RII = Σ(w×n)/(W×N); W=5, N=100. RII > 0.80 = highly dominant. Bold rows = top-5 ranked factors

In the planning aspect, several problems were identified, including inaccurate identification of the work scope, changes in work requirements during the overhaul process, and suboptimal project risk estimation. These conditions resulted in additional work that affected the project implementation cost and duration.

In the inventory aspect, delays in material procurement, limitations in the availability of critical spare parts, and incompatibility between material specifications and actual field requirements were identified. These findings indicate that the inventory management system has a significant influence on the smooth implementation of the overhaul project (Jusoh & Kasim, 2017).

Resource management was also identified as a contributing factor to the failure to achieve performance targets. Limited availability of competent personnel, uneven workload distribution, and constraints related to specific equipment resulted in suboptimal work productivity.

Furthermore, project team implementation management revealed issues related to coordination, communication, and work supervision, which contributed to the occurrence of rework and delays in work completion.

Comparative findings of actual project data

The analysis of actual project data demonstrated a correlation between respondents' perceptions and the conditions observed in the field. Various additional tasks that emerged during the overhaul implementation were proven to increase project costs and extend the work duration. In addition, several activities required rework due to discrepancies identified during inspection after the unit was returned to operation.

Project data also indicated that several activities were still dependent on the availability of spare parts after the unit resumed operation. This condition reinforces the finding that inventory management is one of the most dominant factors affecting the success of overhaul projects. Delays in material availability not only affect the project schedule but also influence the quality and operational availability of the units after the overhaul process.

Table 6

Root Cause Analysis (RCA) – Tree Diagram: Non-Achievement of SE Overhaul Performance at PLTU Unit 3

Performance Problem (Effect)	Intermediate Cause	Root Cause (RCA Finding)
Cost Overrun	Additional scope work; material price escalation	Pre-overhaul scope identification inadequate; cost contingency planning absent
Schedule Delay	Critical spare parts unavailable; additional unplanned work	Criticality-based procurement not practiced; material lead-time not managed
EAF = 88.5% (below ≥90% target)	Unit returned to service with pending work	Resource shortage and weak team coordination prevented full completion before return
EFOR = 11.5% (above ≤5% target)	Post-overhaul forced outages from unresolved defects	Inspection findings not fully addressed; quality control gates insufficiently enforced
Quality – partially achieved	Rework found after unit return to operation	Supervision and inter-team coordination gaps during execution

Source: Developed by authors based on RCA findings (root cause tree diagram structure)

From an operational perspective, the EAF value, which remains at 88.5%, and the EFOR value of 11.5% indicate that the unit has not yet achieved the expected level of availability and reliability. These findings indicate that the success of an overhaul project should be evaluated not only based on work completion but also on the unit's performance after returning to operation.

Discussion

Evaluation of the Performance Achievement Level of Overhaul Project Results

The results of the study show that the Overhaul Serious Inspection (SE) project of Steam Power Plant Unit 3 at PT XYZ has not achieved most of the performance indicators established by the company. Of the six indicators evaluated, only several quality indicators demonstrated relatively on-target achievement, while the cost, schedule, efficiency, unit availability (Equivalent Availability Factor [EAF]), and unit reliability (Equivalent Forced Outage Rate [EFOR]) indicators still showed suboptimal results. These findings indicate that the success of an overhaul project cannot be assessed solely based on the completion of physical work but must also be evaluated based on the project's ability to restore unit performance in accordance with operational targets after the unit returns to service (Rahadi et al., 2021).

From the perspective of modern project management, project success no longer refers only to the concept of the iron triangle, which consists of quality, cost, and time, but must also consider operational sustainability, asset efficiency, and the long-term benefits generated by the project. Therefore, the non-achievement of EAF and EFOR indicators signals that there is still a gap between overhaul execution and the primary objective of maintenance, namely improving the availability and reliability of power generation units.

Successful overhaul activities should result in increased availability and reliability of power plants. When these two indicators have not been optimally achieved, it can be concluded that fundamental factors remain inadequately managed throughout the overhaul process.

The Influence of Planning on the Non-Achievement of Performance from Overhaul Results

The results of the study indicate that the planning aspect is the most dominant factor influencing the failure to achieve the expected overhaul performance results. These findings address the main research urgency, namely why projects that have been prepared and controlled through various monitoring mechanisms still produce achievements below the expected targets. Planning is the initial stage that determines the quality of implementation throughout all project phases, including work scope identification, resource estimation, material requirements planning, and project risk control.

Planning emerges as the most dominant factor because it is chronologically the first project phase; therefore, errors or omissions at this stage can cascade into subsequent stages. Incomplete scope identification inevitably results in additional work, leading to schedule overruns and cost increases. Inventory shortages, resource limitations, and coordination failures are largely downstream consequences of inadequate initial planning. Conversely, inventory management, which ranked as the second most influential factor, is also partly determined by planning quality, particularly in terms of material take-off accuracy and procurement lead-time analysis. Resource and team execution factors ranked lower because their impacts, although significant, can still be partially mitigated through corrective actions during implementation. However, planning deficiencies cannot be fully rectified retrospectively without substantial cost and schedule consequences.

In the Steam Power Plant Unit 3 overhaul project, additional work scopes, changes in work requirements, and several field findings were identified that had not been anticipated during the planning stage. This condition indicates that the planning process was not yet fully capable of representing the actual condition of the equipment requiring overhaul. Consequently, as the project progressed, various additional tasks emerged, affecting schedule adjustments, increasing material requirements, and escalating project costs.

These findings indicate that assumption-based planning is one of the main causes of project delays. In this study, a similar pattern was identified, where inadequate planning created uncertainties that ultimately affected overall project performance indicators. This demonstrates that planning quality has a direct relationship with the success of overhaul projects.

If the company implements risk-based planning, potential additional work can be identified at an early stage. This approach can reduce project uncertainty, improve schedule accuracy, and strengthen cost control effectiveness. Thus, more comprehensive planning not only enhances project success but also improves unit availability after the completion of the overhaul process.

The Effect of Inventory Management on Overhaul Performance

The findings of this study indicate that inventory management is the second most dominant factor affecting the failure to achieve overhaul performance targets. In the power generation industry, the success of maintenance activities is highly dependent on the availability of materials, critical spare parts, measuring instruments, and other supporting components. When required materials are unavailable at the scheduled time, maintenance activities may experience delays and potentially create a cascading effect on other work packages.

In the PLTU Unit 3 overhaul project, it was found that several work activities were still awaiting spare parts even after the unit had returned to operation. This condition demonstrates a gap between actual material requirements and the inventory planning system applied during the project. These discrepancies contributed to delays in work completion and potentially affected the overall quality of the overhaul outcomes.

This finding indicates that material availability is one of the most critical factors determining the success of power plant maintenance projects. Fatuma further explained that material delays can increase downtime, reduce workforce productivity, and escalate project costs. The findings of this study confirm that similar conditions occurred in the Steam Power Plant Unit 3 overhaul project.

A potential solution is the development of an inventory strategy based on criticality ranking, in which spare parts are categorized according to their level of importance and impact on plant operations. Through this approach, materials with high operational significance can be prioritized for procurement well before project execution begins. The expected outcomes include smoother work implementation, reduced risk of delays, and improved post-overhaul unit availability.

The Influence of Resource Management on the Performance of Overhaul Results

The aspect of resource management has also been proven to contribute to the inability to achieve the expected performance of overhaul results. Overhaul projects are activities that depend heavily on workforce competence, adequate personnel availability, the availability of work equipment, and effective coordination among organizational functions. When one of these elements is not optimally fulfilled, work productivity will decrease and potentially lead to technical errors during project implementation.

The study found that several jobs experienced obstacles due to limitations in certain resources, both in terms of personnel and supporting equipment. This condition caused some activities to not be completed within the established time targets. In addition, limited competence in certain tasks also has the potential to increase the likelihood of rework.

This result indicates that organizational success is greatly influenced by the competence of the individuals involved. In the context of overhaul projects, technical and managerial competencies are the primary foundations for ensuring that all work is carried out according to established quality standards.

If the company can improve resource quality through training, technical certification, and competency development based on project requirements, work productivity will increase. Other impacts include reduced risks of technical errors, improved work quality, and increased reliability of the generating unit after the overhaul.

The Influence of Team Execution Management on Overhaul Performance

In addition to planning, inventory, and resources, the study also shows that team execution management significantly influences the success of overhaul projects. Overhaul activities involve multiple parties, including owners, contractors, subcontractors, and various supporting functions. Therefore, coordination and communication are critical factors that determine the smooth execution of work.

The results of the study showed that several activities experienced delays and rework due to suboptimal coordination among implementation teams. This condition indicates that project success depends not only on individual capabilities but also on the effectiveness of collaboration established throughout the project.

Team competence and quality are among the main factors affecting project success. Research by Parsa & Torfi (2017) even identifies project team quality as the factor with the greatest influence on the success of power plant overhaul projects.

Improving communication quality, strengthening field leadership, and implementing digital-based coordination systems are several solutions that can be applied to enhance team execution effectiveness. If these solutions are implemented consistently, the company can reduce potential conflicts, accelerate decision-making processes, and improve work completion efficiency.

Analysis of EAF and EFOR Post-Overhaul Unattainability

One of the important findings in this study is the low level of unit availability, represented by the Equivalent Availability Factor (EAF), and the high level of forced disruption, represented by the Equivalent Forced Outage Rate (EFOR), after the completion of the overhaul. The EAF value of 88.5% and the EFOR value of 11.5% indicate that the primary objective of the overhaul, namely improving unit availability and reliability, has not been fully achieved.

In the power generation industry, EAF and EFOR are strategic indicators used to evaluate maintenance performance. A low EAF value indicates that the unit is unable to provide the expected generation capacity, whereas a high EFOR value indicates a higher frequency and/or longer duration of unplanned forced outages, causing the unit to be unavailable for operation without prior notice.

This condition demonstrates that problems occurring during the overhaul project do not end at the implementation stage but continue into the post-overhaul operational phase. In other words, deficiencies in planning quality, inventory management, resource management, and team execution ultimately contribute to a decline in generating unit performance.

Comparison of Research Findings with Novelty of Previous Research

The main novelty of this study lies in the integration of evaluation approaches based on the Relative Importance Index (RII), Root Cause Analysis (RCA), and Comparative Analysis to identify the root causes of the failure to achieve overhaul performance targets. In contrast to the study by Rahadi et al. (2021), which focuses on the application of the Theory of Constraints (TOC), this study specifically evaluates the factors contributing to the non-achievement of overhaul performance indicators.

Compared with the research of Parsa & Torfi (2017), this study not only identifies the success factors of overhaul projects but also investigates the cause-and-effect relationships underlying the failure to achieve performance targets. Meanwhile, project performance is influenced not only by material availability and management support but also by systemic interactions among planning, inventory management, resource allocation, and team execution.

Thus, this study provides a new contribution in the form of a more comprehensive integrated evaluation approach for analyzing the success of power plant overhaul projects. The findings expand the existing literature, which has previously focused more on partial factors influencing project success.

Table 7

Integrated Evaluation Framework: RII + RCA + Comparative Analysis

Stage	Method	Purpose	Output
1.Factor Identification	Questionnaire Survey (n=100)	Collect perception data from owners and contractors on causal factors	Likert-scale rating matrix
2.Factor Prioritization	Relative Importance Index (RII)	Rank causal factors by relative importance score	RII ranking table (Table 5)
3.Causal Tracing	Root Cause Analysis (RCA – Tree Diagram)	Trace dominant factors to fundamental root causes	Root cause tree diagram
4.Cross-Validation	Comparative Analysis (Actual Project Data)	Validate perception findings against actual cost/schedule/EAF/EFOR	Verified factor-impact mapping
5.Strategy Validation	Focus Group Discussion (FGD) with SMEs	Validate findings and develop actionable recommendations	Improvement strategy matrix

Source: Developed by authors

Managerial Implications and Impact of Implementation of Improvements

Based on the overall results of the study, it can be concluded that the future success of the overhaul project requires a more integrated approach. Companies need to strengthen risk-based planning, develop a more proactive inventory management system, improve resource competencies, and enhance coordination in team implementation.

If these recommendations are implemented consistently, the expected impacts include improved project timeliness, reduced unplanned costs, enhanced work quality, increased EAF values, decreased EFOR values, and improved overall power generation unit reliability. In the long term, these improvements will provide strategic benefits in the form of increased operational efficiency, reduced risks of plant disruptions, and enhanced stakeholder confidence in the company's performance. Thus, the urgency of this research is demonstrated by its ability to identify the primary causes underlying the underperformance of overhaul outcomes and provide improvement directions that can be applied to enhance the success of future overhaul projects.

CONCLUSION

This study evaluated the achievement of six performance indicators (quality, cost, time, efficiency, unit availability (EAF), and unit reliability (EFOR)) in the Overhaul Serious Inspection (SE) project at Steam Power Plant Unit 3 at PT XYZ and identified the dominant causal factors contributing to their non-achievement. The results confirmed that five of the six indicators were not achieved: cost realization exceeded the budget due to additional scope work, project completion was delayed, unit efficiency fell below the target, unit availability reached only EAF = 88.5% compared with the >90% industry benchmark, and unit reliability was compromised with EFOR = 11.5%. Only relative quality conformance was partially achieved. The dominant causal factors, ranked based on RII and confirmed through RCA, were: (1) planning, (2) inventory management, (3) resource management, and (4) team execution management. Planning and inventory management were identified as the most influential factors because deficiencies in these areas triggered cascading impacts across other performance indicators.

The scientific contribution of this research lies in the development of an integrated evaluation approach that combines RII, RCA, and comparative analysis, providing a more comprehensive diagnostic framework than single-method evaluation approaches (Figures 1–2). From a practical perspective, the findings provide actionable recommendations, including: (a) risk-based integrated planning supported by pre-outage equipment inspections, (b) criticality-based inventory procurement prioritization, (c) workforce competency development and adequate resource allocation, and (d) digitally assisted coordination to improve team execution. This study has several limitations: it focuses on a single overhaul object (SE-type Steam Power Plant Unit 3) and does not include cross-unit comparisons, which limits direct generalizability to other power plant types or overhaul scopes. Future research is recommended to expand investigations across multiple generating units or companies, develop predictive risk-scoring models, and validate the integrated evaluation approach through longitudinal studies.

ACKNOWLEDGEMENT

The authors would like to express sincere gratitude to the management and technical staff of PT XYZ for their cooperation, data access, and support throughout the research process. Special thanks are extended to all 100 respondent's owners and contractors—who participated in the questionnaire survey and Focus Group Discussion (FGD). The authors also acknowledge the Subject Matter Experts (SMEs) whose technical validation enriched the findings. This research received no specific external funding.

AUTHOR CONTRIBUTION STATEMENT

Author 1: Conceptualization, Methodology, Data Collection, Formal Analysis, Writing – Original Draft. Author 2: Supervision, Validation, Writing – Review & Editing, Project Administration. All authors have read and agreed to the published version of the manuscript.

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