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Analysis of The Implementation of Maintenance Management System in The Use of SAP Plant Maintenance Module at PT Inalum: A Case Study of The Primary Aluminum Industry

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Abstrak

Manajemen pemeliharaan merupakan faktor penentu kinerja industri, khususnya pada sektor padat modal seperti peleburan aluminium. PT Indonesia Asahan Aluminium (INALUM), sebagai satu-satunya produsen aluminium primer di Indonesia, telah mengimplementasikan modul SAP Plant Maintenance (SAP PM) untuk memperkuat Maintenance Management System (MMS) sekaligus mempersiapkan transformasi digital menuju SAP S/4HANA. Penelitian ini bertujuan untuk mengevaluasi pelaksanaan sistem tersebut, memahami persepsi pengguna, serta mengidentifikasi tantangan organisasi dan teknologi yang memengaruhi efektivitasnya. Penelitian menggunakan pendekatan campuran dengan desain studi kasus deskriptif. Data dikumpulkan melalui kuesioner terhadap 95 responden, wawancara semi-terstruktur dengan manajer dan staf, observasi aktivitas pemeliharaan, serta dokumentasi perusahaan. Analisis dilakukan dengan pendekatan tematik, Root Cause Analysis (RCA), serta kerangka Technology–Organization–Environment (TOE). Hasil penelitian menunjukkan adanya kesenjangan antara fungsi ideal SAP PM dan praktik penggunaannya sehari-hari. Permasalahan utama mencakup ketidakseragaman input data, kurangnya pelatihan pengguna, keterbatasan integrasi indikator kinerja, serta lemahnya tindak lanjut manajerial. Studi ini menyimpulkan bahwa peningkatan kompetensi pengguna, dukungan organisasi yang lebih kuat, dan adaptasi teknologi yang tepat merupakan kunci untuk mengoptimalkan manfaat MMS serta memastikan kesiapan perusahaan menghadapi migrasi sistem di masa depan.

Kata Kunci: ERP; SAP PM; manajemen perawatan; PT INALUM; industri aluminium primer

Abstract

Maintenance management has become a decisive factor for industrial performance, particularly in capital-intensive sectors such as aluminum smelting. PT Indonesia Asahan Aluminium (INALUM), the only primary aluminum producer in Indonesia, has implemented the SAP Plant Maintenance (SAP PM) module to strengthen its Maintenance Management System (MMS) and prepare for digital transformation toward SAP S/4HANA. The purpose of this study is to assess how the system is being implemented, to capture users' perceptions, and to identify organizational and technological challenges that affect system effectiveness. This research applied a mixed-method approach with a descriptive case study design. Data were collected through questionnaires involving 95 employees, semi-structured interviews with managers and staff, observation of maintenance activities, and company documentation. The analytical framework combined thematic analysis, Root Cause Analysis (RCA), and the Technology–Organization–Environment (TOE) model. The findings highlight a gap between the intended functions of SAP PM and its actual use in daily practice. Key issues include inconsistent data entry, insufficient user training, limited integration of key performance indicators, and inadequate managerial follow-up. The study concludes that aligning user competence, organizational support, and technological adaptation is essential to maximize MMS benefits and ensure readiness for future system migration.

Keywords: ER; SAP PM; maintenance management; PT INALUM; primary aluminium industry.

1. Introduction

The Industrial Revolution 4.0 has fundamentally changed the way the manufacturing industry manages the reliability of assets and maintenance systems. In capital-intensive sectors, maintenance management systems (MMS) are increasingly seen as a key element to maintain operational continuity, cost efficiency, and occupational safety [1] [2]. PT Indonesia Asahan Aluminium

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(INALUM), the only primary aluminum producer in Indonesia, began integrating the SAP Plant Maintenance (SAP PM) module in 2016 to digitize maintenance activities while preparing for the migration to SAP S/4HANA. This module is designed to standardize the planning, reporting, and measurement of maintenance performance through indicators such as Mean Time to Repair (MTTR) and Mean Time Between Failure (MTBF) [3][4].

However, the results of INALUM's internal audit show that there are unresolved problems. SAP PM is not optimally used for downtime or backlog analysis, integration with limited production systems, and maintenance performance indicators are not always available in full. This condition has an impact on maintenance costs that are 3-5 times higher than industry benchmarks. This situation confirms the need for an evaluation that focuses not only on technical aspects, but also organizational readiness, employee understanding, and implementation compliance with MMS principles [5]

Previous research on ERP adoption has emphasized technology readiness, top management support, and training as important success factors [6][7][8] However, there are still three main research gaps. First, the role of employees' conceptual understanding of MMS on the effectiveness of SAP PM has not been widely studied. Second, most studies tend to use a survey-based quantitative approach, while mixed-methods approaches that are able to explore organizational dynamics in greater depth are still rarely applied. Third, the application of the Technology–Organization–Environment (TOE) framework in SAP PM-based maintenance systems in heavy industries, especially SOEs that have bureaucratic complexity, is still very limited.

This study is here to answer this gap by examining the perception of INALUM employees towards the MMS principle, their experience in using SAP PM, and strategies that can bridge the gap between conceptual understanding and implementation practice. The contribution of this research lies in the application of TOE with a mixed-methods approach to uncover organizational and human resource factors that are often overlooked in technical analysis. The results of the research are expected to enrich the academic literature and provide practical recommendations for INALUM in ensuring migration readiness towards SAP S/4HANA.

2. Literature Review and Hypothesis Development

2.1 Maintenance Management System (MMS) dan CMMS

Maintenance Management System (MMS) is a system designed to plan, control, and optimize maintenance activities with the aim of ensuring the availability and reliability of assets [1] Recent developments show that MMS is increasingly integrated with ERP systems so that it allows real-time monitoring of asset conditions, work backlogs, and spare parts availability ([9][10]. Recent studies emphasize that the effectiveness of MMS is not only determined by technology, but also by organizational culture and user competencies [11].The evolution of MMS gave birth to the Computerized Maintenance Management System (CMMS) which is able to provide data on failure trends, manage inventory, and support predictive analysis [12]. Recent research has even shown that CMMS is starting to adopt Artificial Intelligence (AI) and Business Intelligence to strengthen the monitoring of maintenance performance indicators [13].

2.2 SAP Plant Maintenance (SAP PM)

SAP Plant Maintenance (SAP PM) is an ERP module that functions to digitize the entire maintenance process, from recording breakdowns to planning work [3}. The success of SAP PM implementation does not depend solely on the availability of the system, but also on training, managerial support, and organizational readiness [7][14][15] show that organizational readiness plays a direct role in determining the effectiveness of ERP. However, most of the research focuses more on the technical aspect, while the role of conceptual understanding of MMS principles in maximizing SAP PM is still rarely studied.

2.3 Key Performance Indicators (KPIs) in Maintenance

KPIs such as Mean Time to Repair (MTTR), Mean Time Between Failures (MTBF), and Overall Equipment Effectiveness (OEE) are standard measures in assessing maintenance performance [16]. The accuracy of KPIs is highly dependent on the consistent quality of input data [5]. Recent research emphasizes the need for KPIs that are adaptive and aligned with organizational strategies [11]. [13] added that the integration of Business Intelligence in CMMS allows for more predictive and dynamic KPI measurement. [17] even emphasized the combination of quantitative indicators with qualitative audits for a more holistic evaluation.

2.4 TOE framework (Technology–Organization–Environment)

The TOE Framework describes the adoption of technology based on three dimensions: technology, organization, and environment [18]. A number of studies confirm that TOE is relevant for understanding the adoption of information systems, including ERP [19][20]. In the context of heavy industry and SOEs, TOE is increasingly significant because organizational size factors, regulatory pressures, and vendor support have a major influence on implementation outcomes [21]. However, the application of TOE specifically to SAP PM in the heavy metals industry is still very limited.

2.5 Divergence between Perception and Practice

A number of studies show that there is a gap between theoretical understanding and maintenance practices in the field. Training and documentation often do not lead to consistency of daily practice due to resource constraints or organizational culture [22][23]. [24] emphasizes the importance of triangulating data—surveys, interviews, and observations—to improve the validity of these gap assessments. However, it is still rare for research to use a mixed-methods approach to comprehensively uncover differences in perceptions and practices, especially in the context of SAP PM.

2.6 Risk Management in MMS and ERP Implementation

Risk management is a critical aspect in ensuring the successful implementation of ERP and MMS systems. [25] showed that structured risk governance influences the success of ERP in the public sector, while [26] identified more than 50 ERP risks ranging from user resistance to business strategy mismatches. ISO 31000:2018 also emphasizes that risk management must be integrated into all organizational policies. In heavy industry, risks such as low data quality, lack of interdepartmental integration, and weak oversight can hinder MMS optimization [21].

3. Methods

This study uses a descriptive qualitative approach with a case study design [27]. The case study was selected to gain an in-depth understanding of the implementation of the Maintenance Management System (MMS) and SAP Plant Maintenance (SAP PM) module at PT INALUM, focusing on user perceptions and organizational practices.

3.1 Research Design and Data

The research design integrates several qualitative techniques, namely questionnaires, semi-structured interviews, participatory observations, and document analysis. Primary data is obtained from employees directly involved in maintenance activities, while secondary data comes from company documents such as SOPs, downtime reports, backlogs, and maintenance performance records.

3.2 Population and Sample

The research population is employees of the maintenance department at PT INALUM, especially in the Smelter Plant and Hydropower Operations unit. The sample was selected by purposive sampling technique, which is six key informants consisting of managers, supervisors, and operators. In addition, a total of 95 employees of the maintenance department participated in filling out an open questionnaire.

3.3 Research Instruments

The research instrument is in the form of interview guidelines and questionnaire grids prepared based on the Technology–Organization–Environment (TOE) framework. The variables studied include:

- Technology: ease of use of SAP PM, system integration, data quality.
- Organization: user competence, training, managerial support.
- Environment: regulatory pressure, benchmarking, vendor/partner support.

3.4 Data Analysis Techniques

The data were analyzed by thematic analysis [28] which included transcription, coding, categorization, and theme formation. The themes are then mapped according to the dimensions of the TOE to maintain conceptual consistency. To explore the root of the problem, Root Cause Analysis (RCA) is used which maps the cause-and-effect relationship between factors that affect the implementation of SAP PM.

3.5 Validity and Triangulation

The validity of the data was strengthened through triangulation of sources and methods [24] by comparing the results of questionnaires, interviews, documents, and field observations. The study integrated three data sources—interviews, questionnaires, and organizational documents. Triangulation is applied by comparing response patterns across these sources to ensure consistency. In this study, the differences between qualitative interviews (which highlight training gaps) and questionnaire results (which measure them) as well as document reviews reinforce internal validity. RCA is also used as a triangulate tool to ensure consistent data-driven recommendations from a variety of sources.

3.6 Research Model

The research model combines the dimensions of TOE and RCA to assess the relationship between employees' understanding of

MMS, organizational readiness, and SAP PM usage practices. This model is used to formulate short, medium, and long-term strategies to support migration readiness to SAP S/4HANA.

3. Results and Discussions

This study explores the implementation of SAP PM as a digital maintenance management tool at PT INALUM. Data is collected through surveys, interviews, and document analysis to capture quantitative and qualitative insights. The goal is to evaluate how the Maintenance Management System (MMS) supported by SAP PM is perceived and practiced at different levels of the organization, and to identify gaps between expectations and implementation realities. This section presents the results of data analysis, arranged thematically to answer the research objectives without repeating methodological details.

3.1. Main Descriptive Results

The survey involved 95 respondents from three levels of the organization (operator, supervisor, and managerial), supplemented by six key informant interviews. The descriptive findings highlight the distribution of respondents and the scope of data collection.

Table 1. Level and number of respondents

No	Level	Respondent	Tenure (years)		
			0-10	11-20	>20
1	Managerial	18	1	5	12
2	Supervisor	44	17	23	4
3	Operator	33	12	18	3

3.2. Thematic

The results are organized into four thematic areas based on the TOE framework and qualitative analysis:

3.2.1. Understanding Maintenance Management System (MMS)

Supervisors and managers generally understand the preventive and strategic role of MMS, but operators still interpret it narrowly as corrective maintenance. This vertical divergence creates gaps in consistent execution.

3.2.2. SAP PM Utilization

The implementation of SAP PM has not been optimal, characterized by inconsistent data input, training limitations, and the lack of use of SAP PM as a strategic evaluation tool. Systems function more as a record-keeping tool than a data-driven decision-maker.

3.2.3 Technological, Organizational, and Environmental Constraints (TOE)

Technological barriers include a lack of a user-friendly interface and the absence of real-time reporting. Organizational problems include inadequate training, lack of SOPs, and minimal management incentives. Environmental pressures from regulators and comparisons to world-class standards demand greater integration and efficiency.

3.2.4 Divergence of Perception vs Practice

Technological barriers include a lack of a user-friendly interface and the absence of real-time reporting. Organizational problems include inadequate training, lack of SOPs, and minimal management incentives. Environmental pressures from regulators and comparisons to world-class standards demand greater integration and efficiency.

Table 2. Summary of supervisor and manager interview results

Position	MMS Understanding	Usage of SAP PM	Organizational Support	Performance Maintenance (KPI)
Supervisor 1	Already understand the maintenance plan and procedures, need improved training & review of the new system	SAP is used, but a lot of data is incomplete because coordination and validation are still weak	Have had training, but it has not been sustainable and not all levels are affordable	The data for KPIs is incomplete because many MOs are holes, making it difficult to analyze MTTR/MTBF
Supervisor 2	Understand the concept and implementation of MMS, including control of preventive maintenance procedures	SAP is used, but the data is inconsistent; Reporting is not yet automated and input awareness is still low	There is training but it is uneven; difficulties with data access and no comprehensive evaluative review	There is no comprehensive KPI reporting yet; Awareness about data is not yet uneven
Supervisor 3	Fully understand the role of MMS in preventive maintenance scheduling and evaluation	Used as the basis for equipment evaluation and history; SAP is very helpful	Support is pretty good, including SAP upgrades; But access to data reports is restricted by the authority	SAP is used to measure availability & consumption of spare parts; Effectiveness is monitored but not perfect
Manager 1	It has been integrated in short-long term planning;	SAP is the main source of assessing maintenance	Organizations ready for digitalization, are heading for	SAP is used for MTBF, MTTR, % PM, cost breakdown and strategic

Position	MMS Understanding	Usage of SAP PM	Organizational Support	Performance Maintenance (KPI)
	Implementation reviews are carried out periodically	performance; The data is sometimes inaccurate due to manual input	predictive maintenance with new tools	decision-making basis
Manager 2	It has not been fully understood at all levels, especially the implementers	Not yet used as the main tool because many jobs have not entered SAP	Support is not optimal; no MMS policy review yet	Not being able to rely on SAP data yet; A lot of work is not recorded in the system so it is not measured properly
Manager 3	The understanding of MMS is not even at all levels; managerial skills are quite good, but the implementers still see MMS as an administration, not a work culture	SAP PM is used but data input is often inconsistent; This affects the accuracy of long-term planning	The infrastructure is quite good, but digital literacy of human resources and continuous training is still lacking; Organizational spport is still gradual	KPIs such as availability, MTBF, MTTR, %PM, breakdown cost already exist, but are not consistent due to limited data input; Reports are not yet fully accurate for strategic decision-making

3.3. Discussion and Comparison

Compared to previous research, the case of PT INALUM shows a unique pattern in the dynamics of IT adoption, especially in the context of heavy industrial SOEs. [25] highlights that barriers to adoption are often related to the complexity of interfaces and low system utilization, but INALUM's findings show that this problem is reinforced by bureaucratic structures and work mechanisms that are more hierarchical than the private sector. [22] emphasizes that sporadic training can weaken the internalization process of the system, but in the case of INALUM, the effect is more pronounced due to the high dependence on formal work patterns and the lack of unit autonomy in process improvement. Meanwhile, [8] and [29] affirm the importance of top management support in successful adoption, but INALUM's findings suggest that even with declarative support, SAP PM implementation remains hampered by long approval chains, rigid division of functions, and SOE regulations that limit operational decision-making flexibility. The following table presents a summary of the results of the root cause analysis based on field findings and the TOE Framework:

Table 3 - Root cause analysis based on field findings and TOE framework

Symptoms of Problems	Main Root Causes	TOE Dimension	Problem Categories	Recommendations and Implementation Time
SAP input is inconsistent and incomplete	Lack of technical training and understanding of SOPs for data input	Organizational	HR Competencies	SAP PM retraining for all levels (Short-term)
Tool historical data is undocumented and the backlog is increasing	Absence of dashboard monitoring or periodic evaluation system	Technological	Technological Unpreparedness	SAP PM dashboard development (Medium-Term)
High maintenance cost per ton of product	Job backlogs and reactive jobs are more dominant	Organizational	Process and planning	Implementation of a more disciplined PM plan (Medium Term)
SAP PM is not integrated across departments	SAP systems are not connected to warehouses, planning, operations	Technological	System connectivity	Integration between SAP systems and modules (Long-term)
No SAP PM evaluation and audit forum	There is no periodic evaluation policy of system maintenance	Organizational	System management	Formation of SAP system audit and maintenance team (Medium Term)
Downtime is not recorded accurately	There are no standard forms and effective recording SOPs	Technological	Data standardization	Revision and standardization of form downtime (Short Term)
Operators have difficulty using SAP PM	The user interface is less intuitive, and the training is uneven	Technological + Organizational	HR & Technology Readiness	Improved training & usability testing (Medium Term)

This Root Cause Analysis shows that most of the problems stem from the organization's limitations in supporting the adoption of new systems, as well as technological unpreparedness in terms of integration and reporting. These causes are strengthened by weak cross-functional governance and the absence of a comprehensive evaluation mechanism.

3.4 Synthesis & Strategic Implications

In the perspective of TOE, this indicates that environmental and organizational dimensions not only act as external factors, but interact strongly and mediate technological readiness, especially in bureaucratic ecosystems such as SOEs. Thus, the INALUM case broadens the understanding of the TOE Framework by showing that organizational bureaucracy in state-owned enterprises can be a significant mediating factor, affecting technology readiness, quality of adoption, and speed of internalization of digital maintenance systems.

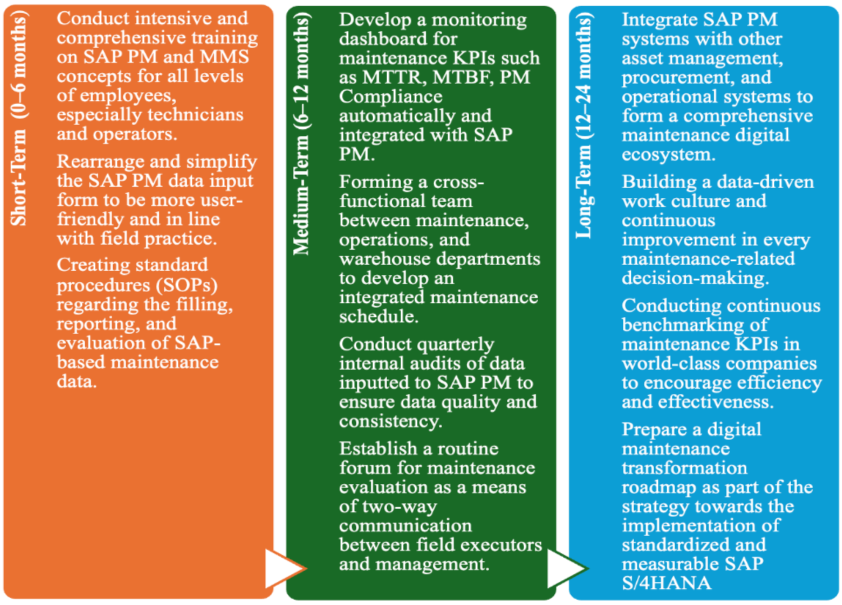

Figure 1. Summary of recommendations for improving the implementation of MMS and SAP PM

4. Conclusion

The findings of the study enrich the understanding of how the TOE framework works in the context of the implementation of the Maintenance Management System and SAP PM in the aluminium smelting industry. This study shows that the MMS literacy gap between employee levels, technological complexity, and low organizational readiness are crucial factors that interact with each other in influencing the effectiveness of the system. This confirms that the success of MMS depends not only on technical features, but also on organizational and environmental factors that determine the adoption rate, data quality, and maturity of the maintenance process.

For PT INALUM, the results of the research lead to three main steps. In the short term, companies need to strengthen training, simplify input formats, and improve data consistency through clearer SOPs. In the medium term, INALUM can build an integrated KPI dashboard, conduct periodic audits, and establish a data management unit to strengthen maintenance analytics. In the long term, the integration of SAP PM with other modules, the preparation of an RCM-based digitization roadmap, and collaboration with external partners will support the shift towards more reliable and data-driven maintenance.

This research has limitations in the narrow scope of work units, so generalizations are still limited. Future research may validate these findings in several heavy industry SOEs to improve generalizations and expand understanding of the dynamics of MMS and ERP implementation.

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