Evaluation of the Implementation System for Maintenance, Repair, and Operations (MRO) Processes and Its Impact on Supply Chain Performance in the Mining Industry

THESIS

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Evaluation of the Implementation System for Maintenance, Repair, and Operations (MRO) Processes and Its Impact on Supply Chain Performance in the Mining Industry

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We hereby declare that this Thesis is from student's own work, has been read and presented to Institut IPMI Board of Examiners, and has been accepted as part of the requirements needed to obtain a Master of Business Administration Degree and has been found to be satisfactory.

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This Thesis is a presentation of our original research work. Wherever contribution of others is involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

Also, this work is being submitted in partial fulfillment of the requirements for the Master of Business Administration degree and has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Abstract

Mining is among the most asset-intensive industries there is, yet the Maintenance, Repair, and Operations (MRO) system that keeps its equipment running is rarely examined. Earlier studies tend to treat maintenance management, spare-part inventory, cost control, and digital integration as separate problems, which leaves a gap in understanding how they jointly shape supply chain performance. This study therefore asks how the MRO system is structured, which KPIs are used to judge it, what barriers hold it back, and how well its information is integrated. The objective is to evaluate MRO implementation and its impact on supply chain performance at a large-scale mine in a remote part of Kalimantan, Indonesia. Five subject-matter experts were purposively selected: a maintenance engineer (12 years' experience), a procurement officer (13), a warehouse controller (15), a supply planner (11), and a reliability engineer (13), aged between 43 and 50. Each owns a different link in the MRO chain, so together they cover the workflow end to end, from failure detection through purchase to issue. Written semi-structured interviews were triangulated with company documents and site observation, then analyzed thematically in NVivo 12 within an interpretivist case study design. The findings show a system that is sound on paper but bypassed under pressure: when equipment stops, people phone the warehouse rather than trust the screen. Beneath almost every symptom sits poor data quality: duplicate material codes, stock mismatches, hurried failure records. The study concludes that data governance, not new technology, is the first fix.

Keywords: *Maintenance, Repair, and Operations (MRO), supply chain performance; mining industry qualitative case study, data quality*

Chapter 1 Introduction

1.1. Background

Few industries tie up as much capital in physical assets as mining does. Extraction, transportation, processing the cycle never really stops, and none of it moves without heavy machinery and critical equipment being ready when needed. Add to that the harsh environments these operations run in, and the high value of the assets involved, and maintenance stops being a back-office concern. It becomes strategic (Rojas, Fernández, & Herrera, 2025).

Sitting at the center of all this is the Maintenance, Repair, and Operations (MRO) system, the set of activities that keeps machinery, equipment, and facilities working. MRO covers how spare parts and consumables are sourced, stored, and used, so that maintenance gets done without unnecessary production stoppages (Mobley, 2011). The stakes are higher in mining than in most sectors. Every idle hour carries a real cost, which means how well a company runs its MRO processes feeds straight into productivity, safety, and the bottom line.

The way MRO is understood has shifted over time. What used to be treated as a support function is now seen as something that actively drives operational performance, with maintenance and inventory management recognized as tightly bound to supply chain outcomes (Manenzhe, Bevis, & Gouws, 2023). Run it well and the benefits compound: inventory stays at sensible levels, lead times shorten, avoidable downtime disappears, and the right materials show up where they are supposed to. Run it poorly and the reverse happens unplanned stoppages, budgets blown, supply lines disrupted. In a competitive sector, that gap matters.

Digital tools have changed the picture considerably. Predictive maintenance models built on the Internet of Things (IoT), machine learning, and artificial intelligence (AI) let companies watch equipment health as happens, anticipate failures, and fine-tune their maintenance schedules (Rojas et al., 2025). Across several industries, this has cut unplanned downtime sharply. But technology only delivers when the foundations are there: clean data, forecasts that hold up, and departments that talk to each other. Those foundations are exactly where many mining companies still struggle (Werbinska-Wojciechowska, Grabowski, & Dziula, 2025).

Inventory management is another piece that makes or breaks MRO. A single mining operation might need tens of thousands of distinct spare parts to keep its fleets, processing plants, and auxiliary systems going. Many of those parts are expensive and slow to arrive, so getting inventory control wrong cuts both ways too little and production halts, too much and capital sits frozen on the shelf. Siyad and Khayal (2025) point to inefficient inventory management as one of the biggest sources of financial loss in maintenance work, driving up carrying costs, inviting obsolescence, and draining liquidity.

To get on top of this, companies have leaned on a range of optimization strategies ABC analysis, criticality-based stocking, vendor-managed inventory (VMI), just-in-time replenishment (Werbinska-Wojciechowska et al., 2025). Each is an attempt to hold the line between keeping costs down and keeping operations reliable. The trouble is that the balance stays hard to strike, even with good software behind it. Mining adds its own complications: equipment fails when you least expect it, production schedules move, and the supply chain itself is fragile long shipping times, remote sites, parts that must travel a long way to arrive (Dayo-Olupona, Adelaja, & Fatogun, 2023).

Technology and process are only half the story, though. People and the way they are organized matter just as much. Inventory policy must line up with what operations need, and that only happens when maintenance, procurement, and warehouse teams communicate well. When they don't, the symptoms are familiar purchase requisitions sit too long, forecasts miss, and easy savings slip away (Manenzhe et al., 2023). Training is part of it too. Staff who haven't been brought up to speed will struggle to use digital systems properly or read maintenance data correctly, and the technology never delivers what it promised.

Then there is the supplier side. Critical spares in mining often come from original equipment manufacturers (OEMs) based overseas, which means long lead times and logistical headaches. Relationships built on trust change that equation suppliers respond faster, deliveries land on time, and arrangements like consignment stock or framework agreements become possible (Siyad & Khayal, 2025). Working this closely with suppliers also sharpens forecasting and makes it easier to react quickly when equipment fails without warning.

Put all this together and one thing becomes clear: MRO is not just a technical system. It is a process that pulls together technology, people, and organizational structure at the same time. Get it right and it lifts the whole supply chain more reliable, more responsive, more cost-efficient. Get it wrong and it does the opposite, turning into a bottleneck that drives up downtime, wastes resources, and chokes the flow of materials across the network.

Mining today operates under two pressures at once: hold costs down, keep standards up. That makes a hard look at MRO effectiveness almost unavoidable, because it is the link between what happens inside the maintenance function and what the supply chain delivers overall. This study works through four of those factors inventory management, cost-reduction strategies, maintenance-supply integration, and supplier collaboration to see how, together, they shape supply chain performance in the mining industry.

The aim runs in two directions at once. On the practical side, the research shows how things like process coordination, collaboration, and organizational learning decide whether an MRO system succeeds. On the theoretical side, it positions MRO where it belongs as the connective tissue between maintenance reliability and a supply chain that performs.

1.2.Problem Statement

Mining companies are caught in a constant balancing act to keep equipment reliable but keep the cost of doing so down. Maintenance, Repair, and Operations (MRO) systems are what hold that effort together, tying maintenance work, spare parts, and procurement into one chain. Yet for all their strategic weight, a great many mining firms still cannot get their MRO systems to properly support supply chain performance (Manenzhe, Bevis, & Gouws, 2023).

The nature of mining itself makes MRO harder to get right. Sites are remote, conditions are punishing, and everything depends on heavy machinery. When a machine fails in that kind of setting, it can take a whole production line down with-it expensive downtime, safety risks, logistics thrown into disarray. The usual defence is to stockpile spare parts so operations never stop. It works, up to a point, but it comes at a price: bloated holding costs and a large slice of working capital locked away in inventory (Werbinska-Wojciechowska, Grabowski, & Dziula, 2025).

Recurring theme in the research is that mining organizations rarely have systems that join maintenance planning to inventory and supply chain management (Rojas, Fernández, & Herrera, 2025). That gap shows up as scattered communication, procurement that lags, and stock that is either duplicated or long past useful. A maintenance team might ask for a component procurement has never heard of, or cannot get hold of quickly, and the equipment sits idle in the meantime. Procurement, for its part, often buys in bulk against forecasts that were never accurate to begin with, and the warehouse is filled with overstock. Taken together, these inefficiencies eat away at both maintenance reliability and supply chain performance (Dayo-Olupona, Adelaja, & Fatogun, 2023).

Digital adoption is another sore point, and an uneven one. Predictive maintenance and real-time monitoring have a proven track record on reliability and cost, yet plenty of mining operations are still running on paper or on ERP modules that don't talk to one another. Information can't move cleanly between departments, and the spare-parts data that proactive decisions depend on stock levels, lead times, consumption rates stay out of view (Rojas et al., 2025). The result is a maintenance function stuck in reactive mode, cleaning up after failures instead of heading them off.

On top of all that sit the human and organizational factors, which complicate matters further. No maintenance framework succeeds on technology and process alone lives or dies on the people running it. In many mining companies, departments operate in silos, collaboration is thin, and training is limited, all of which get in the way of joining maintenance and supply together. Staff push back on new systems when nobody has explained why they matter, and management often fails to put the support or resources behind continuous improvement (Siyad & Khayal, 2025).

Supplier collaboration is yet another weak spot. When critical components come from distant or overseas suppliers, poor coordination translates directly into long lead times and deliveries you cannot count on. Without collaborative arrangements vendor-managed inventory (VMI), consignment agreements, shared forecasting, the supply chain loses responsiveness, and the odds of a stock-out during a critical maintenance job climb (Werbinska-Wojciechowska et al., 2025).

Threaded together, these problems point to one underlying concern: mining organizations have largely failed to find the sweet spot between cost efficiency, operational reliability, and a genuinely integrated supply chain. Inventory inefficiencies that never go away, departments that don't communicate, supplier relationships that stay shallow, maintenance that only reacts each is a symptom of the same thing, an MRO system that has not been implemented well.

Earlier research has certainly tackled maintenance management and inventory optimization but usually one at a time. What is missing is a study that looks at how MRO practices work together to shape supply chain performance, especially in mining, where the operational complexity and environmental constraints are unlike anywhere else (Manenzhe et al., 2023; Siyad & Khayal, 2025). We still know little, in qualitative terms, about the real experiences, obstacles, and good practices that make MRO implementation work across maintenance, supply, and procurement.

This study steps into that gap. It sets out to evaluate how effective MRO implementation is in mining by examining four factors inventory management quality, cost-reduction strategies, maintenance-supply integration, and supplier collaboration and how each feedfeedo supply chain performance. The goal is a deeper, context-specific reading of how MRO can be tuned for greater efficiency, responsiveness, and reliability right across the mining supply chain.

1.3. Research Questions

At the heart of any research project are the key questions that set the stage for discovery and keep the work headed in the right direction. These questions are more than just starting points, they help pinpoint what truly matters, making sure that every part of the study moves closer to solving the problem at hand. For this investigation into MRO systems within the mining sector, the research questions are crafted to dig deep into how well the current setup is performing, the specific obstacles companies are facing, and the potential improvements that could make a real difference.

The central question guiding this study is how well does the current MRO implementation support operational efficiency, reliability, and long-term sustainability in the mining industry?

The answer to this question is several questions that will be used in this research:

1. What is the current structure in MRO system?
2. What are the KPIs measured to assess effectiveness of MRO systems?
3. What are the main challenges or barriers affecting the efficiency of the implementation in MRO system?
4. How well does the MRO system integrated all the information to overall maintenance performance?

These questions are interconnected and combining it together we are aiming to get full complete picture of how MRO does systems perform in mining industry. By addressing these questions, expectation outcome provides more insight and helps mining organizations enhance their operational excellence.

1.4.Research Objectives

Broadly, this study sets out to evaluate how MRO processes are implemented and to work out what that implementation does to supply chain performance in mining. That involves two things at once: judging how well the maintenance work itself is carried out, and tracing how the wider MRO practices inventory management, cost reduction, system integration, supplier collaboration shape supply chain reliability, responsiveness, and cost efficiency.

For achieving this purpose, the study outlines several specific objectives aimed at providing a comprehensive view of how MRO systems function within mining operations:

1. Examine the overall structure and quality of MRO systems in selected mining companies
2. Evaluate the effectiveness of MRO inventory management practices in maintaining optimal spare parts levels, preventing shortages, and supporting operational reliability.
3. Assess the role of MRO inventory holding-cost reduction strategies in enhancing financial and operational efficiency.
4. Analyze the integration of digital tools such as enterprise resource planning (ERP) and computerized maintenance management systems (CMMS) within MRO processes

These objectives are not just about checking whether an MRO system functions. They are meant to feed a culture of continuous improvement and operational excellence. The study deliberately connects what happens on the ground with strategic performance goals, linking maintenance reliability to the broader success of the supply chain. By holding the technical, organizational, and human sides together in one view, it offers a rounded picture of how MRO implementation can be refined for lasting productivity in mining. Ultimately, the findings should give decision-makers the evidence they need to act and to build operational resilience and long-term competitiveness in the process.

1.5.Scope and Limitations of the Study

This study zeroes in one setting: a single mining organization, or a specific operational unit within it, that runs large-scale equipment and handles routine maintenance. Working through a single case lets the research get close to the detail of how MRO activities are structured, how they are carried out, and how people at different levels experience them. The findings belong to that one organization, but they should still offer useful reference points for other mining operations wrestling with the same MRO problems.

Specifically, the study includes the following components:

1. Analysis of existing MRO frameworks and workflows, including system design, process integration, and communication flows among maintenance, procurement, and inventory functions.
2. Evaluation of key performance indicators (KPIs) related to maintenance efficiency, equipment uptime, spare parts management, and cost control.
3. Collection of qualitative insights through interviews, document reviews, and field observations to understand user experiences, challenges, and perceptions of system effectiveness.
4. Development of recommendations and strategies aimed at strengthening MRO implementation and improving its overall contribution to supply chain performance in the mining industry.

Methodologically, the study is qualitative, drawing on thematic analysis to surface the patterns and themes that explain how MRO systems are experienced and understood. A qualitative lens fits here because it reaches past the measurable numbers to the lived experience of the people doing the maintenance and supply chain work the part of the story metrics alone cannot tell (Braun & Clarke, 2006).

Like any research effort, this study faces certain limitations that may affect its breadth and depth. These limitations are recognized upfront to ensure transparency and to clarify the scope of interpretation:

1. Data Availability and Accessibility, study relies on access to internal maintenance records, reports, and personnel insights. Some operational data may be restricted due to confidentiality policies
2. Time Constraints, research is conducted within a defined academic period, which restricts the amount of time available for prolonged observation or longitudinal analysis of system changes over time.
3. Human Factors, qualitative data are collected through interviews and discussions, responses may reflect personal perceptions, biases, or situational experiences. However, these perspectives are valuable for understanding the human context behind MRO implementation.
4. Technological Scope, study does not attempt to evaluate or redesign the company's digital tools, such as Enterprise Resource Planning (ERP) or Computerized Maintenance Management Systems (CMMS). Instead, it examines how these systems are currently utilized and perceived within existing operational structures (Rojas, Fernández, & Herrera, 2025).

Limitations aside, the study aims to give an honest, thoughtful, and even-handed account of how MRO systems work inside a mining operation.

1.6.Significance of the Research

The value of this research works at several levels at once from sharpening day-to-day operations to adding to academic knowledge and to more sustainable ways of running the industry.

1. For the organization and management
2. For the technical and maintenance team
3. For the mining industry as a whole
4. For academic and research purposes
5. For policy and sustainability perspectives

1.7. Thesis Structure

The thesis runs across five chapters, each building on the last so the reader can follow the argument step by step. Here is how they fit together.

Chapter 1 Introduction sets everything up. It lays out the background that explains why the topic is worth studying, states the problem plainly, and names the goals the research is chasing. From there it moves through the research questions, marks out what the study covers and what it leaves aside, acknowledges its limits, and makes the case for why the work matters before closing with a short map of the chapters ahead.

Chapter 2, literature review, digs into what has already been established about MRO systems, maintenance management, and how these processes play out in industrial and mining settings. Working through earlier studies, the major theories, the leading models, and the industry's best practices, it maps what is known and just as importantly where the gaps are. That mapping is what pins down the openings this study addresses and lays the conceptual foundation the rest of the work stands on.

Chapter 3 turns to methodology, setting out how the study was done: the research approach, how data was collected, how Informants were chosen, and the analytical tools used to evaluate the MRO system. The point of the chapter is to keep the research transparent, systematic, and repeatable.

Chapter 4 presents the results. It works through the findings against the research questions and objectives, drawing out the key observations, trends, and patterns, then reads them critically tying them back to existing theory and literature while pulling out what is specific to the mining context.

Chapter 5 closes the loop. It pulls the whole study together around its central findings and conclusions, offers practical recommendations for improving MRO implementation in mining, and points to where future research could deepen how MRO systems are understood and applied across industry.

Chapter 2 Literature Review

2.1. Introduction

For a mining company, running safely, efficiently, and productively is not simply something to aim for over the long run, it is the difference between surviving and not. Day after day, these operations lean on solid Maintenance, Repair, and Operations (MRO) systems to keep equipment in shape and production flow. When the systems hold up, machines and facilities stay reliable, problems get fixed fast, and the whole operation runs with fewer interruptions.

But an MRO system is about far more than just using the latest software or having the right tools on hand. It’s a whole ecosystem built around people, procedures, and technology working together. The real measure of an MRO system’s success isn’t found in data alone and it's about whether everyone involved understands their roles, communicates openly, and feels empowered to act. Gaining a true understanding of how all these pieces fit together means looking closely at day-to-day experiences, attitudes, and interactions, not just tracking numbers.

That is the reason this chapter pauses to take stock of what experts and earlier studies have said about building and sustaining effective MRO systems, the obstacles that keep getting in the way, and the part human factors play in whether things get done. From those lessons, it then builds a conceptual framework: a way of thinking that guides how this study approaches the real-world, qualitative side of MRO implementation in mining.

2.2.The Concept of Maintenance, Repair, and Operations (MRO)

Maintenance, repair, and operations (MRO). Thie concept refer to the process and activity to keep inventory for organization requirement for equipment, facility, and operation for production. MRO encompasses all actions within equipment maintenance, spare parts management, and support all activities that ensure operation reliability (Mobley, 2011). It always plays a big and vital role in managing lifecycle assets, from acquisition to disposal.

MRO system acts as backbone of operational process and describes MRO as the heart of reliability management the reason is to ensure that the right materials and information are available at the right time (Campbell and Reyes Picknell, 2015). A good MRO framework minimizes equipment downtime, optimizes inventory, and improves safety performance.

In the mining industry, MRO is not only focused on technical performance but also on financial stability. When machine broke down, production stopped and led to economic losses. MRO effectiveness influence productivity, cost efficiency, and safety compliance (Tsang, 2002).

Qualitative research highlights MRO success depending on how people understand and deal with it. Misalignment, unclear procedures and lack of information can undermine the most advanced systems. The implementation of MRO system should consider human behavior, organization culture, and leadership goals to achieve goal of success.

2.3. MRO in Mining Industry

The mining industry presents unique operational challenges that make MRO implementation complex. Mines are typically located in remote areas, operate around the clock, and rely on large-scale, heavy-duty machinery. Equipment such as haul trucks, crushers, and conveyors are subject to continuous stress, making maintenance a central operational priority (Santos et al., 2018).

MRO in mining requires collaboration between maintenance, procurement, and inventory management. Mining company struggle with fragmented process and communication barriers (Parida and Kumar, 2006). Maintenance teams may not always have visibility into inventory levels and procurement timeline this issue leading to delay and inefficiencies.

Qualitative standpoint implementation MRO system in mining industry can influence organization culture and human interaction. Employee perceptions and attitudes toward technology, and sense of ownership significantly affect how systems are used in operation. When other systems like ERP, CMMS are releasing success can depend on user acceptance and managerial support (Ceglarek et al, 2015).

Exploring these human and organizational dimensions provides valuable insight into why MRO systems either succeed or struggle in the mining context. It also underscores the need for continuous learning, communication, and adaptation as key drivers of sustainable implementation.

2.4. MRO and Inventory Management in the Mining Industry

Mining operations are capital intensive, and asset driven. The effectiveness of MRO systems directly affects availability of inventory equipment, and it will give an impact to production stability and cost control. Poor spare parts management often leads to stock outs, redundant purchases, and excess inventory all of these can raise operational costs (Dayo Olupona, Adelaja, and Fatogun, 2023). Conversely effective inventory management practices help companies to maintain optimal stock levels while ensuring timely availability of critical parts.

Digital technology like internet of things, artificial intelligence, data analytics can help MRO inventory management to predictive maintenance (Rojas, Fernández, and Herrera, 2025). Powered by these technologies, allows companies to anticipate failures and order replacement parts proactively, reducing both downtime and inventory holding costs.

However, with these advancements require more than technology, this requires more discipline, data accuracy, and cross functional collaboration remain essential for achieving meaningful improvement (Manenzhe, Bevis, and Gouws, 2023). Therefore, effectiveness MRO inventory management in mining depends on both technical systems and organizational practices.

2.5.Challenges in Implementation MRO Systems

Implementing an effective MRO system requires more than financial investment and it requires organizational alignment and cultural readiness. The literature identifies several recurring challenges as below:

1. Resistance to change

   Many organizations face employee resistance during system implementation. This resistance often stems from fear of job disruption, lack of training, or uncertainty about the benefits of change (Campbell

& Reyes-Picknell, 2015). Qualitative studies suggest that addressing employee perceptions early through participation and communication can ease this transition.

2. Poor communication and coordination

   Mining operation, maintenance, procurement and warehouse departments work in silos (Manzini and Regattieri, 2010). This issue explains that silos can cause delays, especially in spare parts delivery and make more efforts and inconsistent data sharing and lack of collaboration make system efficiency drop and reduce trust among teams.

3. Technological challenges

   Digital tools cannot guarantee success (Ceglarek et al, 2015). emphasize that when organizations focus solely on software implementation without user engagement, the system often fails to deliver the expected value.

4. Lack of continuous evaluation

   Many mining companies implement MRO systems but rarely assess their long-term effectiveness. Without regular feedback and evaluation, weaknesses remain unaddressed, and learning opportunities are lost (Marquez, 2007).

These challenges highlight the need for a balanced approach that integrates technical systems with human and organizational development. Qualitative research plays a crucial role in uncovering the subtle factors attitudes, behaviors, and interpersonal dynamics that influence these challenges.

2.6. Supply Chain Performance and MRO

In the end, supply chain performance is where the quality of an MRO system shows up. When MRO processes in mining run efficiently, supply becomes more reliable, more responsive, and cheaper to sustain and that, in turn, keeps production going. The argument in the literature is that effective maintenance strategies feed straight into better supply chain performance by matching materials management to what operations demand (Siyad and Khayal, 2025). Proactive maintenance trims the emergency procurement and transportation costs that so often destabilize a supply chain (Werbinska-Wojciechowska et al., 2025). Reading MRO implementation through the supply chain, then, gives a fuller measure of how well it works and closes the distance between technical maintenance and business results.

2.7.The human and Organization Dimension of MRO

An MRO system only works well when the team behind it cooperates and stays engaged. Efficiency climbs once employees grasp what the system is for and feel their contribution counts (Parida and Kumar, 2006). People who see their own role as part of something bigger tend to stick to maintenance standards and pitch in on improvement work.

The opposite is just as true. When decisions come down from the top and communication only flows one way, people feel shut out and disengagement and mistakes follow (Campbell & Reyes-Picknell, 2015). Which is to say, leadership and organizational culture sit close to the heart of whether MRO succeeds.

There is also learning, adaptation, and empowerment to consider. Continuous improvement runs on employees being able to raise ideas, spot problems, and help solve them. In mining physically hard work, under stress supportive leadership and a culture where people speak openly are not luxuries. They are what keep maintenance operations effective over time.

2.8.Evaluating MRO Systems in Qualitative Context

Looking at MRO implementation qualitatively means digging into experiences, perceptions, and meanings rather than stopping at the numbers. Metrics such as Mean Time Between Failures (MTBF) or Mean Time to Repair (MTTR) are genuinely useful, but they cannot tell you why something succeeded or failed. A qualitative evaluation asks different questions: how do employees see the system, what gets in their way, how do they read their own role in it? That interpretive angle is what brings the human side of MRO performance into view how technology, leadership, and teamwork actally shape the day-to-day running of maintenance. Thematic analysis suits this kind of study particularly well, because it is built to draw out the patterns of meaning that surface in what Informants say (Braun and Clarke, 2006).

2.9.Theoretical Foundation of the Research

A handful of current theories help explain how MRO practices shape organizational and supply chain performance. Together they form the analytical backbone of this study the lens through which the links between inventory management, cost control, and supply outcomes are examined in a mining setting.

1. Maintenance Management Process Theory

   Effective maintenance systems depend on structured workflows including planning, scheduling, execution, and post-maintenance feedback (Manenzhe et al, 2023).

   This study supports the MRO Inventory Management Quality variable, highlighting that systematic and disciplined maintenance processes enhance supply chain reliability.

2. Inventory Holding-Cost Reduction and Lean Maintenance

   Werbinska-Wojciechowska et al. (2025) discuss how proactive maintenance strategies and learn inventory practices minimize unnecessary stock while maintaining operational readiness. Lean maintenance reduces waste by focusing on value-added activities, continuous improvement, and better forecasting of spare parts requirements.

   This perspective underpins the MRO Inventory Holding-Cost Reduction Practices variable, linking cost efficiency to improved supply responsiveness and financial sustainability.

3. Socio-Technical Systems (STS) and Process Integration Theory

   Siyad and Khayal (2025) highlight that technological and social systems must function together to achieve operational excellence. In mining, this means aligning maintenance, warehouse, and procurement teams under a shared process.

   This theory supports the Maintenance–Supply Integration variable, emphasizing cross-functional coordination as a determinant of supply chain performance.

4. Supplier Relationship and Collaborative Advantage Theory

Modern supply chains thrive on collaboration rather than transactional relationships. Siyad and Khayal (2025) note that supplier collaboration in maintenance management enhances reliability through improved lead times, technical support, and information sharing. In mining, partnerships with OEMs and distributors ensure the availability of critical spares and reduce emergency procurement.

This theory anchors the Supplier Collaboration for MRO variable, linking relational quality with supply chain responsiveness and reliability.

5. Supply Chain Performance Theory

Rojas et al. (2025) and Dayo-Olupona et al. (2023) explains that supply chain performance encompasses four major dimensions: reliability, responsiveness, cost, and asset utilization. They argue that maintenance and inventory practices are major contributors to these outcomes, particularly in asset-heavy industries like mining.

2.10. Thinking Framework

This research incorporates following frameworks of thinking to approximate the variable

Table 2.1 Thinking Framework

MRO System Structure and Quality	This dimension refers to the overall design, governance, and procedural discipline of the MRO system. It includes maintenance planning, scheduling, data accuracy, workflow standardization, and performance monitoring. A well-structured MRO system ensures coordination between maintenance, warehouse, and procurement functions, supporting operational reliability and production continuity.
MRO Inventory Management Effectiveness	This component evaluates how effectively spare parts are planned, classified, and controlled to maintain optimal stock levels. It focuses on preventing stock shortages, minimizing excess inventory, and ensuring the timely availability of critical

	parts. Effective inventory management strengthens equipment uptime and reduces operational disruption.
MRO Inventory Holding Cost Reduction Strategy	This dimension examines strategies aimed at reducing unnecessary inventory costs while preserving operational readiness. It includes review policies, criticality-based stocking, demand forecasting, and continuous improvement practices. The objective is to balance financial efficiency with service level performance and reliability.
Digital Integration within MRO Processes	This component assesses the integration of digital tools such as ERP and CMMS within maintenance and inventory workflows. It emphasizes system connectivity, data transparency, real time visibility, and cross functional coordination. Effective digital integration enhances decision making, improves planning accuracy, and supports supply chain performance.

2.11. Previous Research

Table 2.2 Previous Research

Author	Title	Findings
Frazzon et al. (2014)	Spare parts supply chains operational planning using technical condition information from intelligent maintenance systems	Shows that integrating maintenance condition data into spare parts planning improves forecasting accuracy, reduces inventory cost, and strengthens service levels. Highlights the link between maintenance and inventory decisions.
Zhang et al. (2021)	Spare parts inventory management: A literature review	Reviews spare parts inventory models and emphasizes demand uncertainty management and differentiated

		control policies. Calls for more empirical validation in industrial environments.
Muniz et al. (2020)	Spare parts inventory management: A new hybrid approach	Proposes a hybrid criticality and optimization approach that reduces excess stock while maintaining operational readiness in asset intensive industries.
Manenzhe et al. (2020)	The influence of data quality and organizational practices on maintenance performance	Finds that maintenance effectiveness depends on structured workflows, data discipline, and cross functional coordination.
Rihi et al. (2022)	Predictive maintenance in mining industry: Grinding mill case study	Demonstrates that predictive analytics reduces downtime and improves equipment reliability in mining operations.
Robatto Simard et al. (2024)	Development and usability evaluation of a CMMS prototype for preventive and predictive maintenance	Shows that CMMS enhances maintenance planning and coordination but requires strong usability and integration design.
Kulshrestha et al. (2024)	Spare parts management in Industry 4.0 era: A literature review	Explains how digital tools improve spare parts forecasting and cost control but identifies governance and integration challenges.
Cantini et al. (2024)	A data driven methodology for the periodic review of spare parts inventory	Demonstrates that data driven review policies improve cost efficiency while maintaining service levels.

Scarf (2024)	Joint maintenance and spare parts inventory models: A review	Highlights the gap between theoretical maintenance inventory models and practical implementation in asset heavy industries.

Previous studies on Maintenance, Repair, and Operations highlight several key dimensions, including maintenance process structure, spare parts inventory management, cost efficiency strategies, and digital system integration. Research consistently shows that structured maintenance workflows supported by strong data governance improve operational reliability and reduce downtime (Manenzhe et al., 2020). Reviews of integrated maintenance and inventory models further emphasize the importance of aligning maintenance decisions with spare parts planning (Scarf, 2024).

In the area of spare parts inventory management, scholars focus on demand uncertainty, criticality classification, and differentiated control policies. Zhang et al. (2021) and Muniz et al. (2020) demonstrate that structured inventory approaches can reduce excess stock while maintaining service levels. However, empirical validation in mining environments remains limited, particularly in assessing how such practices prevent shortages and sustain operational continuity.

Cost reduction strategies have also received attention. Cantini et al. (2024) and Kulshrestha et al. (2024) show that data driven review policies and digital technologies enhance inventory turnover and financial efficiency. Nevertheless, these studies often examine cost performance separately from operational responsiveness and reliability.

Digital transformation research highlights the role of ERP and CMMS in improving maintenance planning and predictive capabilities (Rihi et al., 2022; Robatto Simard et al., 2024). Although these tools demonstrate clear benefits, existing studies rarely examine how digital systems integrate across maintenance, warehouse, and procurement functions within a unified MRO framework.

Overall, prior research confirms the importance of structured maintenance, optimized inventory policies, cost control, and digital enablement. However, the literature remains fragmented, with limited empirical work evaluating MRO systems as an integrated mechanism that directly links operational practices to supply chain performance in the mining sector.

Table 2.3 Research Gap

Research Gap	Summary of Previous Research	Contribution to This Study
Limited holistic evaluation of MRO system structure in mining	Prior studies examine maintenance processes, spare parts optimization, and data quality separately. Manenzhe et al. (2020) emphasize workflow discipline and data governance, while Scarf (2024) reviews integrated maintenance and inventory models. However, most research focuses on models rather than evaluating the overall structural quality of MRO systems in real mining organizations.	This study evaluates the overall structure and quality of MRO systems in selected mining companies, providing an integrated assessment that combines process design, governance, inventory alignment, and operational reliability.
Fragmented evidence on effectiveness of MRO inventory management in operational mining contexts	Zhang et al. (2021) and Muniz et al. (2020) discuss spare parts classification and optimization techniques. While these studies provide strong analytical	This research empirically evaluates how MRO inventory practices maintain optimal spare levels, prevent shortages, and support operational

	models, empirical validation in mining environments remains limited, particularly regarding stockout prevention and operational reliability outcomes.	continuity in mining companies, bridging theory and practice.
Insufficient integration of cost reduction strategies with operational performance metrics	Cantini et al. (2024) and Kulshrestha et al. (2024) demonstrate that data driven review policies and digital spare parts management improve cost efficiency. However, most studies emphasize financial metrics without systematically linking holding cost reduction to operational responsiveness and reliability in mining settings.	This study examines how MRO inventory holding cost reduction strategies influence both financial efficiency and operational stability, offering a balanced performance perspective.
Limited empirical research on ERP and CMMS integration across MRO processes	Robatto Simard et al. (2024) and Rihi et al. (2022) highlight the benefits of CMMS and predictive maintenance systems. However, research often analyzes technological tools	This research analyzes the integration of ERP and CMMS within MRO workflows and evaluates how digital system alignment supports coordination, data transparency, and supply

	independently, with limited discussion of cross functional integration between maintenance, warehouse, and procurement functions within ERP and CMMS environments.	reliability in mining operations.
Lack of integrated framework linking MRO practices to supply chain performance outcomes	Existing literature reviews such as Scarf (2024) and Zhang et al. (2021) highlight theoretical integration of maintenance and inventory decisions, yet few empirical studies connect MRO implementation directly to supply chain performance dimensions such as reliability, responsiveness, cost efficiency, and asset utilization.	This study develops and applies an integrated framework linking MRO system quality, inventory effectiveness, cost control, and digital integration to supply chain performance in mining companies.

Although prior studies demonstrate that structured maintenance processes, optimized spare parts policies, cost reduction strategies, and digital tools improve operational performance, the literature remains fragmented. Most research examines these elements separately, either through analytical models or technology specific case studies, rather than evaluating MRO systems as an integrated framework.

In addition, empirical evidence within mining environments is still limited. Few studies assess how MRO structure, inventory effectiveness, holding cost reduction strategies, and ERP or CMMS integration collectively influence operational reliability and supply chain performance. As a result, there is a need for comprehensive research that connects technical maintenance practices with broader financial and supply outcomes in mining companies.

Chapter 3 Methodology

3.1 Introduction

This chapter sets out the methodology behind the study, "Evaluation of the Implementation System for Maintenance, Repair, and Operations (MRO) Processes and Its Impact on Supply Chain Performance in the Mining Industry." It walks through the research design, how data was gathered, how it was analysed, and the ethical considerations that ran alongside all of it. The aim is straightforward: to show that the methodology chosen is the right fit for the study, that it was applied systematically, and that it lines up with what the research set out to do.

Mining is about as demanding and asset heavy as industries get. Reliability, cost efficiency, keeping operations running without a break all of it rests on MRO systems that have been implemented well. But MRO performance is never just a matter of technology or process. It also turns on how people behave, the calls they make, and the relationships between those who manage and use these systems. Pinning down that tangle of human-system interaction takes an approach that reaches past numbers and technical metrics.

That is why the study is qualitative. Its focus is on how people perceive, experience, and make sense of what happens within their own organizations. Aspers and Corte (2019) describe qualitative research as "an iterative process in which improved understanding is achieved by making new, significant distinctions resulting from getting closer to the phenomenon studied" (p. 155). Working this way lets the researcher get right into the real practices of maintenance engineers, procurement officers, and supply chain managers, and to surface the meanings and dynamics that quietly decide whether MRO works.

By staying close to what Informants live through, and to the real conditions of mining operations, the methodology yields findings that are rich, descriptive, and importantly usable. The study takes an interpretivist stance, which holds that reality is built through human interaction, and that grasping people's perspectives is the key to explaining how organizations behave. Yin (2018) backs this reasoning, especially for case studies, where qualitative inquiry is well placed to unpack the "how" and "why" of complex organizational systems.

To keep the work credible and rigorous, the methodology follows current standards for trustworthiness in qualitative research. Nowell et al. (2017) tie trustworthiness to a few things done consistently: careful documentation, triangulating data, checking back with Informants, and being transparent about interpretation. All of those are built into this study to strengthen the dependability and validity of what it finds.

The rest of the chapter takes the methodology apart piece by piece. Section 3.2 covers the overall research design and the philosophical stance behind it. Section 3.3 sets the scene and context, and Section 3.4 explains how Informants were chosen and sampled. Section 3.5 lays out the data collection methods semi-structured interviews, document analysis, and field observation and Section 3.6 turns to how that data was analyzed, using NVivo and thematic analysis. Section 3.7 deals with how trustworthiness was secured, and Section 3.8 spells out the ethical principles that govern data collection and reporting.

By pairing interpretive depth with systematic analysis, this framework serves the study's larger goal: to produce meaningful, evidence-grounded insight into how MRO systems can be improved, and how that improvement lifts supply chain performance in mining.

3.2 Research Design

The research design provides the blueprint that directs the entire study, defining how data are collected, analyzed, and interpreted to answer the research questions. This study employs a qualitative case study design, selected for its ability to explore complex organizational processes in depth and to interpret the lived experiences of individuals involved in Maintenance, Repair, and Operations (MRO) implementation within the mining industry.

3.2.1. Philosophical Orientation

The research sits within the interpretivist paradigm, which starts from the idea that reality is socially constructed built up through human interaction and experience. Saunders, Lewis, and Thornhill (2019) put it this way to understand how people behave, you must study the meanings and interpretations they attach to their actions and their surroundings. That is a different bet from positivism, which chases objective measurement and broad generalization.

For this study, interpretivist footing makes sense. MRO implementation and supply chain performance are not driven by technical systems alone people, culture, and the way an organization works shape them just as much. So, evaluating how well these systems perform means understanding how employees, engineers, and managers read them and work with them. As Aspers and Corte (2019) note, qualitative research is an iterative business of edging closer to the thing being studied, deepening understanding through interpretation and reflection along the way.

This stance also fits with Creswell and Poth's (2018) point that qualitative researchers set out to construct meaning from Informants' experiences, using flexible methods that bend as new findings emerge. Seen through that lens, the study is after more than what happens in the MRO process. It wants the why and how in particular, how people make sense of the challenges, the collaboration, and the system's performance inside their own working lives.

3.2.2. Qualitative Approach

Staying on those "how" and "why" questions is what lets the study produce insight that is rich, rooted in context, and pointed squarely at its objectives. In keeping with its philosophical base, the approach also supports iterative analysis: the researcher moves back and forth between collecting data and interpreting it, sharpening understanding as themes surface (Aspers & Corte, 2019). That kind of flexible, evolving engagement pays off especially in a setting like mining, where MRO processes are anything but static.

Tracy (2020) emphasizes that a qualitative orientation allows researchers to study social phenomena holistically, examining not just what happens but why and how it happens. In this study, the qualitative approach enables the exploration of:

1. How MRO systems are implemented in practice
2. How different stakeholders perceive and interact with the system
3. Why do certain processes contribute to or hinder supply-chain performance.

By focusing on these "how" and "why" questions, the study can generate rich, contextually grounded insights that directly address its research objectives.

In alignment with its philosophical foundation, the qualitative approach also facilitates iterative analysis where the researcher moves back and forth between data collection and interpretation to refine understanding as themes emerge (Aspers & Corte, 2019). This flexible, evolving engagement is particularly valuable in organizational contexts like mining, where MRO processes are dynamic and multifaceted.

3.2.3. Case Study Design

The study is built as a case study of a design that gives a full framework for investigating a real-world phenomenon in its natural setting (Yin, 2018). Case studies come into their own when the research is driven by how and why questions, and when the line between the phenomenon and its environment is genuinely blurry.

The focus falls on a single mining organization, picked for two reasons: its MRO structure is representative, and it offered access to genuinely rich qualitative data. It makes it an ideal place to study MRO implementation, precisely because so many interdependent departments maintenance, procurement, warehouse, and supply chain must coordinate for the operation to stay reliable.

A case study also lets several data sources be woven together interviews, document reviews, observation which tightens triangulation and shores up the validity of the findings (Stake, 2020). That is what makes it possible to capture both sides of MRO at once: the technical and the human, and the way they are bound together across supply chain management.

Although it is a single-case design, the study borrows from ethnography through direct, non-Informant observation of maintenance and supply chain work. Watching workflows unfold, noting how people communicate, seeing how they handle equipment these techniques add depth and authenticity to the analysis (Saunders et al., 2019). Blending the rigour of a case study with an ethnographer's eye is what gives the study a rounded picture of how MRO is practised, not just how it looks on an org chart.

The design was steered, too, by the conceptual and theoretical framework from Chapter 2 the one linking MRO system structure and quality, inventory management, holding-cost reduction strategy, and digital integration. Anchoring the case in that framework kept the investigation systematic and made sure the findings could speak meaningfully to both academic and industry conversations.

3.2.4. Alignment with the Study's Objectives

The design maps cleanly onto what the study is trying to do evaluate how MRO systems get implemented, pin down the challenges in running them, and work out what they do to supply chain performance. The qualitative case study fits those aims on several fronts:

1. Depth over Breadth the study prioritizes in-depth exploration of experiences and practices rather than broad generalizations. This depth allows the researcher to uncover nuanced factors that influence system effectiveness, such as coordination patterns, leadership involvement, and interdepartmental communication.

2. Contextual Understanding. By embedding the research within the natural setting of the mining organization, the design captures the environmental, organizational, and cultural contexts that shape MRO outcomes (Creswell & Poth, 2018).

3. Theoretical Integration. The research design is tightly linked to the conceptual framework presented in Chapter 2, ensuring that empirical findings directly address theoretical constructions such as inventory management, maintenance planning, and supply-chain responsiveness.

4. Practical Relevance. The study is situated in a real industrial environment. The design allows for practical recommendations that are both evidence-based and context-sensitive.

Keeping the objectives, the philosophical stance, and the methodological choices pulling in the same direction is what gives the study its internal coherence and analytical validity. The approach is built to generate findings that are meaningful in both directions sharpening academic understanding on one hand, informing operational practice in mining on the other.

To sum up, the design brings three things together interpretivist philosophy, qualitative inquiry, and a case study strategy to investigate MRO implementation in mining. That combination gives the study both the flexibility and the depth it needs to capture how many-sided maintenance and supply chain processes really are. The sections that follow set out the setting, how Informants were selected, and the methods used to collect and analyze the data.

3.3 Research Variable

This research uses a qualitative approach, therefore. The research variables are conceptual constructs derived from the research objectives rather than statistical variables. These variables serve as analytical lenses that guide data collection, interview design and thematic analysis

Table 3.1 Research Variables

MRO System Structure and Quality	1. Organizational Configuration Effective maintenance systems require structured coordination between maintenance, procurement, and inventory functions (Fraser, Hvolby, & Tseng, 2015). 2. Role Clarity and Accountability Clearly defined responsibilities reduce operational ambiguity and improve system reliability (Nezami, Yildirim, & Lee, 2020). 3. Process Standardization Standardized workflows enhance consistency and reduce variability in maintenance execution (Parida et al., 2015). 4. Information Flow Mechanism Integrated information sharing across departments improves operational responsiveness (Haddud, DeSouza, Khare, & Lee, 2017). 5. System Governance and Control

	Structured approval and monitoring mechanisms are critical for maintenance effectiveness (Fraser et al., 2015). 6. System Usability and Operational Reliability Digital system quality affects user adoption and process efficiency (Nezami et al., 2020).
MRO Inventory Management Effectiveness	1. Spare-Part Availability High service levels reduce downtime risk (Bacchetti & Saccani, 2019). 2. Stockout Frequency Frequent stockouts negatively impact maintenance reliability (Hu et al., 2018). 3. Safety Stock Policy Buffer stock decisions must balance risk and cost (Syntetos, Babai, & Gardner, 2016). 4. Inventory Turnover Efficient turnover indicates better alignment between demand and supply (Bacchetti & Saccani, 2019). 5. Service Level to Maintenance Spare parts logistics directly influence maintenance performance (Hu et al., 2018). 6. Demand Forecasting Accuracy Intermittent demand forecasting is essential in spare part management (Syntetos et al., 2016).
MRO Inventory Holding Cost Reduction Strategy	1. Inventory Classification Strategy ABC and criticality-based classification improve cost control (Faccio, Persona, & Sgarbossa, 2014). 2. Capital Tied in Inventory High-value spare parts require careful capital allocation (Basten & van Houtum, 2014). 3. Obsolete and Slow-Moving Stock Control

	Excess and non-moving inventory increase holding cost (van Jaarsveld & Dekker, 2016). 4. Optimization Methods Analytical inventory models improve cost-performance balance (Basten & van Houtum, 2014). 5. Cost-Performance Tradeoff Service level and holding cost must be balanced strategically (van Jaarsveld & Dekker, 2016). 6. Financial Efficiency Impact Inventory optimization contributes to working capital improvement (Faccio et al., 2014).
Digital Integration within MRO Processes	1. ERP and CMMS Interoperability System connectivity enables seamless data exchange (Haddud et al., 2017). 2. Real-Time Data Visibility Real-time access improves responsiveness and decision accuracy (Tortorella, Fettermann, Anzanello, & Sawhney, 2020). 3. Data Accuracy and Synchronization Consistent data improves predictive maintenance effectiveness (Carvalho et al., 2019). 4. Automation of Workflows Automation reduces manual errors and improves process speed (Tortorella et al., 2020). 5. Decision Support Capability Digital tools enhance analytical and performance monitoring capacity (Carvalho et al., 2019). 6. Cross-Functional Transparency Digital integration reduces silos and improves collaboration (Haddud et al., 2017).

3.4 Research Setting and Context

The research was carried out inside a large-scale mining organization, a rich, complicated setting for studying how MRO is implemented and what it does to supply chain performance. Mining is asset-intensive by nature, and staying operational depends on a few things holding together: reliable heavy equipment, maintenance done well, and spare parts on hand when they are needed. Those elements decide production efficiency, cost, and safety all at once, which is exactly why MRO systems form the backbone of a mining operation (Manenzhe, Bevis, & Gouws, 2023).

3.4.1 Industry Context

Few operational environments are as unforgiving as mining. It leans heavily on machinery, its sites are remote, and its logistics chains are long and tangled. Between the harsh conditions, the constant equipment wear, and the steep cost of any downtime, preventive maintenance and efficient repair are not optional they are what keep productivity sustainable. Werbinska-Wojciechowska, Grabowski, and Dziula (2025) make the point that maintenance effectiveness in mining rides on more than technical systems; organizational structure, communication, and human expertise matter every bit as much.

In that context, MRO systems are the mechanism that ties everything together maintenance planning, procurement, inventory management, and the coordination that keeps them in step. Their job is to make sure the right components are in the right place at the right moment so critical machinery keeps turning. And yet, for all the progress in computerized maintenance management systems (CMMS), plenty of mining operations still wrestle with the same problems: spare-parts shortages, clunky workflows, and departments talking past one another any of which can throw supply chain performance badly off course (Dayo-Olupona, Adelaja, & Fatogun, 2023).

3.4.2 Theoretical Guidance and Material Selection

The choice of site and materials followed the interpretivist framework from Section 3.2 and the conceptual model laid out in Chapter 2 a framework that treats systems as socially constructed things, coloured by human interpretation and organizational culture. With that in mind, the data sources were picked deliberately: interviews, internal documents, and observation, each chosen because it could throw light on both the formal system as designed and the informal practices that shape how it performs (Aspers & Corte, 2019).

The quality and relevance of materials were determined by three key factors:

1. Authenticity. Data was obtained directly from personnel actively engaged in MRO operations and from official company records.
2. Diversity. The study included multiple data types (textual, verbal, and observational) to allow for triangulation.
3. Depth. Each source was evaluated for its ability to provide meaningful, context-rich insight into system operations and stakeholder experiences.

Keeping theory and method aligned in this way means the study does two jobs at once: it answers its own research questions, and it adds something to the wider theoretical conversation about MRO effectiveness and supply chain management across asset-intensive industries.

3.4.3 Researcher Positionality and Reflexivity

Qualitative work openly accepts that the researcher is not a neutral observer but an active instrument in gathering and interpreting data. That is why being reflexive and transparent about where the researcher stands matters so much for keeping the analysis rigorous and credible (Creswell & Poth, 2018; Nowell, Norris, White, & Moules, 2017).

The researcher came to this work with professional experience in supply chain systems, inventory optimization, and digital planning platforms. That background brought a solid grounding in how MRO concepts work in practice. It also allowed for deeper engagement during the interviews the kind of domain knowledge that makes it possible to ask technically informed follow-up questions and to read operational terminology correctly.

That same experience, though, carries a risk. Having worked in MRO environments can seed bias confirmation bias, or assumptions carried in beforehand about how effective systems are and where integration tends to break down. Several steps were taken to keep those risks in check.

However, prior experience in MRO-related environments may introduce potential bias, particularly in the form of confirmation bias or pre-existing assumptions about system effectiveness and integration challenges. To mitigate these risks, several strategies were implemented.

First, the semi-structured questions were written to stay open and neutral, so Informants could speak their minds without being nudged toward a particular answer. Second, a structured coding framework built on predefined variables was paired with inductive coding, which left room for unexpected themes and stopped the analysis leaning too hard on prior assumptions. Third, the study triangulated across departments maintenance, procurement, warehouse, planning, and reliability comparing how each function saw things, which is what gives triangulation its credibility (Creswell & Poth, 2018).

Alongside this, reflective notes were kept throughout the analysis, recording the analytical choices made and any moment where the researcher's own reading might have crept in. Holding on to that audit trail of coding decisions is what underpins the transparency and dependability of the findings (Nowell et al., 2017). Where it helped, early interpretations were summarized and checked back in follow-up discussions, to make sure they matched what Informants meant.

Taken together, these measures are meant to strike a balance professional expertise on one side, methodological rigour on the other so that the findings rest on what Informants said, not on what the researcher expected to hear.

3.5 Research Informants

Qualitative study only works if the right people are in the room people with direct, first-hand knowledge of what is being studied. For this research, that meant professionals working inside the MRO system and its link to supply chain performance at a large-scale mining organization. Since the whole point was to understand how MRO is implemented and experienced in practice, Informants were chosen purposefully, for what they could offer: rich, detailed, context-specific insight (Creswell & Poth, 2018).

3.5.1 Informant Profile

Informants were selected from the organization's maintenance, procurement, warehouse, and supply-chain functions. This diversity of perspectives allowed the study to capture both operational and strategic dimensions of MRO system implementation. The inclusion of various job roles also ensured that findings reflected how processes and decisions are experienced throughout different organizational levels.

1. Maintenance Engineers and Supervisors responsible for overseeing preventive and corrective maintenance, ensuring equipment reliability, and coordinating maintenance schedules

2. Procurement and Purchasing Officers involved in sourcing spare parts, managing supplier relationships, and negotiating contracts that support maintenance operations.

3. Warehouse and Inventory Controllers manage stock levels, track materials, and handle the issuance of parts for maintenance work orders.

4. Supply-Chain and Planning Coordinators align maintenance schedules with material availability, supplier lead times, and logistics planning.

5. Reliability Engineers and Department Managers provide oversight on maintenance policies, performance indicators, and cost-optimization strategies.

Each of these stakeholder groups interacts with the MRO system from a unique standpoint, contributing to a holistic understanding of how MRO implementation affects operational efficiency, equipment reliability, and supply-chain responsiveness.

3.5.2 Informant Inclusion Criteria

To be included in the study, Informants had to meet the following criteria:

1. Experience: At least three years or more of direct involvement in maintenance, procurement, or supply-chain operations within the mining company.
2. Role Relevance: Active participation in processes related to MRO management, such as inventory control, equipment maintenance, supplier coordination, or procurement decision-making.
3. Willingness to Participate: Consent to participate in semi-structured interviews and share candid reflections about their experiences and challenges with MRO systems.
4. Availability: Accessibility during the data collection period for interviews or follow-up discussions.

These criteria ensured that each Informant possessed relevant experiential knowledge that would enrich the study's findings.

3.5.3 Ethical Considerations for Informants

Ethically, the ground rules were clear from the start. Taking part was entirely voluntary. Before anyone was asked to contribute, they were told what the research was for, what their involvement would look like, and how their confidentiality would be protected. Because the interviews were written and asynchronous, consent was obtained and confirmed directly in writing with each Informant over the messaging platform. Each one explicitly agreed that their responses could be used for academic research, confirmed they understood how anonymization would work, and kept the right to withdraw at any point before the thesis was submitted.

Anonymity was guarded carefully. No personal identifiers appear anywhere in the findings each Informant is named only by a code (I1 through P5) and their broad professional role. Company names, exact locations, and anything else that might have identified a Informant or their employer were stripped out during data preparation. Everything else the original interview documents, the anonymized analytical copies, the consent confirmations, and the NVivo project files was kept on password-protected devices that only the researcher could open. Between them, these steps protected Informants' rights, privacy, and dignity from beginning to end.

In short, Informants were chosen through purposive sampling so that every one of them brought something worth knowing about how MRO works in a mining setting. Pulling in voices from across the department’s maintenance through to supply chain management let the study capture the interdependencies that shape both MRO implementation and supply chain performance. That spread of perspectives is what making a holistic, grounded analysis possible.

3.6 Data Collection Methods

Data collection is where a qualitative study either earns its depth or loses it it is the raw material out of which every theme, meaning, and pattern is later drawn. The aim here was to build a genuinely in-depth understanding of how MRO systems are implemented in a mining organization and how they ripple through to supply chain performance. To get there, the study combined three methods: semi-structured interviews, document review, and non-Informant observation. Triangulating across them is what lets different perspectives and data types come together into something both credible and rich (Vogt, Gardner, & Haeffele, 2023).

As Aspers and Corte (2019) put it, qualitative inquiry is an iterative process of drawing nearer to whatever is being studied. Bringing these sources together let the researcher look at both the formal systems and the human interactions around them, assembling a whole picture of MRO practice in its natural setting. The methods were chosen precisely because they catch two things at once: what happens inside the system, and how the people in it experience, read, and work around its challenges.

3.6.1 Semi-Structured Interviews

The primary method of data collection was semi-structured interviews, which allowed Informants to share their experiences freely while ensuring that key topics were consistently explored across all sessions. According to Tobin and Begley (2020), semi-structured interviews strike an effective balance between flexibility and structure, encouraging open discussion while maintaining focus on the research objectives.

Interviews were conducted asynchronously using a written interview format delivered through a secure messaging platform. The researcher prepared a structured interview document containing the full set of questions organized around the study's research variables, with space for Informants to type their responses directly beneath each question. This document was distributed to each Informant individually through WhatsApp, and Informants returned their completed documents through the same platform at their own convenience.

This approach was adopted to accommodate the operational realities of Informants, who work in demanding industrial environments with irregular shift patterns and limited availability for live interviews. Asynchronous written interview methods are increasingly recognized in qualitative research as a practical and defensible alternative to face-to-face interviews, particularly for professional Informants in time-constrained settings (Salmons, 2022; James & Busher, 2016). Written asynchronous formats offer several advantages that are especially relevant for this study: Informants can respond when convenient, they have time to reflect before answering, and their responses are captured directly in text form without requiring audio transcription. These characteristics align well with the demands of mining operations, where live interviews would be difficult to schedule reliably.

Where a returned response required clarification or additional detail, the researcher followed up with the Informant through further messages to probe or expand on specific points, consistent with the semi-structured nature of the method. Each completed interview document was saved in its original form as primary source data. For analytical purposes, duplicate copies were created and anonymized by assigning each Informant a unique code (I1 through P5) and removing any identifying details before the data was imported into NVivo 12 for coding and thematic analysis.

It is acknowledged that written asynchronous interviews differ from live verbal interviews in several important ways. Informants can edit and refine their responses, which may produce more considered but less spontaneous accounts than live conversation would yield. The researcher also has fewer opportunities to observe non-verbal cues or to follow unplanned lines of inquiry in real time. These trade-offs were considered acceptable given the operational constraints of the Informant group, and the direct written capture of responses was judged to strengthen rather than weaken the integrity of the data, since the words analyzed are exactly the words the Informants chose to submit.

The question for this study will be mapped into research objectives with questions as below

Table 3.2 List of Informants and Questions

Variable	Sample Interview Questions	Informant	Division	Gender	Age	Years of Experience	Relevance
Structure and quality MRO systems	How are roles and responsibilities defined within the MRO workflow in your department?	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Clarifies responsibility for work order creation, spare-part request, and maintenance approval.
		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Identifies authority for purchase requisition approval and supplier engagement.
		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	Explains ownership of stock updates and material issuance.

		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Shows accountability for demand forecasting and replenishment planning.
		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	Defines responsibility for failure recording and reliability analysis.
	How does information flow from your department to other departments within the MRO system?	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Flow from maintenance request to procurement and warehouse.
		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Flow from requisition to purchase order to goods receipt.
		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	Flow from stock issue to system update.

		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Flow from forecast to procurement and inventory.
		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	Flow from failure event to maintenance and planning.
	what extent are processes standardized within the system?	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Standardization of preventive maintenance schedules.
		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Standardized purchasing procedures.
		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	Standardized inventory classification.
		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Standard forecast methodology.
		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	Standard failure coding and reporting.

What are the KPIs measured to assess effectiveness?	What operational indicators are most important in evaluating your department's performance?	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Equipment availability, downtime rate.
		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Lead time, cost efficiency.
		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	Stock availability, inventory accuracy.
		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Forecast accuracy, service level.
		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	MTBF, failure rate.
	How are these KPIs generated and	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Work order history and downtime records.

	monitored within the MRO system?						
		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Purchase order tracking.
		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	Stock movement logs.
		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Demand versus actual comparison.
		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	Failure event data.
	How are KPI results used in managerial decision making?	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Adjust preventive maintenance strategy.

		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Evaluate supplier performance.
		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	Adjust safety stock levels.
		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Revise forecast assumptions.
		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	Improve asset reliability strategy.
What are the main challenges or barriers affecting efficiency?	What operational bottlenecks do you experience when using the MRO system?	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Delay in spare-part availability.
		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Incomplete technical specifications.

		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	System lag or stock mismatch.
		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Inaccurate demand signals.
		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	Incomplete data capture.
	Are there data quality or communication issues that affect performance?	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Incorrect part numbers.
		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Misalignment between request and purchase.
		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	Inconsistent inventory records.

		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Lack of real-time updates.
		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	Missing failure details.
	How do these challenges impact overall maintenance performance?	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Increased downtime.
		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Emergency purchases.
		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	Stockouts or overstock.
		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Forecast instability.

		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	Reduced reliability accuracy.
How well does the MRO system integrate all information to overall maintenance performance?	Does the system provide real-time visibility of information across departments?	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Visibility of spare-part availability.
		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Visibility of demand urgency.
		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	Visibility of incoming materials.
		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Visibility of consumption patterns.

		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	Visibility of failure trends.
	How effectively are maintenance, procurement, inventory, and reliability data connected?	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Connection between failure and spare consumption.
		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Link between lead time and maintenance need.
		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	Link between stock level and forecast.
		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Link between asset plan and procurement cycle.
		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	Link between failure data and planning.

	how does system integration influence maintenance reliability and cost efficiency?	I1 (Mining Engineering)	Maintenance Engineers	Male	46	12	Reduced unplanned downtime.
		I2 (Mining Engineering)	Procurement and Purchasing Officer	Female	43	13	Reduced urgent purchasing cost.
		I3 (Mining Engineering)	Warehouse and Inventory Controllers	Male	50	15	Balanced inventory cost.
		I4 (Mining Engineering)	Supply Chain Planning	Female	47	11	Improved supply chain stability.
		P5 (Mining Engineering)	Reliability Engineers	Male	49	13	Long-term asset performance improvement.

3.6.2 Document Review

The second source was document analysis, which added evidence of the organization's formal structures, policies, and performance indicators for MRO. Reviewing documents is a long-established way of triangulating it brings a more objective angle that sits alongside, and balances what Informants describe in their own words (Yin, 2018; Vogt et al., 2023).

The following internal documents were examined with organizational approval

1. Maintenance and MRO policies and standard operating procedures (SOPs)
2. Preventive maintenance schedules and work-order reports
3. Inventory control sheets, stock movement logs, and KPI dashboards
4. Procurement records and supplier performance evaluations
5. Strategic plans or audit reports related to reliability or cost optimization.

These documents showed how the systems were meant to be designed and measured and, just as usefully, where the documented process and the actual practice parted ways. Working through them strengthened the credibility of the findings by triangulation and gave a factual yardstick for holding what Informants said up against what the records officially claimed (Nowell et al., 2017).

3.6.3 Triangulation and Data Integration

Weaving several data sources together is central to making qualitative research trustworthy. As Vogt et al. (2023) and Nowell et al. (2017) stress, triangulation makes a study stronger by letting the researcher confirm emerging patterns and cross-check findings from more than one vantage point.

To keep the work credible and analytically tight, the study triangulates across several bodies of evidence. Leaning on more than one perspective is what reduces the risk of any single view distorting the picture, and it firms up the validity of the findings (Creswell & Poth, 2018; Carter, Bryant-Lukosius, DiCenso, Blythe,

& Neville, 2014). Three complementary forms of triangulation are used here: across Informants, across data types, and across methods. Where interviews, organizational documents, and operational observations line up, the themes MRO system structure, inventory effectiveness, cost management, digital integration can be cross validated with far more confidence.

1. Informants

   Informants involved in collecting perspectives from multiple functional roles that involved in MRO system including

   a. Maintenance engineer
   b. Procurement and purchasing officers
   c. Warehouse and inventory control
   d. Supply chain management team
   e. Reliability engineer

   Strategy of convergence is theme from each department is compared against perspective of other departments.

2. Data types

   Data type involved for integrating some information as below:

   a. Interview data
   b. Organization documents
   c. System generated operational records

   The strategy of convergence is to interview insights are compared with organizational documents to identify consistency or divergence in reported operational patterns

3. Method

   Methods are to integrate semi-structure interviews, document review and limited to Informant observations. The observation strategy is to observe interface data, workflow processes and cross-department coordination meetings. These observations are focused on how spare part request and process, how system data is accessed, how does reconciliation occur and information and visibility in dashboard.

The strategy of converging is to interview and suggest process inefficiency and observe evidence is used to confirm whether workflow is the bottleneck or there will be manual interventions in current situations

All the data was organized systematically in NVivo 12, which made managing, coding, and analyzing it far more efficient. Because NVivo can link excerpts across different data types, interpretations stayed anchored in evidence drawn from several sources at once reinforcing both the transparency of the analysis and the rigor of the method (Bazeley & Jackson, 2019).

3.6.4 Data Collection Procedure

The overall data collection procedure was guided by methodological best practices (Salmons, 2022; Creswell & Poth, 2018)

1. Access and Permission: Formal approval was obtained from company management and relevant departments before initiating the study.
2. Informant Recruitment: Stakeholders meeting the inclusion criteria were invited to participate voluntarily and provided with information sheets and consent forms.
3. Interview Phase: Structured interview documents were distributed to each Informant through a secure messaging platform. Informants completed the documents at their own pace and returned them for analysis. Follow-up messages were used where additional clarification was required. Completed documents were saved in their original form and then anonymized for analytical use.

4. Document Retrieval: Organizational documents were collected with permission and reviewed securely on-site or through encrypted digital files.
5. Observation Sessions: The researcher observed maintenance and inventory activities, maintaining detailed field notes.
6. Data Organization: All textual and visual data were anonymized, stored securely, and imported into NVivo for systematic coding and thematic exploration.

This structured yet flexible approach ensured that data collection was comprehensive while remaining responsive to emerging insights a hallmark of high-quality qualitative research (Aspers & Corte, 2019).

3.6.5 Ethical and Reflexive Considerations

Ethical integrity was kept front and centre all through data collection. Informants were told plainly what the study was for, what their rights were, and that taking part was entirely their choice. Confidentiality was handled by giving each person a pseudonym (I1, I2, and so on) and scrubbing identifying details from the transcripts. Any sensitive organizational data was managed in line with institutional research ethics standards and held in encrypted folders (Sutton & Austin, 2015).

The researcher also practiced reflexivity, maintaining a journal to record personal reflections, assumptions, and decisions made during fieldwork. This reflexive practice minimized bias and supported the transparency and dependability of interpretations (Nowell et al., 2017).

The study's approach to data collection was, then, both triangulated and ethically grounded three methods, working in concert, to explore MRO implementation in a mining organization. Each pulled its own weight: interviews caught personal experience, documents laid bare the formal structures, and observation brought the everyday practices into view. Together they produced data that was comprehensive, credible, and thick with context a firm footing for the thematic analysis that comes next.

3.7 Data Analysis

Analyzing qualitative data is a reflective, interpretive craft it asks for structure and, at the same time, a sensitivity to how rich human experience is. The goal here was never just to sort information into boxes. It was to draw out the meanings and patterns buried in the words, documents, and observations of the people who live with the MRO system day in and day out. As Saldaña (2021) puts it, qualitative analysis means "listening with the mind as much as with the ears" using the data to tell a story that keeps hold of Informants' voices and the complexity of their world.

The material gathered interview transcripts, field notes, organizational documents was worked through using thematic analysis, a flexible and widely trusted method for finding and interpreting patterns in qualitative data (Braun & Clarke, 2006; Nowell et al., 2017). It was chosen because it lets the researcher move back and forth between the data and its interpretation, weighing not only what Informants said but why they said it. That back-and-forth is the very heart of qualitative inquiry as Aspers and Corte (2019) describe it: a steady effort to get closer to the phenomenon, deepening understanding through repeated passes over the data.

To handle and make sense of such a large body of qualitative material, the study used NVivo 12, a piece of computer-assisted qualitative data analysis software (CAQDAS). NVivo acted as an organizational companion storing, coding, retrieving, and visualizing the relationships across data sources while the interpretive work itself stayed firmly with the researcher (Bazeley & Jackson, 2019). Leaning on it kept the analysis systematic, transparent, and traceable, which strengthened both its rigour and its trustworthiness (Woods, Macklin, & Lewis, 2016).

3.7.1 Analytical Approach

The analysis was inductive and interpretive, in keeping with the interpretivist philosophy set out earlier. Instead of testing hypotheses fixed in advance, the researcher worked to let meaning rise out of the data itself. Creswell and Poth (2018) describe inductive qualitative analysis as a process in which themes emerge naturally, led by what Informants experienced rather than by assumptions imported from outside. That fit the MRO context especially well, where human decisions, technical processes, and organizational culture are so tightly wound together.

It also took to heart Saldaña's (2021) view that coding is not mechanical labour but an intellectual act reflection and interpretation, not sorting. Every round of coding and theme-building was paired with memo-writing, a technique Tracy (2020) recommends for keeping critical thinking and reflexivity alive during analysis. Those memos became a record of how insights shifted and how meanings were refined as the work went on.

3.7.2 Data Analysis Sequence

Data analysis began immediately after the first interview and continued throughout the research process. The steps below describe how the data were analyzed from preparation and familiarization through interpretation and synthesis.

1. Data Preparation and Familiarization

   All interviews were audio-recorded and transcribed verbatim to preserve Informants' exact words, tone, and phrasing. Transcripts were reviewed alongside the recordings to ensure accuracy. Observational notes and organizational documents were digitized and formatted for integration into NVivo.

   The researcher then immersed in the data by reading and rereading each transcript, noting early impressions and recurring ideas such as communication breakdowns, inventory challenges, or supplier delays. This deep engagement fostered a holistic understanding of the MRO environment and allowed the researcher to "hear" Informants' voices beyond the literal text (Tracy, 2020). Early reflections were documented as analytical memos, forming the foundation for later coding and theme development.

2. Organizing and Importing Data into NVivo

   All qualitative data interview transcripts, field notes, and documents were imported into NVivo 12, establishing a centralized digital database. NVivo provided a systematic framework for organizing data into cases and classifications, allowing efficient retrieval and cross-referencing.

Each Informant was assigned a unique code (I1, I2, etc.), and stakeholder groups (maintenance, procurement, warehouse, supply-chain, and management) were categorized for comparison. This structure enabled the researcher to later analyze similarities and differences between perspectives across departments.

3. Initial Coding (Generating Codes)

   Using NVivo's open coding tools, the researcher conducted a line-by-line examination of the transcripts and documents to identify meaningful units of information words, sentences, or paragraphs that captured relevant ideas. Each segment was assigned a code or "node," representing specific concepts such as "stock-out events," "team communication," or "supplier reliability."

   Coding was primarily inductive, emerging directly from the data, though it was guided by the study's conceptual framework to ensure relevance to the research objectives. During coding, NVivo's annotation and memo features were used to record the researcher's thoughts about why certain codes were important or how they related to others.

   This process resulted in an extensive list of initial codes, each linked directly to data excerpts, forming the building blocks for subsequent theme generation (Saldaña, 2021).

4. Searching for and Developing Themes

   After completing the coding process, related codes were grouped together into potential themes. NVivo's visualization tools including cluster analysis, word-frequency queries, and coding matrices were used to explore relationships between codes and identify higher-level patterns.

Codes such as “shortages,” “emergency requests,” and “spare-parts delays” merged into the theme Inventory Availability and Responsiveness.

Codes including “maintenance-procurement coordination” and “information sharing” combined into Operational Integration and Communication.

Codes such as “long supplier lead times” and “dependence on external vendors” were organized under Supplier Collaboration and Reliability.

The process was iterative and reflective: as new insights emerged, earlier codes were revisited and refined. The themes evolved over several rounds of analysis until they clearly represented coherent and distinctive dimensions of the data (Clarke & Braun, 2021).

5. Reviewing and Refining Themes

   Each preliminary theme was reviewed against the entire dataset to confirm that it accurately reflected the data and maintained a clear distinction from other themes. NVivo’s “matrix coding query” and “text search” features allowed the researcher to examine how frequently and consistently each theme appeared across Informant groups.

   Themes that overlapped were either merged or redefined. For example, an early theme called “integration barriers” was divided into Process Alignment Challenges and Technology Integration Issues to better represent the nuances revealed during analysis.

   Peer debriefing sessions with academic supervisors were conducted to validate theme development and guard against researcher subjectivity (Tracy, 2020). These discussions helped ensure that all interpretations remained grounded in the data rather than influenced by personal assumptions.

6. Defining, Naming, and Describing Themes

   Once finalized, each theme was carefully defined and named to capture its conceptual essence. The researcher developed theme summaries that included

   a. A concise definition and scope of the theme
   b. Supporting Informant quotations.
   c. Links to corresponding documents and observations.
   d. Analytical notes explaining why the theme was significant.

   This step provided both clarity and coherence, allowing the themes to serve as the narrative framework for the findings presented in Chapter 4. Each theme was supported by rich, descriptive evidence that illustrated the human experiences behind organizational processes.

7. Synthesizing and Interpreting Themes

   The final phase involved synthesizing the themes into a coherent explanation of how MRO systems are implemented and how they shape supply-chain performance. NVivo's "relationship maps" and "model visualization" tools were used to illustrate connections between key themes, such as how communication and supplier relationships jointly influenced inventory efficiency and maintenance reliability.

   Interpretation extended beyond description to explanation exploring not only what challenges existed, but why they occurred and how stakeholders understood them. This analytical synthesis bridged empirical findings with the conceptual framework and relevant literature (Aspers & Corte, 2019; Creswell & Poth, 2018).

3.7.3 Thematic Analysis

The analysis worked through Braun and Clarke's (2006) six-phase model, adapted to fold in the reflective, iterative cycles that Nowell et al. (2017) and Terry et al. (2017) recommend:

1. Familiarization with the Data. researchers began by reading each transcript and document multiple times to become fully immersed in the content. Audio recordings were replayed to capture tone and emphasis, and reflective notes were written in a research journal. This process helped the researcher connect emotionally and cognitively with Informants' experiences, a crucial first step in identifying meaning (Terry et al., 2017).

2. Generating Initial Codes. Data were then imported into NVivo 12, where significant phrases, sentences, or paragraphs were coded according to their content and meaning. Codes were both inductive (emerging from the data) and deductive (guided by the conceptual framework). NVivo facilitated the coding process by allowing text to be tagged and organized systematically, creating an easily navigable database of emerging concepts (Bazeley & Jackson, 2019).

3. Searching for Themes. Related codes were clustered into potential themes that represented key aspects of the MRO process, such as coordination across departments, inventory cost challenges, supplier collaboration, and digital system utilization. NVivo's visualization tools including word-frequency charts and cluster maps assisted in identifying relationships and overlaps among codes.

4. Reviewing and Refining Themes during this stage, preliminary themes were reviewed against the coded data and the entire dataset to ensure internal consistency and distinctiveness. Some themes were merged, while others were divided or renamed to better capture their essence. According to Clarke and Braun (2021), this reflective adjustment stage ensures that themes truly represent Informants' realities rather than the researcher's assumptions.

5. Defining and Naming Themes each finalized theme was clearly defined, with supporting quotations and evidence noted in NVivo. The researcher wrote detailed analytical memos describing how each theme related to the research questions and the conceptual framework. This stage deepened the interpretation, revealing patterns that linked operational behaviors to organizational outcomes.

6. Producing the Analytical Narrative final phase involved synthesizing the themes into a coherent narrative that explained how MRO systems were implemented and how they influenced supply-chain performance. Direct Informant quotations were integrated to illustrate each theme, providing authenticity and allowing readers to "hear" the voices of those within the mining organization. As Tracy (2020) suggests, vivid representation and transparency in reporting enhance both credibility and resonance of qualitative findings.

3.7.4 The Role and Value of NVivo in This Study

While the researcher remained the primary instrument of analysis, NVivo 12 played a vital supporting role in ensuring analytical structure and consistency. Its application in this study served five main purposes:

1. Data Organization: NVivo stored all transcripts, field notes, and organizational documents in a single, searchable database, preventing data fragmentation.

2. Coding Efficiency: The software simplified the coding process, allowing flexible modification of nodes as new insights emerged.

3. Visualization and Pattern Detection: NVivo's charting and query features helped visualize thematic connections and compare patterns across stakeholder groups (e.g., maintenance vs. procurement).

4. Audit Trail and Transparency: Every action from code creation to thematic re-organization was automatically logged, creating a digital audit trail that reinforced the dependability of the analysis (Woods et al., 2016).

5. Triangulation: NVivo enabled easy cross-referencing between interviews, documents, and observation data, supporting a robust triangulation process as recommended by Vogt et al. (2023).

Through NVivo, the researcher could manage the data more effectively, spend more time interpreting rather than manually organizing information, and ensure that insights were anchored in evidence rather than speculation.

3.7.5 Ensuring Rigor and Trustworthiness During Analysis

In qualitative research, rigour does not come from statistical validation it comes from being transparent, being reflexive, and being consistent in a systematic way (Cypress, 2017; Nowell et al., 2017). To hold the analysis to that standard, the study followed the four established criteria for trustworthiness:

1. Credibility: Achieved by triangulating multiple data sources and presenting direct Informant quotations that accurately reflect lived experiences (Tracy, 2020).
2. Dependability: Ensured through detailed documentation of analytical steps, NVivo's audit trail, and peer debriefing with academic supervisors.
3. Confirmability: Strengthened through reflexive journaling and memo-writing to recognize and mitigate personal biases during interpretation (Sutton & Austin, 2015).
4. Transferability: Enhanced through "thick description" of context, Informants, and organizational setting, allowing readers to assess the applicability of findings to similar industrial environments (Creswell & Poth, 2018).

By embedding these practices within the analytical process, the study maintained both methodological integrity and authenticity of interpretation.

3.7.6 Integration of Findings

Once the themes were settled, they were mapped back onto the study's conceptual framework MRO system structure and quality, inventory management, holding-cost reduction strategy, and digital integration. NVivo's visualization tools, its thematic maps and comparison matrices, were used to lay out how these constructs relate to one another, turning qualitative insight into something a practitioner could act on.

This integrative stage is what Aspers and Corte (2019) call analytic closure: the point where, after immersing themselves iteratively in the material, the researcher arrives at a coherent reading of the phenomenon. Throughout the whole study, analysis was immersive, iterative, and reflective built to capture the depth and complexity of MRO implementation inside a mining organization. Thematic analysis gave it a framework that was structured but still flexible enough to catch recurring patterns, while NVivo kept everything organized, transparent, and rigorous. What comes out the other end is a set of rich, evidence-based themes that show how MRO practices shape supply chain performance in mining.

3.7.7 Data Analysis Procedure

This study employs thematic analysis to interpret qualitative data collected through semi-structured interviews. The analysis follows a structured coding process guided by the predefined research variables. A deductive approach is first applied by organizing data according to the four research variables derived from the research objectives. Subsequently, inductive coding is conducted to capture emerging themes within each variable.

The coding process consists of three stages. First, meaningful statements are identified from interview transcripts. Second, these statements are labeled with initial codes that reflect operational issues, performance indicators, or system characteristics. Third, related codes are grouped into sub-themes and aligned with the corresponding research variables.

Ensuring transparency and analytical rigor, a coding tree structure is developed to illustrate the hierarchical relationship between research variables, sub-themes, and initial codes.

The coding tree demonstrates how interview data will be systematically organized during analysis as below

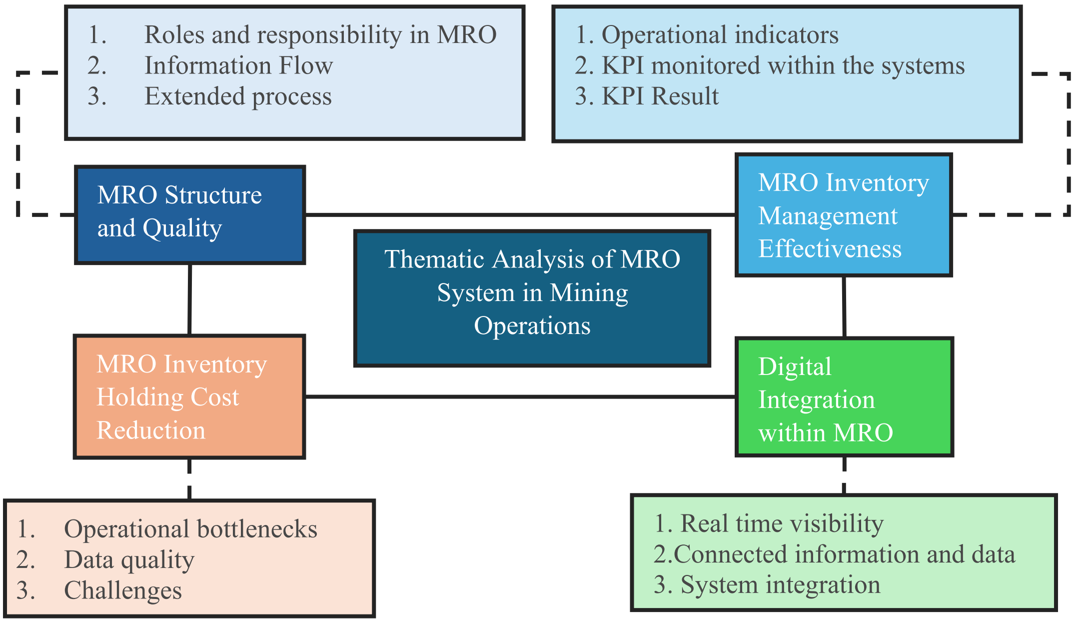


Figure 3.1 Thematic Map

The following illustrations on interview data will be systematically coded and aligned with the predefined thematic structure. These examples serve to enhance transparency of the analytical procedure and do not represent actual research findings. Below are some examples for the question on each variable and how does the coding process will be.

Table 3.3 Variable 1 MRO System Structure and Quality

Variable 1 MRO System Structure and Quality	
Sub-theme: role clarity and accountability	
Coding process	
Level	Coding Output
Raw Statement	Approval responsibility unclear
Open Code	Role ambiguity
Axial Code	Lack of role clarity
Sub-theme	Role Clarity and Accountability
Research Variable	MRO System Structure and Quality

Theoretical Foundations
1. Maintenance Management Process Theory Maintenance effectiveness depends on structured workflows, defined responsibilities, and governance mechanisms (Parida, Kumar, Galar, & Stenström, 2015). 2. Socio-Technical Systems Theory Organizational performance is achieved when social systems and technical systems are aligned (Tortorella, Fettermann, Anzanello, & Sawhney, 2020).

Variable 1 reflects the principles of Maintenance Management Process Theory and Socio-Technical Systems Theory, which emphasize structured coordination, role clarity, and alignment between technological systems and organizational processes as determinants of operational effectiveness.

Table 3.4 Variable 2 MRO Inventory Management Effectiveness

Variable 2 MRO Inventory Management Effectiveness	
Sub-theme: Spare-Part Availability	
Coding process	
Level	Coding Output
Raw Statement	Urgent request due to unavailable parts
Open Code	Stockout occurrence
Axial Code	High stockout frequency
Sub-theme	Spare-Part Availability
Research Variable	MRO Inventory Management Effectiveness
Theoretical Foundations	
1. Spare Parts Inventory Theory Effective spare parts management balances service level and inventory cost (Hu, Boylan, Chen, & Labib, 2018). 2. Service Level Optimization Theory Inventory systems must minimize stockouts while controlling excess stock (Bacchetti & Saccani, 2019).	

Variable 2 is grounded in spare parts inventory management theory, which emphasizes balancing operational reliability and inventory efficiency. Maintaining optimal spare part levels directly influences equipment uptime and supply chain stability.

Table 3.5 Variable 3 MRO Inventory Holding Cost Reduction Strategy

Variable 3 MRO Inventory Holding Cost Reduction Strategy	
Sub-theme: Obsolete and Slow-Moving Stock	
Coding process	
Level	Coding Output
Raw Statement	Long-term non-moving stock
Open Code	Slow-moving inventory
Axial Code	Obsolete stock accumulation
Sub-theme	Obsolete and Slow-Moving Stock
Research Variable	MRO Inventory Holding Cost Reduction Strategy
Theoretical Foundations	
1. Inventory Optimization Theory Inventory levels should be optimized to balance holding cost and service performance (Basten & van Houtum, 2014). 2. Working Capital Management Theory Efficient inventory management improves capital utilization and financial performance (van Jaarsveld & Dekker, 2016).	

Variable 3 is supported by inventory optimization and working capital management theories, which highlight the importance of minimizing holding costs without compromising service reliability in asset-intensive industries.

Table 3.6 Variable 4 Digital Integration within MRO Processes

Variable 4 Digital Integration within MRO Processes	
Sub-theme: ERP and CMMS Connectivity	
Coding process	
Level	Coding Output
Raw Statement	Manual data reconciliation
Open Code	Integration gap
Axial Code	Poor ERP-CMMS synchronization
Sub-theme	ERP and CMMS Connectivity
Research Variable	Digital Integration within MRO Processes
Theoretical Foundations	
1. Supply Chain Integration Theory Integrated information systems enhance coordination and performance (Haddud, DeSouza, Khare, & Lee, 2017). 2. Digital Transformation and Industry 4.0 Theory Digital connectivity improves decision support and operational transparency (Carvalho et al., 2019).	

Variable 4 aligns with supply chain integration and digital transformation theories, which emphasize that system interoperability and real-time data synchronization enhance cross-functional coordination and performance efficiency.

3.8 NVivo 12 Software in Data Analysis

NVivo 12 was the principal data management and analysis software used in this study. Developed by QSR International, NVivo is a specialized Computer-Assisted Qualitative Data Analysis Software (CAQDAS) designed to support researchers in organizing, coding, analyzing, and visualizing qualitative data efficiently. In qualitative research where vast amounts of textual information are collected NVivo serves as an essential tool to maintain analytical structure, transparency, and rigor without compromising interpretive depth (Bazeley & Jackson, 2019).

3.8.1 Role and Relevance of NVivo in This Study

In this research, NVivo 12 played a central role in managing data from semi-structured interviews, document reviews, and non-Informant observations. The mining organization generated a large volume of qualitative material including over 5 interview transcripts, 8 company documents, and detailed field notes. NVivo provided a systematic digital workspace that allowed the researcher to organize this complex dataset effectively, ensuring no information was lost or overlooked.

Through NV the researcher was able to:

1. Import and organize data sources All transcripts, notes, and documents were stored within a single database, ensuring consistency and easy retrieval.
2. Code and categorize themes NVivo's coding feature enabled the identification of key concepts such as inventory responsiveness, system integration, and supplier collaboration.
3. Link evidence across data types of Interview excerpts could be compared directly with company policy documents or field observations, enhancing data triangulation
4. Visualize relationships The software's visualization tools (e.g., word frequency, mind maps, and coding matrices) helped identify

recurring patterns and connections between MRO practices and supply-chain outcomes.

5. Maintain audit trails NVivo automatically logged coding and analytic activities, creating a transparent record of how themes and insights were developed.

By providing these capabilities, NVivo helped the researcher handle large volumes of qualitative information in a structured and replicable way a critical consideration in ensuring methodological transparency and trustworthiness (Woods, Macklin, & Lewis, 2016). NVivo, the researcher was able to

3.8.2 Enhancing Analytical Through NVivo

While NVivo assisted in data organization and analysis, it did not replace the researcher's interpretive role. The researcher remained the primary instrument of analysis, responsible for making conceptual and analytical judgments. NVivo functioned as a supportive analytical tool, helping to manage and visualize data systematically while allowing the researcher to focus on interpretation and meaning making.

As emphasized by Bazeley and Jackson (2019), NVivo enhances analytical

1. Improving the traceability of analytical decisions,
2. Supporting systematic coding consistency, and
3. Facilitating cross-validation between data sources.

In this study, NVivo 12 also contributed to credibility and confirmability, two of the key criteria of qualitative trustworthiness (Lincoln & Guba, 1985; Nowell et al., 2017). Every analytical step from initial coding to theme refinement was digitally traceable, allowing both transparency and replicability

3.8.3 Application in the Current Study

NVivo's utility became particularly valuable given the multi-source nature of this research. Because the MRO process involves multiple departments maintenance, procurement, warehouse, and supply chain NVivo allowed for the comparative analysis of stakeholder perspectives. For instance, the researcher used NVivo's "Matrix Coding Query" to examine how perceptions of inventory accuracy differed between maintenance engineers and procurement staff.

The software also facilitated theme validation through visual models, which mapped relationships between emerging categories. For example, "communication breakdowns" were often linked to "inventory delays" and "supplier constraints," forming part of a larger thematic network on system integration challenges. These visualizations helped the researcher synthesize findings more clearly and link them back to the conceptual framework developed in Chapter 2.

Through NVivo, the study achieved a higher level of analytical precision, ensuring that conclusions about MRO system performance were grounded in verifiable, systematically coded evidence rather than anecdotal interpretation.

Chapter 4 Data Analysis

4.1 Introduction

This chapter lays out what came out of the fieldwork on how MRO systems are implemented in a mining setting, and what that means for supply chain performance. As described in Chapter 3, the data came from three sources: semi-structured interviews with five Informants, a review of internal company documents, and non-Informant observation of day-to-day activities. The five interviewees were drawn from the functions most directly tied to MRO work Maintenance Engineering, Procurement, Warehouse and Inventory Control, Supply Chain Planning, and Reliability Engineering. Each one sees the system from a different angle, and putting their accounts side by side is what makes the picture complete.

The goal here is not just to repeat what people say. It is to make sense of it. Findings are presented variable by variable. Within each section, sub-themes are introduced, illustrated with direct quotes from Informants (coded I1 through P5 to protect their identity), and then cross-checked against what the documents and observations showed. Where the three sources line up, that strengthens the finding. Where they do not, that tension itself is worth examining, and the chapter does not try to smooth it over.

After the four variables have been worked through individually, the chapter steps back for a cross-variable discussion. This is where things get interesting, because in practice these four areas do not sit in separate boxes. A weakness in digital integration tends to show up as an inventory problem. Unclear roles bleed into cost issues. The cross-variable section tries to trace some of these links rather than treating each finding in isolation. A short triangulation summary then pulls together where the different data sources agreed and disagreed, which is important for showing that the conclusions are grounded in more than one type of evidence.

The chapter closes by circling back to the research questions from Chapter 1 and answering them directly, one by one, based on what the data showed. This sets up Chapter 5, where the conclusions and recommendations are developed. Throughout, the aim is to give an honest account of how MRO works on the ground in this mining operation not just the formal processes written down in policy documents, but also the workarounds, frustrations, and small everyday decisions that ultimately shape whether the system delivers on what it is supposed to do.

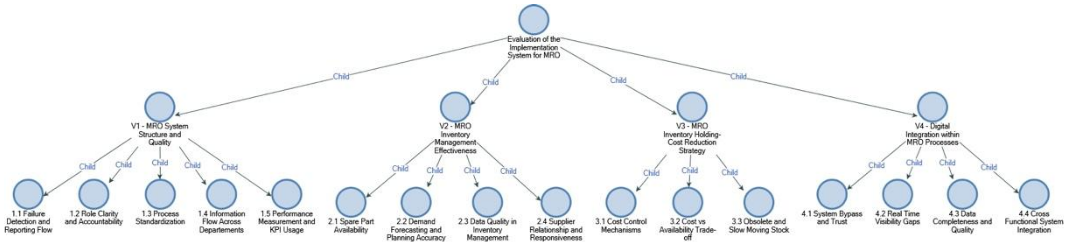


Figure 4.1 Project map for Evaluation of the MRO System

Source: NVIVO 12

4.2 Informant and Data Overview

Five professionals from a single large-scale mining organization participated in this study. They were selected through purposive sampling based on their direct involvement in MRO-related functions, with each Informant bringing a minimum of eleven years of operational experience. The diversity of their roles allowed the study to capture both the hands-on realities of maintenance work and the strategic considerations of planning and procurement.

A few words about the operation itself, because the setting matters for understanding the findings. Mine is in a remote part of Kalimantan. Getting there involves a domestic flight followed by a long drive on unpaved road. It runs around the clock, three shifts, and the fleet includes the kind of heavy equipment you would expect at an operation of this scale: haul trucks, hydraulic excavators, bulldozers, graders, plus fixed plant like crushers and conveyor systems. Keeping all that running is the core challenge. Most spare parts, especially OEM components, come from distributors in Jakarta or from overseas. A domestic order might arrive in a few days if things go well. An imported part can take weeks. That logistics reality puts enormous pressure on the MRO system. If the inventory is wrong or the forecast is missing, the site cannot just walk down the street and pick up what it needs. It waits. And while it waits, equipment sits idle, production slows, and costs climb. The physical environment adds another layer. Temperatures are high, dust gets into everything, and during wet season the rain is heavy enough to affect access roads and outdoor maintenance work. Equipment wears faster here than it would in a milder setting, which means maintenance intervals are not always predictable even when the schedules say they should be.

Table 4.1 Informant Profile Summary

Code	Role	Gender	Age	Last of Education	Experience	Department
I1	Maintenance Engineer	Male	46	Mining Engineering (Sarjana Teknik S. T)	12 years	Maintenance
I2	Procurement Officer	Female	43	Mining Engineering (Sarjana Teknik S. T)	13 years	Procurement
I3	Warehouse Controller	Male	50	Mining Engineering (Sarjana Teknik S. T)	15 years	Warehouse & Inventory
I4	Supply Planner	Female	47	Mining Engineering (Sarjana Teknik S. T)	11 years	Supply Chain Planning
I5	Reliability Engineer	Male	49	Mining Engineering (Sarjana Teknik S. T)	13 years	Reliability Engineering

In addition to the interview data, the study drew on internal company documents including maintenance standard operating procedures, preventive maintenance schedules, work order reports, inventory control sheets, stock movement logs, KPI dashboards, procurement records, and supplier performance evaluations. These documents provided a factual baseline against which Informant accounts could be compared. Field observation at the mining site offered a third source of evidence, allowing the researcher to see firsthand how workflows, communication patterns, and system interactions play out in practice.

The combination of these three data sources forms the evidentiary base for the thematic analysis that follows. Where findings are supported by more than one source, this convergence is noted to strengthen the credibility of interpretation.

Table 4.2 Source clustered by word similarity

File A	File B	Pearson correlation coefficient
Files\\I3_Warehouse_Inventory	Files\\I1_Maintenance_Engineer	0,534285
Files\\I2_Procurement_Officer	Files\\I1_Maintenance_Engineer	0,464067
Files\\I4_Supply_Planner	Files\\I3_Warehouse_Inventory	0,444225
Files\\I4_Supply_Planner	Files\\I1_Maintenance_Engineer	0,435376
Files\\P5_Reliability_Engineer	Files\\I4_Supply_Planner	0,417332
Files\\I3_Warehouse_Inventory	Files\\I2_Procurement_Officer	0,417318
Files\\P5_Reliability_Engineer	Files\\I3_Warehouse_Inventory	0,404792
Files\\I4_Supply_Planner	Files\\I2_Procurement_Officer	0,386734
Files\\P5_Reliability_Engineer	Files\\I1_Maintenance_Engineer	0,382211
Files\\P5_Reliability_Engineer	Files\\I2_Procurement_Officer	0,31571

The cluster analysis of sources by word similarity reveals that I3 (Warehouse Controller) and I1 (Maintenance Engineer) shared the most similar vocabulary across their interviews, with a Pearson coefficient of 0.534. This makes sense operationally, as these two functions interact most frequently during the daily cycle of spare parts requests and issuance. I2 (Procurement Officer) also showed moderate similarity with I1, reflecting the procurement function's direct involvement in responding to maintenance needs. P5 (Reliability Engineer) showed the lowest similarity with I2 (Procurement), at 0.316, which is consistent with the fact that these two roles occupy different ends of the MRO process reliability focuses on failure analysis and long-term equipment strategy, while procurement focuses on sourcing and supplier management. The overall spread of correlation values, ranging from 0.316 to 0.534, confirms that the five Informants brought genuinely different perspectives and vocabularies to the same set of questions, supporting the value of the multi-departmental sampling approach adopted in this study.

Figure 4.2 Word Map

4.3 Findings by Research Variable

The following sections present the findings organized around the four research variables. Each variable is discussed through the sub-themes that emerged during thematic analysis in NVivo 12. Informant quotations are used throughout to ground the interpretations in the voices of those who work within the MRO system.

4.3.1 MRO System Structure and Quality

The first research examines how the MRO system is structured, how roles and responsibilities are defined, and how well processes are standardized and communicated across departments. Five sub-themes emerged from the analysis of Informant responses, document review, and field observation.

A. Failure Detection and Reporting Flow

The way equipment failures are detected and reported sets the tone for everything that follows in the MRO cycle. Across the interviews, a consistent picture emerged: the initial signal almost always comes from the field rather than from any centralized monitoring system. I1 described how operators on the ground are typically the first to notice something wrong, whether through sound, vibration, or simply a feeling that the machine is behaving differently. In his words, the first sign usually comes from the field, not from the office. Operators call if they hear unusual sounds, vibrations, or feel the machine is not running normally.

Technicians also play a detection role during routine inspections, catching issues that operators might not notice.

Once a problem is identified, a triage decision follows. I1 explained that the team checks whether the issue can wait until the next planned maintenance window or whether immediate action is required. This decision happens quickly and often informally it depends more on experience and gut feeling than on any structured decision matrix. On the reliability side, P5 noted that failure data is mostly captured through maintenance work orders but added that deeper analysis is only triggered when the situation warrants it. The implication is that routine failures may not always receive the analytical attention they deserve, which creates gaps in the organization's ability to learn from repeated issues.

Document review supported these accounts. Preventive maintenance schedules and work order templates were in place, but the actual reporting flow appeared to rely heavily on informal communication rather than the formal pathways documented in SOPs. What the researcher saw during the site visit lined up with what Informants described. At one point during the workshop observation, an excavator came in with a hydraulic problem. The operator did not file a report or enter anything into the system first. He walked straight to the maintenance bay, found the lead technician, and explained the issue mostly with hand gestures and by imitating the sound the machine was making. The technician took a look, talked briefly with a colleague standing nearby, and started pulling tools together. No work order had been opened yet. Near the workshop entrance there was a whiteboard listing the day's planned jobs, but this unplanned arrival was handled entirely through conversation. The system would catch up later. That scene captured, in about ten minutes of real time, exactly the dynamic I1 was describing: the field moves first, and the formal process follows.

B. Role Clarity and Accountability

When asked about how responsibilities are divided, Informants painted a picture with two distinct modes. Under normal operating conditions, the division of labor is reasonably clear. I1 stated that in normal conditions it is clear enough maintenance identifies what is needed, warehouse checks stock, and procurement handles external purchase if necessary. I3 echoed this by confirming that the warehouse team is responsible for updating every stock movement.

The picture changes considerably during urgent breakdowns. I1 was candid about this shift, explaining that when a breakdown happens during production hours, nobody really waits in sequence. Maintenance calls warehouse immediately, warehouse may already be calling procurement, and procurement sometimes asks for technical details while the maintenance team is still in the field. As I1 put it, the responsibility is there, but in urgent situations people work more based on response speed than formal order. I2 reinforced this from the procurement side, noting that for urgent breakdown cases, the urgency sometimes becomes more important than the purchase value because the production impact can be much bigger than the purchase amount itself.

A third dimension of role clarity concerns data accuracy. I3 acknowledged that while the warehouse team is responsible for system updates, accuracy ultimately depends on discipline during issue and receipt. If one movement is delayed in recording, the discrepancy shows up later. P5 added that failure coding is already standardized, but field input still varies depending on who closes the report. These observations suggest that while formal accountability structures exist, the consistency of execution varies significantly depending on the individual and the circumstances.

C. Process Standardization

Every Informant acknowledges that formal standards and procedures exist within their department. However, a recurring theme was the gap between what is written down and what happens in practice. I1 noted that preventive maintenance schedules are set, but field judgment still plays a big role. The same equipment type does not always behave the same because one unit may work under heavier load than another. Sometimes the schedule says the equipment is still safe, but from experience, the team already knows it should be checked earlier.

This pattern of formal standards being supplemented or overridden by experience-based judgment appeared across departments. I3 mentioned that inventory is already separated by movement and criticality, but in daily operations people still rely a lot on experience because not every item behaves exactly according to classification. From the procurement side, I2 observed that procedures are standardized on paper, but in practice, the item category changes the speed. Fast-moving items with regular suppliers are straightforward, while imported or technical items usually need more back and forth. I4 confirmed the same dynamic in planning: for fast-moving items, the methodology is more structured, but for irregular parts, judgment still dominates.

What emerged from these accounts is not a failure of standardization per se, but rather a system where standards serve as a starting point that is routinely adjusted based on contextual knowledge. Whether this flexibility is a strength or a vulnerability depends on how well the adjustments are documented and communicated and the evidence suggests that this documentation often lags the actual decisions being made.

D. Information Flow Across Departments

One of the most consistent findings across all five interviews was the preference for informal communication channels, especially during urgent situations. I1 was direct about this: for urgent things, it is still by phone or direct talk. The system helps with recording, but when equipment is down, people do not wait for screen updates. I2 described a similar pattern from the procurement perspective, explaining that for urgent cases, the first few minutes are usually spent calling people rather than opening too many screens, because the team needs to understand how urgent the request really is.

Beyond the choice of communication channel, Informants highlighted a deeper issue: the quality of information flowing between departments significantly affects downstream speed and accuracy. I2 offered a revealing observation about how timing works in MRO purchasing. The delay is not only about supplier speed, but sometimes the earlier part of the process already takes time because technical clarification moves back and forth before procurement can really act. From outside, it may look like purchasing is slow, but often the delay starts before the purchase order is even created. I4 reinforced this from the planning side, noting that planning quality depends on upstream consistency. Even a good planning model becomes weak if maintenance signals arrive too late or too differently each time.

These findings point to a systemic issue where formal information architecture does not match the speed and flexibility that operations demand. The workaround informal, phone-based communication is effective in the short term but creates its own problems: decisions are not always recorded, institutional memory is lost, and the same clarification cycles repeat themselves because solutions are not captured in the system.

The researcher saw a version of this in the planning office. One of the supply planners had two screens going. The left one showed the ERP system. The right one had an Excel spreadsheet, a locally kept tracker for delivery dates and open purchase requests. When asked about the spreadsheet, the planner shrugged and said the system does not always update fast enough, so we keep our own version. It was not a secret. It was just how things worked. On the wall behind the desk, a printed maintenance schedule for the week had been annotated by hand. Someone had crossed out two jobs and added a note in the margin about a rescheduled inspection. None of those changes were visible in the digital system yet. These are small details, but they tell a bigger story. The formal system and the real workflow are not the same thing. People bridge the gap with their own tools, their own spreadsheets, their own handwritten notes. It works, mostly, but it means a lot of operational knowledge lives outside the system where nobody else can see it or learn from it.

E. Performance Measurement and KPI Usage

Each department tracks its own set of performance indicators, and Informants were generally clear about which metrics matter most to them. I1 identified equipment availability and downtime as the primary concerns, noting that production immediately sees those numbers and questions come very quickly when a critical machine stops. I2 focused on lead time and supplier delivery performance. I3 emphasized stock accuracy as the foundation of warehouse performance. I4 pointed to forecast accuracy and service level, while P5 tracked MTBF and recurring failure patterns.

What was more interesting than the KPIs themselves was how they are generated and used. I1 explained that while KPI data comes partly from the system, the team still checks manually before reviews because numbers alone do not explain what really happened. I2 described a similar process, looking at exceptions manually because one delayed purchase order can have different causes. This manual verification suggests that Informants do not fully trust the system-generated data to tell the complete story, which connects back to the data quality issues discussed under other variables.

When KPI numbers deteriorate, the response follows an escalation pattern. I1 describes how a discussion with the supervisor comes first, and if the problem keeps repeating, the reliability team gets involved for deeper analysis. P5 confirmed that when a failure pattern persists, the replacement interval or maintenance approach is reviewed. These responses suggest that KPIs do function as triggers for action, but the action tends to be reactive rather than preventive problems need to repeat before they receive systematic attention.

Stepping back from the individual sub-themes, two theoretical perspectives help make sense of what the data is showing. Manenzhe, Bevis, and Gouws (2023) argue, through what they call Maintenance Management Process Theory, that maintenance effectiveness depends on structured workflows, clear responsibilities, and governance that holds people accountable. On the surface this organization meets those conditions. Workflows exist. The roles are documented. The KPIs are tracked. But the evidence keeps pointing to the same problem: under pressure, the structure bends. Field judgment overrides the schedule. Roles blur. Phone calls replace system notifications. That bending is not random. It follows a pattern, and the pattern is better explained by Socio-Technical Systems Theory, the framework Siyad and Khayal (2025) use to argue that performance comes from the fit between technical systems and social systems. In this mining operation, the two are not well matched. The technical side, the ERP, the CMMS, the SOPs, is designed for orderly, sequential processing. The social side, the people, the relationships, the experience, is optimized for speed and flexibility under uncertainty. When those two logics collide, which happen every time there is an unplanned breakdown, the social system wins. People do what works, not what the system prescribes. That is not a problem with people. It is a design problem. The technical system has not yet earned the trust and speed that the operational reality demands.

4.3.2 MRO Inventory Management Effectiveness

The second research variable explores how effectively spare parts inventory is managed and how inventory practices support or hinder operational continuity. Four sub-themes emerged from the data.

A. Spare Part Availability

Across all departments, spare part availability emerged as the single most discussed operational concern. I1 was blunt about where the real bottleneck lies most often it is spare parts. Manpower can be ready, equipment can already be isolated, but if one component is missing, then everything shifts. This statement captures a frustration that was echoed, in different ways, by every other Informant.

I3 noted that critical stockouts do not happen very often, but when they do, the cause is usually unexpected usage or delayed replenishment. The infrequency of stockouts does not diminish their impact I2 described a case where a motor component failed during operation with no local stock available. Because the equipment was critical, the item had to be sourced immediately, and freight costs became unusually high because delivery speed was more important than price. That single incident illustrates how one missing part can cascade into significant unplanned expenditure.

I1 also described a case where the system showed a bearing as available, but when the warehouse was checked physically, the item was not in the expected rack. It turned out that part of the stock had already been moved and not updated in the system. I3 confirmed that stock accuracy is the main indicator the warehouse watches, adding that if system and physical stock do not match, everything else becomes difficult. These accounts reveal that spare part availability is not just a matter of whether parts have been purchased, it is equally about whether the system accurately reflects what is physically present and where.

The warehouse visit made this tangible. It is a big, semi-enclosed building. Heavy items like final drives, swing bearings, and hydraulic cylinders sit on the ground level. Smaller parts, filters, seals, electrical components, go on the upper racks. Most bins had barcoded labels tied to the inventory system, but not all of them. Some labels were handwritten and starting to fade, which does not help when someone is in a hurry looking for a specific part number. At one point the researcher watched a warehouse operator handle an urgent request. He checked the system on his handheld device. Then he walked over to the physical location to make sure the item was there. Then he radioed maintenance to confirm. That double-check, system first then eyes on the shelf, added a few minutes to the process. But in a place where the nearest alternative source for a critical excavator bearing is a distributor in Jakarta, three to five days away if you are lucky, nobody is willing to trust a screen when a wrong answer means days of downtime. That extra walk to the shelf is the tax the organization pays for not fully trusting its own data.

B. Demand Forecasting and Planning Accuracy

I4 provided the clearest picture of how demand planning works and where it breaks down. For planned shutdowns, the demand signals from maintenance are usually reliable. The real challenge comes from unplanned failures, which change demand very quickly and in ways that the forecast cannot anticipate. I4 described a period when actual usage moved much faster than expected because one equipment family experienced repeated issues earlier than planned. That kind of demand spike throws off not just the immediate replenishment cycle but also the planning assumptions for subsequent periods.

The ripple effects of forecast misses extend beyond inventory. I4 noted that one shipment delay can immediately affect reorder timing for several items, creating a chain reaction that destabilizes the supply pipeline. When forecast repeatedly misses for the same category, the reorder logic is reviewed but this review happens after the damage is done, not before. The system learns, but slowly, and often only after operational disruption has already occurred.

C. Data Quality in Inventory Management

Data quality emerged as a foundational issue that cuts across almost every other finding. I3 identified duplicate material codes as one of the most persistent problems, explaining that the same item sometimes enters under slightly different naming. This creates confusion during stock checks, makes consumption history unreliable, and complicates forecasting. Beyond duplicates, I3 raised an issue that others had not mentioned: location discipline. People often focus on stock quantity, but location discipline is equally important. A part can exist, but if the location record is not precise, the response still becomes slow.

Both I1 and I3 independently identified data quality as the single most important area for improvement. When asked what their first step would be if they were leading an improvement effort, I1 said he would start with basic data quality because many issues eventually come back to that. I3 said essentially the same thing clean material master data and storage discipline together, because many small daily issues usually come from there. The convergence of these two perspectives, from different departments with different daily concerns, is one of the strongest findings in this study. It suggests that data quality is not a technical side issue but the central bottleneck around which many other MRO inefficiencies revolve.

D. Supplier Relationship and Responsiveness

Supplier dynamics received less attention in the interviews than internal processes, but I2's account offered meaningful insight. For major suppliers, the relationship has moved beyond transactional. I2 described how some suppliers already understand the company's operational urgency and know that when certain item categories appear in an order, the site needs fast response. This kind of supplier familiarity reduces the need for lengthy explanations during urgent procurement and can shorten lead times significantly.

However, this relational advantage applies primarily to major, established suppliers. For less frequently purchased items or new supplier relationships, the procurement process remains more cumbersome and time-consuming. The implication is that supplier collaboration, while valuable, is unevenly distributed across the MRO portfolio and may not cover the long tail of less common but potentially critical spare parts.

The theoretical perspective that fits most naturally here is Spare Parts Inventory Theory, specifically the framing by Hu, Boylan, Chen, and Labib (2018), who argue that effective spare parts management is fundamentally about balancing service level against inventory cost. That tension showed up clearly in the interviews. Stockouts happen not because someone decided to understock but because the data feeding the stocking decisions is unreliable. Duplicate codes, wrong locations, inconsistent naming. The forecasting challenge is real too, especially for unplanned demand, but even a good forecast cannot fix bad master data. If the system thinks you have three bearings when you have one, no amount of planning sophistication will prevent the stockout. That is why I1 and I3 both pointed to data quality as their top priority, independently and from completely different departments. They are seeing the same root cause from different angles.

On the supplier side, Siyad and Khayal (2025) argue that collaborative supplier relationships improve maintenance reliability through better lead times, information sharing, and technical support. The evidence here partially supports that. Major suppliers who have worked with the company for years do provide faster, more responsive service. I2 described suppliers who already know what a particular order pattern means and respond accordingly, without needing a long explanation. But that advantage only extends to a handful of key suppliers. For the rest of the MRO portfolio, the less common items, the new supplier relationships, and procurement still operate in a more transactional mode. The collaborative benefit is real but narrow. That unevenness is a vulnerability that the current approach does not systematically address.

4.3.3 MRO Inventory Holding-Cost Reduction Strategy

The third research variable examines how the organization manages the tension between keeping enough stock to avoid downtime and keeping costs under control. Three sub-themes emerged.

A. Cost Control Mechanisms

The primary cost control tools described by Informants were framework agreements and blanket purchase arrangements. I2 explained that for repeated items, framework agreements reduce purchasing cycle time and usually make pricing more stable. Blanket arrangements also help because demand does not need a full sourcing process all the time. These mechanisms are well-established and appear to work effectively for high-frequency, predictable items.

From the warehouse side, I3 described a different type of cost control: periodic review of minimum stock levels. The team checks whether actual movement still justifies the current stocking level and adjusts accordingly. This review process is important but, based on I3’s description, appears to be more reactive than proactive, it catches misalignments after they have developed rather than preventing them.

B. Cost versus Availability Trade-off

The tension between cost efficiency and operational availability ran through several interviews as a persistent dilemma. I2 framed the decision simply: the team looks first at how critical the item is, and if downtime exposure is high, availability usually wins. I4 described the same trade-off from the planning perspective, noting that building safety stock earlier helps manage long lead times, but too much safety also creates holding cost discussions with management.

I1 added an important nuance that complicates cost-based decision-making. Technical urgency is not always visible from item value. Sometimes a small, inexpensive component causes bigger operational risk than an expensive equipment part. This observation challenges the common practice of prioritizing inventory investment based on item cost a cheap bearing that causes a production stoppage may deserve more stocking attention than an expensive component with a predictable replacement cycle. The mismatch between item value and operational criticality is a gap that the current system does not fully address.

C. Obsolete and Slow-Moving Stock

I3 described a problem that many asset-intensive organizations face with old parts accumulate in the warehouse because the associated equipment still technically exists, even if usage is rare. Nobody wants to release them because they may still be needed one day. This “just in case” mentality is understandable from a risk perspective, but it ties up warehouse space and capital in items that may never be used.

The identification process for obsolete stock relies on aging reports, which are then discussed with maintenance to determine whether items are still relevant. This process works but is inherently slow and conservative maintenance teams are naturally reluctant to approve the disposal of parts that could, theoretically, be needed in a future breakdown. The result is a gradual accumulation of non-moving stock that erodes inventory efficiency over time without any single dramatic event triggering attention.

The researcher saw physical evidence of this during the warehouse visit. In the far section of the building, several storage bays held components that were visibly dusty, some still in original packaging that had yellowed from prolonged storage. The warehouse controller, walking alongside, pointed to a set of undercarriage parts for an older bulldozer model. They had been there for over three years. No movement. The bulldozer was still in the fleet register but had been reassigned to light duties with minimal hours. Maintenance had not formally requested disposal because the machine technically still existed. What if it breaks down next quarter? That question, even when the probability is low, is enough to keep parts on the shelf indefinitely. It is a reasonable instinct at the individual level, but at the system level it means capital and space are tied up in items that will most likely never be used.

Werbinska-Wojciechowska, Grabowski, and Dziula (2025) describe lean maintenance as a philosophy of continuously eliminating waste from inventory and maintenance processes. The idea is straightforward: do not hold more than you need, review regularly, and cut what is not adding value. This organization applies to some of those ideas. Framework agreements and blanket POs reduce transaction costs. Minimum stock reviews catch some misalignments. But the application stops short of what lean principles require. The clearest example is the obsolete stock problem. Lean thinking would say: if a part has not moved in three years and the equipment it serves is barely operational, dispose of it and free up the capital and warehouse space. But that is not what happens. The parts stay because nobody wants to be responsible for releasing something that might, maybe, someday be needed. That reluctance is understandable from a risk perspective, but it is the opposite of lean.

There is another angle worth noting. Basten and van Houtum (2014) point out that inventory optimization in asset-intensive settings requires going beyond cost-based classification. I1 made a similar observation from the field: a cheap bearing can cause a bigger production disruption than an expensive component with a long, predictable lifecycle. Standard ABC analysis, which ranks items by purchase value, misses that kind of operational risk. Criticality-based approaches are better suited, but the evidence suggests this organization has not fully made that shift yet. The gap between what inventory theory recommends and what the operation does is a space where targeted improvement could deliver real savings without putting reliability at risk.

4.3.4 Digital Integration within MRO Processes

The fourth research variable explores how well digital systems such as ERP and CMMS connect the various functions involved in MRO and whether the technology supports or hinders coordination. Four sub-themes emerged.

A. System Bypass and Trust

One of the most telling findings of this study is the extent to which users bypass the formal system during urgent situations. I1 was candid: before looking too much at the system, people often call warehouse directly because they need quick confirmation. This is not a failure of training or awareness it is a rational response to a system that does not deliver information fast enough when decisions need to be made in minutes, not hours.

The underlying issue is trust. I1 identified what he considers the single biggest improvement opportunity to make stock status fully reliable. If maintenance can trust what appears in the system, many decisions become faster. I2 confirmed this gap from the procurement side, noting that the request appears in the system, but sometimes the urgency is not fully visible there, requiring direct confirmation to understand whether the request is routine or already affecting operation. When the system cannot reliably convey both the factual status (what is in stock) and the contextual urgency (how badly it is needed), users default to human channels. The system becomes a record-keeping tool rather than a decision-support tool.

The researcher saw this play out during the visit. In the maintenance planning room, there were multiple workstations with the CMMS open on screen. But when a breakdown came in, the supervisor's first move was to grab the two-way radio and call the warehouse. Not the system. The radio. Afterward, the researcher asked him about it. His answer was matter of fact: calling is faster, and I need to know right now whether the part is on the shelf, not what the screen says. There was no embarrassment about it. It was just how things are done when time matters. The system got updated later, once things calmed down. That lag between the real action and the system record is exactly what I1 was talking about. And it is not carelessness. It is a rational choice by someone who has learned, through experience, that the system is not fast enough or reliable enough to be the first thing you reach for when a machine is down.

B. Real-Time Visibility Gaps

Closely related to the trust issue is the gap between physical reality and system records. I3 explained that the system is not always fully real-time sometimes physical movement happens first, and the system follows shortly after. I1 described the same pattern from the maintenance side: documentation comes later because the priority is always getting the equipment stable again. Both statements describe a system that consistently lags actual operations.

I4 identified a specific piece of missing information that would improve planning significantly: real-time consumption trend linked to maintenance activity. Without this visibility, planning decisions rely on historical averages that may not reflect current operating conditions. I4 added that while the connection between maintenance plans, failure history, and procurement cycles exists, it is not fully seamless sometimes information sits in different places and needs to be manually assembled. This fragmentation forces planners to spend time gathering data rather than analyzing it.

C. Data Completeness and Quality

Incomplete data emerged as a challenge that affects multiple departments simultaneously. I2 described how purchase requisitions frequently arrive without adequate technical specifications. The material code is there but the technical note is still too general. When the description is too broad, the supplier asks back, and once that happens, the timeline already shifts. Each clarification cycle adds days to the procurement process, and the root cause is not supplier slowness but information gaps at the point of origin.

P5 described a parallel problem with failure data. Sometimes the failure description is too short, so later analysis becomes more difficult than it should be. Incomplete failure records increase reliance on assumptions during reliability analysis because not all technical context is captured. I1's earlier observation about documentation lag connects here as well when work orders are closed after the fact, the details recorded may be less precise than if they had been captured in the moment.

Together, these data completeness issues create a compounding effect. Incomplete failure records led to weaker reliability analysis, which leads to less informed spare parts planning, which leads to either stockouts or overstocking. The chain starts with a technician who does not have time to write a thorough failure report and ends with a supply chain that cannot optimize its inventory.

D. Cross-Functional System Integration

The final sub-theme under digital integration concerns how well information flows between systems and departments. P5 provided the most direct assessment: reliability findings do not always immediately change stock decisions. Spare part decisions are often made based on usage history, while failure behavior can tell a different story. A part may not move often, but if it is linked to a high-impact failure, then the discussion should be different. This disconnect between reliability analysis, and inventory planning represents a missed opportunity the data exists, but it does not flow into the decisions where it would be most useful.

P5 identified this as his priority for improvement: making failure history more actively used in planning decisions. Now the data exists, but not always in a way that directly influences stocking or maintenance timing. If that connection becomes stronger, decisions will probably be more preventive instead of reactive. Both I3 and P5 agreed that better system connectivity would reduce manual cross-checking. I3 anticipated less checking between screens and fewer manual confirmations, while P5 expected that analysis would move faster because fewer manual cross-checks would be needed.

Two theoretical frameworks are useful for interpreting these findings. Haddud, DeSouza, Khare, and Lee (2017), writing about Supply Chain Integration Theory, argue that integrated information systems improve performance by giving different functions shared visibility into the same data. The infrastructure for that exists here. Both ERP and CMMS are in place. Data does move between maintenance, procurement, warehouse, and planning. But the integration has holes. Stock levels are not always current. Urgency does not transmit well through the system. Reliability data sits in its own silo and rarely influences stocking decisions. Those gaps matter because they are exactly the gaps that push people away from the system and toward the phone.

Carvalho et al. (2019) make a useful distinction in their work on digital transformation. They argue that installing technology is not the same as achieving transformation. Transformation happens when digital tools are embedded into actual decision-making, when data flows naturally from capture to action without requiring someone to manually bridge the gap. By that standard, this organization is partway there. Technology captures data. But it does not yet deliver it at the speed and reliability people need when equipment is down and decisions are urgent. So, they work around it. Not because they dislike technology or resist change, but because technology has not yet closed the gap between what it promises and what it delivers in practice. The system bypass behavior is not a failure of adoption. It is a signal that technology still needs to catch up to the demands of the operation.

4.3.5 NVivo Analytical Findings

Beyond the thematic coding of individual responses, NVivo 12 was used to run three analytical procedures that look at the data rather than answer by answer: the matrix coding query, the cluster analysis of nodes by word similarity, and the cluster analysis of nodes by coding similarity. Each one surfaces a pattern that is hard to see when reading transcripts one at a time, and together they add a systematic layer of evidence that supports the qualitative findings presented above.

4.3.5.1.Matrix Coding Query: How Themes Distribute Across Informants

The matrix coding query crosses the sub-theme nodes against the five Informants, showing how many coded references each Informant contributed to each theme. It reveals which themes were shared across the group and which were concentrated in a single function.

The clearest shared theme was department-specific KPIs, which drew references from all five Informants (two from I1 and one each from I2, I3, I4, and P5). This was the only theme every Informant touched, which makes sense because performance measurement is something each function deals with directly. After that, the distribution becomes more concentrated. Stock data mismatch was raised most heavily by I1 (three references) with support from I3 (one reference), confirming that the data accuracy problem is felt most acutely where maintenance meets the warehouse. System bypass during urgency came entirely from I1 (two references), the engineer who decides in the moment whether to trust the screen or pick up the phone.

Some themes were tied to a single role. Forecast miss triggers downstream instability appeared only in I4 (two references), the supply planner who lives with the consequences of a bad forecast. Incomplete failure descriptions appeared only in P5 (two references), the reliability engineer who consumes whatever the technician records. Incomplete technical specification in request appeared only in I2 (two references), the procurement officer who must chase clarification before a purchase can move. This concentration strengthens the analysis rather than weakening it, because it shows each Informant spoke from genuine functional experience. The themes landed where the operational pain is felt.

Table 4.3 Matrix coding query: theme distribution across Informants

	I1_Maintenance_Engineer	I2_Procurement_Officer	I3_Warehouse_Inventory	I4_Supply_Planner	I5_Reliability_Engineer
1 : Operator initiated failure detection	0	0	0	0	0
2 : Technician initiated failure detection	1	0	0	0	0
3 : Triage between urgent and planned response	1	0	0	0	0
4 : Role boundaries blur during urgency	0	0	0	0	0
5 : Roles clear under normal conditions	0	0	0	0	0
6 : Unclear ownership of data accuracy	0	0	0	0	0

7 : Formal standards exist but field judgment overrides	0	0	0	0	0
8 : Standardization varies by item category	0	0	0	0	0
9 : Informal channels preferred for urgent matters	0	0	0	0	0
10 : Upstream information quality affects downstream speed	0	0	0	0	0
11 : Departement specific KPIs	2	1	1	1	1
12 : KPI generation involves manual verification	1	1	0	0	0
13 : KPIs trigger escalation and review	1	0	0	0	1
14 : Delay impact on operations	1	0	0	0	0
15 : Spare part shortage as primary bottleneck	1	0	1	0	0
16 : Stock data mismatch causing delays	3	0	1	0	0
17 : Forecast miss triggers downstream instanbility	0	0	0	2	0
18 : Planned demand is reliable but unplanned	0	0	0	1	0

demand disrupts					
19 : Duplicate material codes	0	0	0	0	0
20 : Location discipline affects response speed	0	0	0	0	0
21 : Material master data as root cause	1	0	0	0	0
22 : Key suppliers understand operational urgency	0	1	0	0	0
23 : Framework and blanket agreements	0	0	0	0	0
24 : Minimum stock periodic review	0	0	0	0	0
25 : Criticality determines priority between cost and availability	0	1	0	1	0
26 : Item value does not always reflect operational risk	1	0	0	0	0
27 : Aging reports as identification tool	0	0	1	0	0
28 : Old stock retained due to uncertainty	0	0	1	0	0
29 : System bypassed during urgency	2	0	0	0	0

30 : System data not fully trusted	0	1	0	0	0
31 : Missing real time consumption data	0	0	0	0	0
32 : Physical movement ahead of system update	1	0	0	0	0
33 : Documentation lag after repairs	1	0	0	0	0
34 : Incomplete failure descriptions	0	0	0	0	2
35 : Incomplete technical specification in request	0	2	0	0	0
36 : Fewer manual steps if system connected	0	0	0	0	0
37 : Reliability data not feeding into planning decisions	0	0	0	0	1

4.3.5.2. Cluster Analysis of Nodes by Word Similarity

The word similarity cluster group's themes by how similar the language was that Informants used when discussing them. Themes sitting close together on the dendrogram were talked about with overlapping vocabulary, suggesting they belong to the same area of concern.

Several groupings support findings discussed earlier in this chapter. KPI generation involves manual verification and role boundaries blur during urgency cluster together, both describing situations where the formal system is not enough on its own and human judgment fills the gap. Informal channels preferred for urgent matters and key suppliers understand operational urgency cluster closely, linking internal communication workarounds with external supplier responsiveness through the shared thread of urgency. A large middle cluster brings together inventory themes such as planned versus unplanned demand, spare part shortage, delay impact, and forecast miss, confirming that Informants experience these as one connected inventory problem. Toward the bottom, system bypass during urgency, item value does not reflect operational risk, documentation lag, and physical movement ahead of system update group together, capturing the gap between what the system records and what happens on the ground.

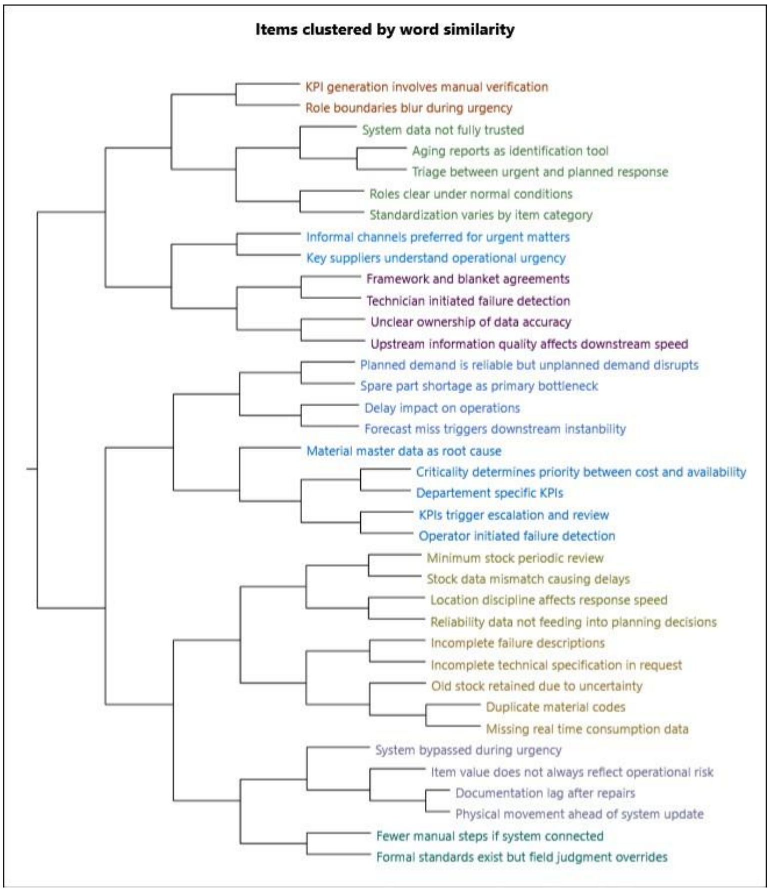


Figure 4.3 Item clustered by-word similarity

4.3.5.3. Cluster Analysis of Nodes by Coding Similarity

The coding similarity analysis group's themes that were coded to the same passages of text. When an Informant discusses one theme and another in the same breath, those themes show high coding similarity, revealing which problems are experienced together in real situations.

The dendrogram shows a tight cluster linking fewer manual steps if system connected, incomplete failure descriptions, and reliability data not feeding into planning decisions. These digital integration themes co-occur in the same passages, supporting the finding that Informants experience system connectivity as one interconnected shortfall rather than separate features. A second cluster groups the inventory data themes: location discipline, minimum stock review, old stock retained due to uncertainty, aging reports, and duplicate material codes all appear together, directly reinforcing the cross-variable finding that data quality is the common thread. A third cluster links role clarity themes such as formal standards versus field judgment, informal channels, and role boundaries blurring, confirming that Informants discussed structure and role questions as a connected set.

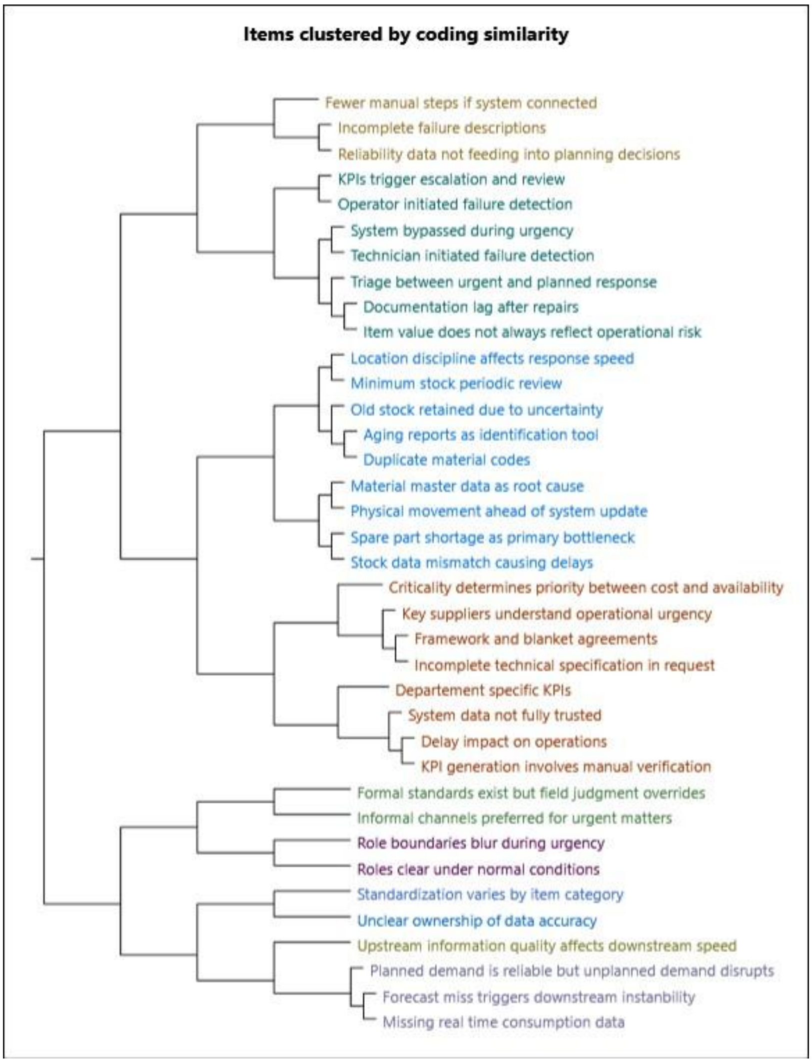


Figure 4.4 Item clustered by coding similarity

4.3.5.4.What the NVivo Analysis Adds

Taken together, these procedures do something by reading transcripts alone cannot. The matrix query shows the findings are grounded in functional experience, with each theme landing where the operational consequence is felt. The word similarity clustering shows Informants used shared language around urgency, data, and system gaps, suggesting these are recognized patterns rather than isolated complaints. The coding similarity clustering shows the problems co-occur in practice, which is the strongest evidence for the cross-variable interconnections discussed in the next section. None of this replaces the qualitative depth of the interview quotes. It provides a second, systematic line of evidence that the patterns identified through close reading are real and consistent across the dataset.

4.4 Cross-Variable Analysis

When the four research variables are examined together rather than in isolation, several important interconnections become visible. These connections help explain why improving any single dimension of MRO performance is difficult without also addressing the others.

4.4.1 Data Quality as the Common Thread

The most striking cross-variable pattern is the central role of data quality. Under V1, Informants described how documentation often lags actual operations and how failure coding varies by individual. Under V2, stock data mismatches and duplicated material codes emerged as direct causes of delays. Under V3, the inability to identify truly obsolete stock is partly a data problem. Under V4, incomplete specifications and failure descriptions slow down procurement and reliability analysis. In every variable, data quality appeared not as a secondary concern but as a foundational issue that amplifies problems across the entire MRO system.

The fact that I1 (maintenance) and I3 (warehouse) independently identified data quality as their number one priority for improvement strengthens this finding. These are two professionals from different departments, with different daily pressures and different relationships with the MRO system, arriving at the same conclusion. This convergence suggests that data quality is not merely one problem among many but the central bottleneck around which other inefficiencies revolve.

4.4.2 The Urgency Paradox

A second cross-variable pattern involves how urgency distorts normal operating procedures. Under V1, role boundaries blur when breakdowns occur during production hours. Under V2, unplanned failures disrupt demand forecasting. Under V3, the cost-versus-availability trade-off is resolved almost automatically in favor of availability during emergencies, regardless of cost. Under V4, the formal system is bypassed entirely when equipment is down.

This creates what might be called an urgency paradox: the situations where the system is most needed (breakdowns, stockouts, production stoppages) are precisely the situations where the system is most likely to be bypassed. The MRO system works adequately during normal operations, but it does not have the speed, reliability, or contextual awareness to support decision-making during the moments that matter most. Informants have adapted by building informal workarounds phone calls, direct conversations, experience-based judgments that are effective in the short term but invisible to the formal system and therefore lost as organizational learning.

4.4.3 Upstream Quality Determines Downstream Performance

A third pattern concerns the directional flow of information quality through the MRO chain. Both I2 and I4 emphasized that downstream performance depends heavily on the quality of upstream inputs. When maintenance signals arrive late or with insufficient detail, procurement cannot act quickly, planning cannot forecast accurately, and the warehouse cannot prepare effectively. The delay is often attributed to the most visible downstream function (usually procurement or logistics), but the root cause frequently lies in the initial information provided by maintenance or engineering.

This upstream-downstream dynamic has implications for how improvement efforts should be structured. Investing in procurement speed or warehouse technology may yield limited returns if the input quality from maintenance remains inconsistent. The findings suggest that improvement initiatives should start at the point where information originates and work forward through the chain, rather than targeting the most visible symptom of delay.

4.4.4 Theoretical Implications of Cross Variable Patterns

The three patterns described above are not just operational observations. They connect back to the theoretical foundations laid out in Chapter 2, and in some cases, they extend or complicate what those theories predict.

Start with the data quality pattern. Manenzhe, Bevis, and Gouws (2023) argue that structured maintenance processes drive reliability. They are right, as far as it goes. But the evidence from this study adds something that their framework does not emphasize strongly enough: process discipline is only as good as the data it runs on. A perfectly governed maintenance workflow that draws on inaccurate material codes, wrong stock locations, and incomplete failure descriptions will still produce stockouts, procurement delays, and missed forecasts. The process looks disciplined, but the outputs are unreliable because the inputs are flawed. Future applications of Maintenance Management Process Theory would benefit from treating data quality not as a background condition but as a primary variable.

The urgency paradox maps directly onto Socio-Technical Systems Theory, the framework Siyad and Khayal (2025) use to explain what happens when technical and social systems are out of alignment. STS theory predicts that when the formal system cannot keep up with operational demands, people build workarounds. That is precisely what the evidence shows. The informal system of phone calls, radio messages, and experience-based shortcuts runs parallel to the formal digital system and takes over whenever time pressure is high. Here is the problem with that: the informal system is effective for solving immediate problems, but it is invisible. Breakdowns resolved through a radio call do not generate the structured data that reliability analysis, demand forecasting, and inventory planning depend on. Each time the formal system is bypassed, the organization solves today's problem but loses tomorrow's learning opportunity. STS theory explains the mechanism, but existing MRO literature has not explored this consequence, the erosion of organizational learning, in enough depth for mining contexts. The urgency paradox is not just about speed. It is about what the organization fails to capture when speed takes priority over documentation.

The upstream-downstream pattern validates what Haddud et al. (2017) describes in Supply Chain Integration Theory: that integration failures at any single point propagate across the entire chain. Rojas, Fernandez, and Herrera (2025) make a similar argument through Supply Chain Performance Theory, framing reliability, responsiveness, and cost efficiency as outcomes that depend on the quality of coordination across functions. The evidence from this study gives those arguments a concrete, grounded illustration. When a technician closes a work order with a three-word failure description, the ripple goes far. The reliability engineer cannot analyze the pattern. The planner cannot forecast the replacement. The procurement officer cannot source efficiently. The warehouse cannot be prepared. Every downstream function pays a price for incomplete information upstream.

Table 4.4 Item clustered by word similarity

Code A	Code B	Pearson correlation coefficient
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0,742891
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0,266462
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0,257021
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0,234761
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0,216421
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	0,208432
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0,206842

4.5 Triangulation Summary

To strengthen the credibility of the findings, this study integrated evidence from three sources: Informant interviews, organizational documents, and field observation. The table below summarizes where these sources converged and where they diverged.

Table 4.5 Triangulation Summary

Theme	Interview Evidence	Document Evidence	Observation Evidence
Informal communication during urgency	All five Informants described bypassing formal channels. I1: people often call warehouse directly. I2: first few minutes spent calling people.	SOPs describe formal request workflows with approval steps. Actual practice during urgent situations did not follow these documented pathways.	Excavator with hydraulic issue arrived at workshop. Operator walked directly to maintenance bay, described problem verbally with hand gestures. Maintenance supervisor used two-way radio to call warehouse during a separate breakdown, not the CMMS. Workshop whiteboard showed planned jobs but unplanned work handled entirely face-to-face.
Stock data mismatch	I1 described bearing showing available in system but not found at expected rack. I3 confirmed stock accuracy is main warehouse performance indicator.	Cycle count records showed recurring discrepancies, particularly for small consumable items with high transaction frequency.	Warehouse operator checked system on handheld device, then walked to physical location to verify item presence, then confirmed by radio. Double-verification added several minutes per urgent request. Some bin labels handwritten and faded, making visual identification difficult.
Documentation lag	I1: documentation comes later because priority is always getting equipment stable. P5: failure descriptions	Work order logs showed time gaps of two to three days between recorded repair completion and system closure in some cases.	No documentation activity observed during active repair work. Technicians focused entirely on equipment stabilization. Maintenance supervisor confirmed paperwork typically completed at end of shift or following day.

	sometimes too short for proper analysis.		
Standardization adjusted by experience	I1, I2, I3, I4 described modifying procedures based on field judgment. I1: from experience we already know it should be checked earlier.	PM schedules documented with fixed intervals. Maintenance history showed actual execution intervals varied for equipment under heavier load conditions.	Printed PM schedule on workshop wall had handwritten annotations marking changed intervals for specific units. Experienced technicians used the schedule as reference rather than strict rule, adjusting timing based on visual and auditory equipment assessment.
Data quality as central concern	I1 and I3 independently named data quality as top improvement priority. I3 identified duplicate material codes as persistent problem.	Material master records contained duplicate codes under slightly different names. Inconsistencies in unit-of-measure and description fields across categories.	Supply planner observed working with ERP on one monitor and a locally maintained Excel spreadsheet on the other for tracking delivery dates. Planner explained: system does not always update fast enough so we keep our own version. Manual cross-referencing between screens was standard practice.

Across all five themes shown above, there was strong convergence between what Informants reported in interviews and what was observed in the field. Documentary evidence generally supported the existence of formal systems and procedures but also revealed gaps between documented processes and actual practices. This convergence across three independent data sources strengthens the trustworthiness of the findings and reduces the risk that any single interpretation is based solely on individual perception.

4.6 Synthesis: Linking Findings to Research Questions

This section returns to the four research questions established in Chapter 1 and answers each one directly. To make the link between the coding and the conclusions explicit, each answer is built around the specific NVivo nodes (sub-themes) that were coded from the Informant data. The relevant node names are identified in each answer, and the supporting matrix and cluster outputs from

Section 4.3.5 are referenced where appropriate. This provides a traceable path from the coded data through analysis to the conclusion.

Research Question 1: What is the current structure in the MRO system?

The structure of the MRO system is captured in the nodes coded under V1, MRO System Structure and Quality. The reporting flow begins in the field, as shown by the nodes *Operator initiated failure detection* and *Technician initiated failure detection*, followed by a *Triage between urgent and planned response*. Under normal conditions the structure is orderly, reflected in the node *Roles clear under normal conditions*. However, the coding also reveals a second mode that takes over under pressure. The nodes *Role boundaries blur during urgency*, *Informal channels preferred for urgent matters*, and *Formal standards exist but field judgment overrides* together describe how the formal structure gives way to informal, speed-driven coordination during breakdowns. Additional structural strains appear in the nodes *Standardization varies by item category*, *Unclear ownership of data accuracy*, and *Upstream information quality affects downstream speed*.

The NVivo outputs in Section 4.3.5 reinforce this reading. In the coding similarity dendrogram (Figure 4.4), the structural nodes cluster together, confirming that Informants discussed them as one connected reality rather than as separate points. The matrix coding query (Table 4.3) locates this strain at the maintenance front line, where I1 contributed the references to *Triage between urgent and planned response*, *System bypassed during urgency*, and *Documentation lag after repairs*. The answer to RQ1, therefore, is that the MRO system has a sound formal structure that operates in two modes: orderly during normal conditions, and improvised during urgent situations, with the shift visible directly in the coded nodes.

Research Question 2: What are the KPIs measured to assess effectiveness of MRO systems?

The KPI findings are captured in three nodes coded under V1: *Departement specific KPIs*, *KPI generation involves manual verification*, and *KPIs trigger* *escalation and review*. The first node, *Departement specific KPIs*, captures the function-specific indicators each Informant described, including availability and downtime for maintenance, lead time and supplier delivery for procurement, stock accuracy for warehouse, forecast accuracy and service level for planning, and MTBF and failure patterns for reliability. The node *KPI generation involves manual verification* captures the recurring point that Informants do not fully trust system-generated numbers and check them by hand before reviewing. The node *KPIs trigger escalation and review* capture how poor KPI results prompt investigation rather than prevention.

The matrix coding query (Table 4.3) gives this answer particularly strong support. The node *Departement specific KPIs* was the only node in the entire dataset that drew references from all five Informants, confirming that performance measurement is a genuinely cross-functional concern. The node *KPI generation involves manual verification* was coded from both I1 and I2, and *KPIs trigger escalation and review* from both I1 and P5, showing that the reliance on manual checking and the reactive use of KPIs are shared across functions. The answer to RQ2 is that KPIs are tracked at the departmental level, generated through a mix of system data and manual verification, and used reactively rather than preventively.

Research Question 3: What are the main challenges or barriers affecting efficiency?

The challenges are captured across a set of nodes coded mainly under V2, MRO Inventory Management Effectiveness, and the data-quality nodes that cut across variables. The most immediate barrier appears in the nodes *Spare part shortage as primary bottleneck*, *Stock data mismatch causing delays*, and *Delay impact on operations*. Demand-side challenges appear in *Forecast miss triggers downstream instability* and *Planned demand is reliable but unplanned demand disrupts*. Beneath these lies the deeper data-quality problem, captured in the nodes *Duplicate material codes*, *Location discipline affects response speed*, and *Material master data as root cause*. Procurement and inventory barriers appear in *Incomplete technical specification in request*, *Old stock retained due to uncertainty*, and *Aging reports as identification tool*.

The cluster analysis in Section 4.3.5 shows these are experienced together rather than separately. In the coding similarity dendrogram (Figure 4.4), the data-quality nodes, *Location discipline affects response speed*, *Minimum stock periodic review*, *Old stock retained due to uncertainty*, *Aging reports as identification tool*, and *Duplicate material codes*, form a single tight cluster, joined nearby by *Material master data as root cause*, *Spare part shortage as primary bottleneck*, and *Stock data mismatch causing delays*. This is direct evidence that data quality is the connective tissue linking the other challenges. The matrix query (Table 4.3) shows that *Stock data mismatch causing delays* was the most heavily coded challenge, with three references from I1 and one from I3. The answer to RQ3 is that the main barrier is spare part availability, driven underneath by data quality, with the coded nodes showing how the symptoms and the root cause connect.

Research Question 4: How well does the MRO system integrate all information to overall maintenance performance?

The integration findings are captured in the nodes coded under V4, Digital Integration within MRO Processes. The trust and bypass problem appears in *System bypassed during urgency* and *System data not fully trusted*. The visibility gap appears in *Physical movement ahead of system update*, *Documentation lag after repairs*, and *Missing real time consumption data*. The data completeness problem appears in *Incomplete failure descriptions*. The most important integration gap is captured in the node *Reliability data not feeding into planning decisions*, and the desired outcome in *Fewer manual steps if system connected*.

Both cluster analyses in Section 4.3.5 support this answer. In the coding similarity dendrogram (Figure 4.4), the nodes *Fewer manual steps if system connected*, *Incomplete failure descriptions*, and *Reliability data not feeding into planning decisions* cluster together, showing they were discussed in the same passages and experienced as one connected shortfall. In the word similarity dendrogram (Figure 4.3), the nodes *System bypassed during urgency*, *Documentation lag after repairs*, and *Physical movement ahead of system update* cluster together, capturing the gap between what the system records and what happens on site. The matrix query (Table 4.3) confirms these concerns are recognized across functions, with *System bypassed during urgency* and *Physical movement ahead of system update* coded from I1, *Reliability data not feeding into planning decisions* from P5, and *System data not fully trusted* from I2. The answer to RQ4 is that integration is partial: the systems are connected on paper, but the coded nodes show consistent gaps in real-time visibility, data completeness, and the flow of reliability data into planning.

4.7 Chapter Summary

The analysis presented in this chapter reveals that the MRO system in the studied mining organization is structurally sound but operationally strained. Formal processes, role definitions, and digital systems are in place, but their effectiveness is undermined by data quality issues, integration gaps, and a persistent reliance on informal workarounds during urgent situations. The four research variables system structure, inventory management, cost reduction strategy, and digital integration are not independent dimensions but interconnected elements of a single operational ecosystem where weaknesses in one area amplify challenges in others.

The most significant finding is the central role of data quality as a cross-cutting bottleneck. Inaccurate stock records, duplicate material codes, incomplete failure descriptions, and delayed documentation create cascading inefficiencies that affect spare part availability, procurement speed, forecast accuracy, and reliability analysis. Two different departments independently identified data quality as their top priority for improvement, providing strong convergent evidence for this conclusion.

The second major finding is the urgency paradox the MRO system functions adequately during routine operations but is systematically bypassed during the urgent situations where it is most needed. This bypass behavior is rational and effective in the short term, but it prevents the organization from capturing operational knowledge in a form that can be analyzed, learned from, and used to improve future performance.

Chapter 5 Conclusion and Recommendations

Chapter 1 started from a straightforward observation. Mining is one of the most asset-intensive industries in the world, and almost nothing in it moves unless the equipment is running. Yet the system that keeps that equipment running, the Maintenance, Repair, and Operations (MRO) system, is usually studied one piece at a time. Some researchers look at spare-part inventory models. Others look at maintenance scheduling, or procurement cost, or the promise of digital tools. Very few look at how those pieces behave when they are pushed together into a single working system inside a real mine, and fewer still ask the people who operate it.

That was the gap this study set out to fill. It asked one central question: how well does the current MRO implementation support operational efficiency, reliability, and long-term sustainability in the mining industry? Four supporting questions carried out the work:

1. What is the current structure of the MRO system?
2. What KPIs are used to measure its effectiveness?
3. What are the main challenges or barriers affecting the efficiency of its implementation?
4. How well does the MRO system integrate information into overall maintenance performance?

Chapter 4 answered these in detail, node by node, quote by quote. This chapter does something different. It steps back from the coding and gives the short answer to each question, draws out what those answers mean for theory and for the people who must run these systems, sets out what the organization should do about it, and is honest about what this study could not reach.

5.1 Answers to the Research Questions

Research question 1 structure. The MRO system at the case organization is properly built. Roles are defined, procedures are documented, and the flow from failure detection through work order, requisition, purchase, and issue is clear on paper. But the structure runs in two modes. Under normal conditions it works. When a machine goes down, it quietly switches into a second mode that appears in no document: role boundaries blur, formal channels are set aside, and the two-way radio replaces the screen. The formal structure describes only half of what happens.

Research question 2 KPIs. Each department measures what it owns. Maintenance tracks downtime and PM compliance, procurement tracks lead time and cost, the warehouse tracks stock accuracy, planning tracks forecast accuracy. These indicators are real and they are used; every participant referred to them. The weakness is that they are departmental, backward-looking, and partly produced by manual verification. They tell the organization what already went wrong. They rarely warn it in advance, and no single indicator captures how well the MRO system performs end to end.

Research question 3 barriers. The most visible barrier is spare-part availability. Underneath it sits something less visible and far more important: data quality. Duplicate material codes, stock records that do not match the shelf, failure descriptions written in a hurry, documentation closed two or three days after the repair. Two participants from different departments, with no knowledge of each other's answers, independently named data quality as their number one priority. That convergence is the strongest single result in this study.

Research question 4 Integration. Integration is partial. The ERP and the CMMS exist, and they do talk to each other, but the join leak. Physical movement runs ahead of the system record. Real-time consumption data is missing. Reliability findings sit in their own silo and rarely change stocking decisions. The infrastructure is in place; the information flow through it is not yet trusted enough to be relied on when it matters.

The most advanced digital platform cannot deliver value if its data is unreliable. The most detailed procedure cannot guide action if it gets set aside the moment a machine goes down. And the most carefully optimized inventory cannot prevent a stockout if the system thinks the part is in rack seven when it is in rack twelve.

5.2 Conclusion

The system is structurally sound but operationally strained. Nothing here is a design failure in the ordinary sense. The problem is that the design assumes calm, and mining is not calm.

Data quality is the bottleneck beneath everything else. It surfaces under every one of the four variables. Bad master data slows procurement, distorts forecasts, hides obsolete stock, and starves reliability analysis. It is not one problem among many; it is the problem the others grow out of.

The urgency paradox undermines learning. The system is bypassed precisely when it is needed most, during breakdowns, stockouts, and stoppages. Bypassing it is not laziness. It is a rational choice by people who have learned that the screen is slower and less reliable than the phone. The cost is that everything learned during the moments of greatest pressure is never captured, and so the organization never learns from them.

Underlying all three is the finding that the four variables, structure, inventory, cost, and digital integration, are not separate levers. Pull one and the others move. Improving inventory without fixing data quality will not hold. Buying a better system without earning user trust simply gives people a more expensive system to walk around.

5.3 What Changes If This is Fixed

It is worth being concrete about what improvement would buy, because the recommendation that follows asks for effort and someone will reasonably ask what it is for.

If master data is cleaned and stock records match the shelf, the double verification that currently costs minutes on every urgent request disappears, and the maintenance engineer stops walking to the rack to check what the system already told him. If failure descriptions carry enough detail, the procurement officer stops chasing clarification and the days lost to each clarification cycle come back. If reliability data reaches the planner, stocking decisions start to reflect failure risk rather than usage history alone, which is the difference between a preventive posture and a reactive one. If urgent work can move quickly inside the system rather than around it, the informal knowledge currently lost to radio calls becomes a record that can be analyzed.

Taking together, the expected impact is shorter equipment downtime, fewer emergency purchases at emergency prices, less capital tied up in stock nobody can confidently retire, and, the part that compounds, an organization that finally learns from its own worst days.

5.4 Implication and Contribution

5.5.1 Theoretical Implications

The study contributes to maintenance and supply chain scholarship in three ways. First, it treats MRO as an integrated system rather than a set of separate optimizations problems and shows empirically that the four dimensions are interdependent. This supports the argument of Rojas, Fernández and Herrera (2025) and Dayo-Olupona, Adelaja and Fatogun (2023) that supply chain performance is a connected set of dimensions rather than a list of metrics and extends it into the MRO domain specifically.

Second, it complicates Supply Chain Integration Theory. That literature holds that integrated information systems improve performance through shared visibility. This case shows that integration is a necessary but not sufficient condition. The systems here are integrated. They are also bypassed. What the theory does not account for is trust: shared visibility only improves performance if users believe what they see.

Third, the study names the urgency paradox, the pattern whereby a well-designed system fails at exactly the moments it was built for, not because of a defect in the system but because of a rational response by its users. Practitioners recognise this immediately. The literature has not articulated it clearly. That name is the study's clearest conceptual contribution.

5.5.2 Practical Implications

For practitioners the message is unusually cheap to act on: start with data, not with technology. Cleaning material master records, enforcing failure coding standards, and reconciling stock against the physical shelf require discipline rather than capital. The cross-variable analysis also offers diagnostic lens. By asking how structure, inventory, cost, and integration feed each other in their own operation, a maintenance or supply chain manager can find which loop is doing the most damage before spending anything.

5.5.3 Managerial Implications

For management, the finding that matters are that bypass behavior is a symptom, not misconduct. Disciplining people for going around the system will not work, because going around the system is currently the correct decision. The managerial task is to make compliance faster than the workaround. That reframes system adoption from a training problem into a design and trust problem, and it shifts KPI ownership from departmental silos toward an end-to-end measure of MRO health that someone is accountable for.

5.5.4 Policy Implications

At company and industry policy level, the study argues for data governance to be treated as an asset-integrity issue rather than an IT housekeeping issue, with named ownership of master data and mandatory validation at the point of entry. For a sector where equipment failure carries safety and environmental consequences, the quality of failure records is not merely an efficiency question. More broadly, industry benchmarking that measures lead time without measuring data accuracy, or stock accuracy without forecast quality, will keep producing an incomplete picture. Better inventory discipline also means less obsolete stock written off, which is a sustainability gain as much as a financial one.

5.5 Recommendation

This study makes one recommendation, because the evidence points to one root cause and it would be dishonest to dress that up as several.

Establish MRO data governance as the foundation and build the system to work under pressure rather than only in calm conditions.

In practice that means assigning clear ownership of material master data; enforcing validation checks at the point of entry so that duplicate codes and vague specifications cannot enter the system in the first place; auditing stock records against the physical shelf on a fixed cycle; standardizing failure coding so that a description is useful to the reliability engineer and the planner without a phone call; and, critically, creating a fast-track pathway inside the ERP and CMMS that lets urgent work orders move through approval, procurement, and issuance with fewer steps, capturing the same information but at the speed a breakdown demands. The point is not to remove controls. It is to make the compliant route the fast route, so that people stop having to choose between doing it properly and doing it quickly.

Everything else the study might have recommended, better forecasting, a disciplined obsolescence review, stronger supplier collaboration on critical spares, more predictive KPIs, depending on this and follows from it. Clean data is what makes a forecast worth trusting, an obsolescence decision defensible, and a leading indicator possible.

Recommendation for future research. The findings here rest on one organization, one commodity, one site. Three lines of work would test and extend them. First, replication across different mining companies, commodities, and geographies, to establish whether the data quality bottleneck and the urgency paradox are general or particular to this case. Second, investigation of the urgency paradox beyond mining, in oil and gas, power generation, and heavy manufacturing, to determine whether it is an industry feature or a feature of asset-intensive operations generally. Third, longitudinal work. This study captured a system at one moment. A study that follows an organization through a data governance programmed, measuring before and after, would establish whether the causal claim made here actually holds when someone tries to act on it.

5.6 Limitations of the Study

Interviews were written and asynchronous, not face to face. Questions were sent to participants and returned in writing, with follow-up messages where clarification was needed. This was a deliberate accommodation to shift patterns and site remoteness, and it means the words analyzed are exactly the words participants chose to submit. But there is a cost. Participants could edit and consider their answers, which tends to produce more polished and less spontaneous accounts. The researcher could not read tone or hesitation, could not follow an unexpected line of thought in the moment, and could not prove as freely as a live conversation allows. Some of what people might have said out loud, in the flow of a real interview, was almost certainly not written down.

Single case. The depth was intentional and necessary. But one organization, one commodity, and one geography do not generalize automatically. The thick description throughout Chapter 4 is offered so that readers can judge for themselves whether these findings transfer to their own setting, consistent with Nowell, Norris, White and Moules (2017). Transferability is the reader's call, not the researchers.

Five participants. Appropriate for a case study built on depth, but narrow. Senior management, field operators, and external suppliers were not heard. Any of those voices might have revealed dimensions this study did not reach.

No pre- and post-intervention measurement. The study observed the system as it currently stands. It did not implement anything and could not measure the effect of doing so. The impacts described in Section 5.4 are grounded in the evidence but remain projected rather than demonstrated.

Academic timeframe. The research was conducted within a fixed window, which limited how long the site could be observed and how far the analysis could follow changes over time.

5.7 Closing Statement

My study has done most of what the textbooks ask. It has the procedures, the systems, the roles, and the indicators. What it does not yet have is a system its own people reach for first when a haul truck goes down at two in the morning. That gap, between a system that works and a system that is trusted, is where the real performance is sitting, and it will not be closed by buying anything. It will be closed by cleaning the data, and by making the right way the fast way.

Bibliography

Aspers, P., & Corte, U. (2019). What is qualitative in qualitative research. Qualitative Sociology, 42(2), 139–160. https://doi.org/10.1007/s11133-019-9413-7

Bacchetti, A., & Saccani, N. (2012). Spare parts classification and demand forecasting for stock control: Investigating the gap between research and practice. Omega, 40(6), 722–737. https://doi.org/10.1016/j.omega.2011.06.008

Basten, R. J. I., & van Houtum, G. J. (2014). System-oriented inventory models for spare parts. Surveys in Operations Research and Management Science, 19(1), 34–55. https://doi.org/10.1016/j.sorms.2014.05.002

Bazeley, P., & Jackson, K. (2019). Qualitative data analysis with NVivo (3rd ed.). SAGE Publications.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Campbell, J. D., & Reyes-Picknell, J. V. (2015). Uptime: Strategies for excellence in maintenance management (3rd ed.). CRC Press.

Cantini, A., De Carlo, F., & Tucci, M. (2024). A data-driven methodology for the periodic review of spare parts inventory. IFAC-PapersOnLine, 58(19), 1–6. https://doi.org/10.1016/j.ifacol.2024.09.001

Carter, N., Bryant-Lukosius, D., DiCenso, A., Blythe, J., & Neville, A. J. (2014). The use of triangulation in qualitative research. Oncology Nursing Forum, 41(5), 545–547. https://doi.org/10.1188/14.ONF.545-547

Carvalho, T. P., Soares, F. A. A. M. N., Vita, R., Francisco, R. D. P., Basto, J. P., & Alcalá, S. G. S. (2019). A systematic literature review of machine learning methods applied to predictive maintenance. Computers & Industrial Engineering, 137, 106024. https://doi.org/10.1016/j.cie.2019.106024

Ceglarek, D., Colledani, M., Váncza, J., Kim, D. Y., Marine, C., Kogel-Hollacher, M., Mistry, A., & Bolognese, L. (2015). Rapid deployment of remote laser welding processes in automotive assembly systems. CIRP Annals, 64(1), 389–394. https://doi.org/10.1016/j.cirp.2015.04.119

Clarke, V., & Braun, V. (2021). Thematic analysis: A practical guide. SAGE Publications.

Creswell, J. W., & Poth, C. N. (2018). Qualitative inquiry and research design: Choosing among five approaches (4th ed.). SAGE Publications.

Cypress, B. S. (2017). Rigor or reliability and validity in qualitative research: Perspectives, strategies, reconceptualization, and recommendations. Dimensions of Critical Care Nursing, 36(4), 253–263. https://doi.org/10.1097/DCC.0000000000000253

Dayo-Olupona, O., Genc, B., Celik, T., & Bada, S. (2023). Adoptable approaches to predictive maintenance in mining industry: An overview. Resources Policy, 86, 104291. https://doi.org/10.1016/j.resourpol.2023.104291

Frazzon, E. M., Israel, E., Albrecht, A., Pereira, C. E., & Hellingrath, B. (2014). Spare parts supply chains' operational planning using technical condition information from intelligent maintenance systems. Annual Reviews in Control, 38(1), 147–154. https://doi.org/10.1016/j.arcontrol.2014.03.014

Haddud, A., DeSouza, A., Khare, A., & Lee, H. (2017). Examining potential benefits and challenges associated with the Internet of Things integration in supply chains. Journal of Manufacturing Technology Management, 28(8), 1055–1085. https://doi.org/10.1108/JMTM-05-2017-0094

Hu, Q., Boylan, J. E., Chen, H., & Labib, A. (2018). OR in spare parts management: A review. European Journal of Operational Research, 266(2), 395–414. https://doi.org/10.1016/j.ejor.2017.07.058

Kulshrestha, A., Jain, V., & Joshi, S. (2024). Spare parts management in Industry 4.0 era: A literature review. Journal of Quality in Maintenance Engineering, 30(1), 248–283. https://doi.org/10.1108/JQME-04-2023-0037

Lincoln, Y. S., & Guba, E. G. (1985). Naturalistic inquiry. SAGE Publications.

Manenzhe, T. D., Bevis, K. S., & Gouws, J. (2023). The influence of data quality and organizational practices on maintenance performance. Journal of Quality in Maintenance Engineering, 29(5), 1–20. https://doi.org/10.1108/JQME-03-2022-0017

Manzini, R., & Regattieri, A. (2010). Maintenance for industrial systems. Springer. https://doi.org/10.1007/978-1-84882-575-8

Márquez, A. C. (2007). The maintenance management framework: Models and methods for complex systems maintenance. Springer. https://doi.org/10.1007/978-1-84628-821-0

Mobley, R. K. (2011). Maintenance engineering handbook (8th ed.). McGraw-Hill.

Muniz, J., Simões, M. G., & Ayres, J. C. (2020). Spare parts inventory management: A new hybrid approach. The International Journal of Logistics Management, 31(3), 583–604. https://doi.org/10.1108/IJLM-04-2019-0119

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. International Journal of Qualitative Methods, 16(1), 1–13. https://doi.org/10.1177/1609406917733847

Parida, A., & Kumar, U. (2006). Maintenance performance measurement (MPM): Issues and challenges. Journal of Quality in Maintenance Engineering, 12(3), 239–251. https://doi.org/10.1108/13552510610685084

Parida, A., Kumar, U., Galar, D., & Stenström, C. (2015). Performance measurement and management for maintenance: A literature review. Journal of Quality in Maintenance Engineering, 21(1), 2–33. https://doi.org/10.1108/JQME-10-2013-0067

Rihi, A., Baïna, S., Mhada, F.-Z., Elbachari, E., Tagemouati, H., Guerboub, M., & Benzakour, I. (2022). Predictive maintenance in mining industry: Grinding mill case study. Procedia Computer Science, 207, 2483–2492. https://doi.org/10.1016/j.procs.2022.09.306

Robatto Simard, S., Gamache, M., & Doyon-Poulin, P. (2024). Development and usability evaluation of VulcanH, a CMMS prototype for preventive and predictive maintenance of mobile mining equipment. Mining, 4(2), 326–351. https://doi.org/10.3390/mining4020019

Rojas, L., Peña, Á., & Garcia, J. (2025). AI-driven predictive maintenance in mining: A systematic literature review on fault detection, digital twins, and intelligent asset management. Applied Sciences, 15(6), 3337. https://doi.org/10.3390/apI15063337

Saldaña, J. (2021). The coding manual for qualitative researchers (4th ed.). SAGE Publications.

Salmons, J. (2022). Doing qualitative research online (2nd ed.). SAGE Publications.

Santos, R., Teixeira, C., Machado, J., & Dourado, A. (2018). Maintenance management in the mining industry: A systematic review. Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability, 232(2), 100–112.

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). Research methods for business students (8th ed.). Pearson Education.

Scarf, P. A. (2024). Joint maintenance and spare parts inventory models: A review. IMA Journal of Management Mathematics, 35(2), 185–221. https://doi.org/10.1093/imaman/dpae002

Siyad, A., & Khayal, I. S. (2025). The effect of supplier collaboration on organisational performance. International Journal of Supply Chain Management, 10(1), 1–15.

Stake, R. E. (2020). The art of case study research. SAGE Publications.

Sutton, J., & Austin, Z. (2015). Qualitative research: Data collection, analysis, and management. The Canadian Journal of Hospital Pharmacy, 68(3), 226–231. https://doi.org/10.4212/cjhp.v68i3.1456

Terry, G., Hayfield, N., Clarke, V., & Braun, V. (2017). Thematic analysis. In C. Willig & W. Stainton Rogers (Eds.), The SAGE handbook of qualitative research in psychology (2nd ed., pp. 17–37). SAGE Publications.

Tobin, G. A., & Begley, C. M. (2004). Methodological rigour within a qualitative framework. Journal of Advanced Nursing, 48(4), 388–396. https://doi.org/10.1111/j.1365-2648.2004.03207.x

Tortorella, G. L., Fettermann, D., Anzanello, M. J., & Sawhney, R. (2020). Lean manufacturing implementation, context and behaviors of multi-level leadership: A mixed-methods exploratory research. Journal of Manufacturing Technology Management, 31(7), 1301–1326. https://doi.org/10.1108/JMTM-08-2019-0310

Tracy, S. J. (2020). Qualitative research methods: Collecting evidence, crafting analysis, communicating impact (2nd ed.). Wiley-Blackwell.

Tsang, A. H. C. (2002). Strategic dimensions of maintenance management. Journal of Quality in Maintenance Engineering, 8(1), 7–39. https://doi.org/10.1108/13552510210420577

van Jaarsveld, W., & Dekker, R. (2016). Estimating obsolescence risk from demand data to enhance inventory control. Omega, 60, 57–69. https://doi.org/10.1016/j.omega.2015.06.004

Vogt, W. P., Gardner, D. C., & Haeffele, L. M. (2023). When to use what research design. Guilford Press.

Werbinska-Wojciechowska, S., Grabowski, M., & Dziula, P. (2025). Towards Maintenance 5.0: Resilience-based maintenance in AI-driven sustainable and human-centric industrial systems. Sensors, 25(16), 5100. https://doi.org/10.3390/s25165100

Woods, M., Macklin, R., & Lewis, G. K. (2016). Researcher reflexivity: Exploring the impacts of CAQDAS use. International Journal of Social Research Methodology, 19(4), 385–403. https://doi.org/10.1080/13645579.2015.1023964

Yin, R. K. (2018). Case study research and applications: Design and methods (6th ed.). SAGE Publications.

Zhang, S., Huang, K., & Yuan, Y. (2021). Spare parts inventory management: A literature review. Sustainability, 13(5), 2460. https://doi.org/10.3390/su13052460

Appendix A Informant 1 Maintenance Engineer (Male, 46 years old, 12 years' experience)

Q: When a piece of equipment needs maintenance, walk me through what happens from the moment the issue is identified until the work is closed out. Who does what along the way?

A: Usually the first sign comes from the field, not from the office. Operators will call us if they hear unusual sound, vibration, or sometimes they already feel the machine is not running normally. In other cases our own technician finds it during inspection. From there, we check first whether it is something that can wait until the planned maintenance slot or whether we need to act immediately. If it is urgent, we open the work order and start checking what parts may be involved. Honestly, before looking too much at the system, people often call warehouse directly because we need quick confirmation. If warehouse says the part is there, then we move fast. If not, then planner and procurement start joining because now it becomes a timing issue. After the repair is done, normally the work order is closed by technician, but in reality sometimes the documentation comes later because the priority is always getting the equipment stable again.

Q: How clear are the responsibilities between your team, procurement, and the warehouse when a spare part is needed urgently?

A: In normal conditions it is actually clear enough. Maintenance identifies what is needed, warehouse checks stock, procurement handles external purchase if necessary. The challenge starts when breakdown happens in production hours because then nobody really waits in sequence. Maintenance calls warehouse immediately, warehouse may already call procurement, and sometimes procurement asks us technical details while we are still in the field. So the responsibility is there, but in urgent situations people work more based on response speed than formal order.

Q: How standardized are your preventive maintenance schedules? Do you mostly follow the system, or do you adjust based on field judgment?

A: We have preventive schedules and they are already set, but field judgment still plays a big role. Same equipment type does not always behave the same because one unit may work under heavier load than another. Sometimes on paper the schedule says still safe, but from experience we already know it should be checked earlier.

Q: Which performance indicators matter most to you and your team?

A: The first one everyone talks about is availability, because production immediately sees that. If one critical machine stops, the question always comes very quickly. Downtime also matters a lot. MTBF is reviewed too, but usually availability and downtime are the ones discussed first in meetings.

Q: How are these KPIs generated are they pulled automatically from the system, or do you compile them manually?

A: Partly from the system, yes, especially work order history and downtime records. But normally before review we still check manually because numbers alone do not explain what really happened. Sometimes one downtime event looks simple in the report, but the technical cause is different.

Q: When the KPI numbers look bad, what usually happens next?

A: Usually there is a discussion with supervisor first. If it keeps repeating, reliability team gets involved because then we need deeper analysis, not only repair action.

Q: What are the most common bottlenecks you run into when trying to get maintenance work done on time?

A: To be honest, most often it is spare parts. Manpower can be ready, equipment can already be isolated, but if one component is missing then everything shifts.

Q: Have you experienced situations where a part was in the system as available but was not actually there when you needed it? Can you describe one?

A: Yes, that happens. One case I remember was bearing stock. In the system it still showed available, but when warehouse checked physically, the item was not in the expected rack. Later it turned out part of the stock had already been moved and not updated immediately.

Q: How do these issues affect your ability to keep equipment running?

A: It adds delay immediately. Sometimes maybe one hour, sometimes longer, depending on whether there is substitute material.

Q: When you need information from procurement, planning, or the warehouse, how do you usually get it through the system, by phone, in person?

A: For urgent things, still by phone or direct talk. The system helps for record, but when equipment is down people do not wait for screen updates.

Q: If you could change one thing about how the system connects maintenance with the other departments, what would it be?

A: I think the biggest improvement would be making stock status fully reliable. If maintenance can trust what appears in the system, many decisions become faster.

Q: Is there anything important about the MRO process that I have not asked you about, but that you think I should know?

A: Maybe one thing people outside maintenance do not always see is that technical urgency is not always visible from item value. Sometimes a small component causes bigger operational risk than expensive equipment parts.

Q: If you were leading an effort to improve the MRO system here, what would be your first step?

A: I would start from basic data quality first, because many issues eventually come back to that.

Q: May I follow up with you if I need clarification on any of your answers?

A: Yes, sure.

Appendix B Informant 2 Procurement and Purchasing Officer (Female, 43 years old, 13 years' experience)

Q: Walk me through what happens on your side from the moment a purchase requisition for a spare part lands in your queue.

A: Usually the first thing I check is whether the request is complete enough to process. Not every requisition arrives in a ready condition. Sometimes the material code is there but the technical note is still too general, so before doing anything we need to confirm what exactly is needed. If the item already has supplier history, the process is faster because we can immediately check previous purchase records. If not, then it takes more time because supplier contact and technical matching need to happen first. For urgent cases, honestly, the first few minutes are usually spent calling people rather than opening too many screens because we need to understand how urgent the request really is.

Q: How is approval authority structured for MRO purchases?

A: There is already approval hierarchy, mostly based on value and category. Lower-value purchases move faster because approval stays at department level, but once the amount increases, more layers are involved. For urgent breakdown cases, sometimes the urgency becomes more important than the value because production impact can be much bigger than the purchase amount itself.

Q: How standardized are your purchasing procedures across different categories of MRO items?

A: The procedure is standardized on paper, but in practice the item category changes the speed. Fast-moving items with regular suppliers are easier because we already know the pattern. Imported or technical items usually need more back and forth.

Q: What indicators are you measured on?

A: Lead time is usually the first thing management checks because that directly affects whether the requesting department feels supported or not. Then supplier delivery performance, especially whether committed dates are actually met. Cost saving is also there, but honestly in MRO it is sometimes not straightforward because technical items do not always give room for negotiation.

Q: How are these tracked, and how often are they reviewed with management?

A: Most of it comes from monthly purchasing reports. The numbers are available in the system, but before review we usually look at exceptions manually because one delayed PO can have different causes. Sometimes delay comes from supplier, sometimes from incomplete request at the beginning.

Q: What are the most common reasons a purchase order gets delayed or has to be reworked?

A: Most often it starts from technical clarification. If the description is too broad, supplier asks back, and once that happens the timeline already shifts.

Q: How often do you receive requisitions with incomplete or unclear technical specifications, and how do you handle that?

A: Still quite common, especially for less frequently purchased spare parts. Usually we go back to maintenance or engineering and ask them to explain using previous purchase history, drawing, or old supplier reference.

Q: Can you describe a situation where an emergency purchase had to be made?

A: There was one urgent case where a motor component failed during operation and there was no stock available locally. Because the equipment was critical, the item had to be sourced immediately and freight cost became unusually high because delivery speed became more important than price.

Q: What strategies does your team use to control or reduce MRO inventory holding costs?

A: For repeated items we try framework agreements because they reduce purchasing cycle time and usually pricing becomes more stable. In some cases blanket arrangements also help because demand does not need a full sourcing process every time.

Q: How do you balance cost pressure against spare part availability?

A: Usually we look first at how critical the item is. If downtime exposure is high, availability usually wins.

Q: How well does the system give you visibility into what maintenance actually needs versus what is being requested?

A: The request appears in the system, but sometimes urgency is not fully visible there. We still need direct confirmation to understand whether this is routine or already affecting operation.

Q: How would you describe your relationship with key suppliers?

A: For major suppliers it is already more than transactional because they understand our operational urgency. Some suppliers already know that when certain item categories appear, it usually means the site needs fast response.

Q: Is there anything important about the MRO process that I have not asked you about, but that you think I should know?

A: One thing that often gets overlooked is that timing in MRO purchasing is not only about supplier speed. Sometimes the earlier part of the process already takes time because technical clarification moves back and forth before procurement can really act. From outside it may look like purchasing is slow, but often the delay starts before the PO is even created

Q: If you were leading an effort to improve the MRO system here, what would be your first step?

A: I would start from improving request quality at the beginning, especially technical completeness. If the first information is already clear, many downstream steps become faster and less repetitive.

Q: May I follow up with you if I need clarification on any of your answers?

A: Yes, that is fine. If there is anything that needs more detail, I can explain further

Appendix C Informant 3 Warehouse and Inventory Controller (Male, 50 years old, 15 years' experience)

Q: Can you walk me through what happens in the warehouse when a maintenance team requests a spare part?

A: Normally they send request through the system, then warehouse checks location and quantity. If the item is straightforward, we issue it directly. But sometimes before issuing we still physically verify because some parts look similar but specification is different.

Q: Who is responsible for keeping stock data accurate in the system?

A: Warehouse team updates every movement, but accuracy still depends on discipline during issue and receipt. If one movement is delayed in recording, later the difference appears.

Q: How standardized is your inventory classification?

A: We already separate by movement and criticality, but for daily operation people still rely a lot on experience because not every item behaves exactly according to classification.

Q: What indicators tell you whether the warehouse is performing well?

A: Stock accuracy is still the main one. If system and physical stock do not match, everything else becomes difficult.

Q: How are these measured, and how often do you reconcile system data with physical stock?

A: Cycle counting is routine. Critical items are checked more often because the impact is bigger if something is wrong.

Q: How often do you experience stockouts on critical items?

A: Not very often, but when it happens it usually comes from unexpected usage or delayed replenishment.

Q: Do you have items sitting in stock for a long time without moving?

A: Yes, many old parts remain because equipment still exists even though usage is rare. Sometimes nobody wants to release them because technically they may still be needed one day.

Q: What is the biggest data quality issue you face?

Duplicate material codes are still difficult because sometimes the same item enters under slightly different naming.

Q: What practices does your team use to reduce holding costs without risking shortages?

A: Mainly reviewing minimum stock periodically and checking whether movement still justifies the level.

Q: How are obsolete or slow-moving parts identified and dealt with?

A: Usually through aging reports, then discussed with maintenance whether still relevant.

Q: Does the system give you real-time view of incoming and outgoing stock?

A: Not always fully real time. Sometimes physical movement happens first and system follows shortly after.

Q: If systems were better connected, what would change in your daily work?

A: Less checking between screens and fewer manual confirmations.

Q: Is there anything important about the MRO process that I have not asked you about, but that you think I should know?

A: Maybe one thing is that people often focus on stock quantity, but location discipline is equally important. A part can exist, but if the location record is not precise, the response still becomes slow.

Q: If you were leading an effort to improve the MRO system here, what would be your first step?

A: I would first clean material master data and storage discipline together, because many small daily issues usually come from there.

Q: May I follow up with you if I need clarification on any of your answers?

A: Yes, no problem.

Appendix D Informant 4 Supply Planner (Female, 47 years old, 11 years' experience)

Q: Can you describe your role in the MRO planning cycle?

A: My role is mostly translating maintenance requirements into stock planning logic. Maintenance gives demand signals, then we decide whether current stock, reorder point, or supplier timing still fits.

Q: Who owns the forecast in this organization?

A: Forecast is shared. Maintenance gives technical expectation, planning converts it into replenishment logic.

Q: How standardized is forecasting methodology?

A: For fast-moving items it is more structured. For irregular parts, judgement still dominates.

Q: What indicators do you track to measure how well planning is performing?

A: Forecast accuracy is one, but in MRO service level usually becomes more practical because availability is what people notice directly.

Q: How do you use these KPIs to adjust assumptions?

A: If forecast repeatedly misses for the same category, reorder logic usually gets reviewed.

Q: How accurate are demand signals from maintenance?

A: For planned shutdowns usually reliable. The challenge comes from unplanned failures because they change demand very quickly.

Q: Can you describe a recent case where forecast missed badly?

A: There was one period when actual usage moved much faster because one equipment family experienced repeated issues earlier than expected.

Q: How do you handle parts with long supplier lead times?

A: Usually by building safety earlier, but too much safety also creates holding cost discussion.

Q: How well does the system connect maintenance plans, failure history, and procurement cycles?

A: The connection exists, but still not fully seamless. Sometimes information sits in different places.

Q: If you could see one missing piece of information, what would it be?

A: Real-time consumption trend linked to maintenance activity would help a lot.

Q: How do disruptions ripple into planning?

A: One shipment delay can immediately affect reorder timing for several items.

Q: Is there anything important about the MRO process that I have not asked you about, but that you think I should know?

A: What is often underestimated is how much planning quality depends on upstream consistency. Even a good planning model becomes weak if maintenance signals arrive too late or too differently each time.

Q: If you were leading an effort to improve the MRO system here, what would be your first step?

A: I would focus first on improving information flow between maintenance, planning, and procurement so the same demand picture is seen earlier by everyone.

Q: May I follow up with you if I need clarification on any of your answers?

A: Yes, of course.

Appendix E Informant 5 Reliability Engineer (Male, 49 years old, 13 years' experience)

Q: What is the role of reliability engineering in the MRO process?

A: Our role is making sure spare part decisions are not only based on history, but also based on failure consequence.

Q: How is failure data captured?

A: Mostly from maintenance work orders, then reviewed again if deeper analysis is needed.

Q: How standardized is failure coding?

A: Already standardized, but field input still varies depending on who closes the report.

Q: Which reliability indicators do you track most closely?

A: Mostly MTBF and recurring failure patterns because they show whether intervention really improves equipment condition.

Q: How are these used in management decisions?

A: If one failure keeps appearing, usually replacement interval or maintenance approach is reviewed.

Q: What are the biggest gaps in failure data you receive from the field?

A: Sometimes failure description is too short, so later analysis becomes more difficult than it should be.

Q: How does incomplete or late data affect reliability analysis?

A: It increases assumption because not all technical context is captured.

Q: Are repeated failures happening because root cause is not fully addressed?

A: Yes, especially when shutdown time is short and only immediate correction is possible.

Q: How well are reliability insights fed back into spare-parts planning?

A: Sometimes still slower than expected. Reliability findings do not always immediately change stock decisions.

Q: If ERP, CMMS, and reliability data were better connected, what would change?

A: Analysis would move faster because fewer manual cross-checks are needed.

Q: Biggest long-term improvement opportunity?

A: Using failure history more actively before stock and maintenance decisions are made.

Q: Is there anything important about the MRO process that I have not asked you about, but that you think I should know?

A: One thing that sometimes does not get enough attention is that spare part decisions are often made based on usage history, while failure behavior can tell a different story. A part may not move often, but if it is linked to a high-impact failure, then the discussion should be different. From reliability side, that gap still appears quite often.

Q: If you were leading an effort to improve the MRO system here, what would be your first step?

A: I would start by making failure history more actively used in planning decisions. At the moment the data exists, but not always in a way that directly influences stocking or maintenance timing. If that connection becomes stronger, decisions will probably be more preventive instead of reactive.

Q: May I follow up with you if I need clarification on any of your answers?

A: Yes, that is fine. If needed, I can explain further, especially if there are questions related to how reliability data is interpreted.

Appendix F Item Clustered by Coding Similarity

Table F.1 Item Clustered by Coding Similarity

Code A	Code B	Jaccard's coefficient
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	1
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	1
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	1
V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	1
V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	1
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	1
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	1

V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	1
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	1
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	1
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	1
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	1
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	1
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	1
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	1
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	1

V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	1
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	1
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	1
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	1
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	1
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	1
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	1
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	1
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	1

V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	1
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	1
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	1
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	1
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	1
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	1
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	1
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	1
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	1

V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	1
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	1
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	1
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.5
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.5
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.5
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.5
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.5
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.5
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.5

V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.5
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.5
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.5
V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.5
V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.5
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.5
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	0.5
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.5
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.5

V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	0.5
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.5
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.5
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.5
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.5
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.5
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.5
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.5
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.5

V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	0.5
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.5
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.5
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.5
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.5
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.5

V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.5
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.5
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.5
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.5
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	0.5
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	0.5
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	0.5
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.5
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.5

V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.5
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	0.5

V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	0.5
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.5

V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.5

V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	0.5
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	0.5

V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	0.5

V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	0.5
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	0.5
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.4
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.4
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.4
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.4
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.4
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.4

V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.4
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.4
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.4
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.4
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.4
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.333333
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.333333
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.333333
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.333333

V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.333333
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.333333
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.333333
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.333333
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.333333
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.333333
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.333333
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.333333
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.333333
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.333333

V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.333333
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.333333
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.333333
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.333333
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.333333
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.333333
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.333333
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.333333
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.333333
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.333333

V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.333333
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.333333
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.333333
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.333333
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.333333
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.333333
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.333333
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.333333
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	0.333333

V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	0.333333
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	0.333333
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.2
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2

V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2

V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.2

Appendix G Item Clustered By-Word Similarity

Table G.1 Item Clustered By-Word Similarity

Code A	Code B	Pearson correlation coefficient
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.742891
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.266462
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.257021
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.234761
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.216421
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	0.208432
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.206842

V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.197681
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	0.197274
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.194191
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.193871
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	0.191928
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.188869
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	0.183255
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.178497
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.177273

V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.172065
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.169782
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.169749
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	0.16783
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	0.165169
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.160357
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.160297
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.159655
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.155306

V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.152554
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.145991
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	0.144376
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	0.141068
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	0.141053
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.140923
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	0.140766
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.140764
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.140762

V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.137709
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	0.137647
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	0.137321
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.136124
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	0.136086
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.135307
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.135073
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.132846
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.128557

V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.126673
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	0.126196
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.124728
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.123845
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	0.12228
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.120928
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.120895
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.119221
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	0.118416

V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.117893
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.11674
V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.116083
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.115972
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.115436
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	0.114302
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.114001
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.113191
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.11224

V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.111977
V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.111724
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.111417
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.108138
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.107977
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	0.10786
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.106361
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.105623
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	0.104321

V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	0.104249
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	0.103613
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	0.102505
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.099455
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	0.098195
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.095896
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.095824
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.094006
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	0.093618

V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	0.093562
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	0.093534
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	0.092492
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.092063
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.088773
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	0.088442
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.088243
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	0.087344
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.08698

V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.086813
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	0.085794
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.084609
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.084525
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	0.083175
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.082889
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	0.082748
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.082462
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.08165

V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.081594
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	0.080217
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	0.077355
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.076676
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	0.074156
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.074003
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.072869
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.072419
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.072388

V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.071337
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	0.070587
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.069454
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Technician initiated failure detection	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	0.069322
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.06912
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.067613
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.067565
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.067134
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.06648

V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.065981
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.0649
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.064721
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.064524
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	0.064353
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.064242
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	0.064155
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.063686
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.062876

V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.062287
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.060715
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	0.060454
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.060292
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.059916
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.056435
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	0.054031
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.053941
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.053227

V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	0.052976
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.051765
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	0.051623
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.051466
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.051466
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.051377
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.050926
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	0.050343

V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	0.050343
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.049834
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	0.049763
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.048949
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.048655
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.047899
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.047724
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.04747
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.047218

V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	0.04714
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.046463
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.04569
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.044246
V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.043954
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.043652
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Spare part shortage as primary bottleneck	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.043484
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	0.04348
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	0.039574

V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	0.039358
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	0.038349
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	0.038148
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.037254
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	0.037092
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.035967
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	0.035502
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	0.035016

V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.034534
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.034518
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.034391
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	0.033389
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.033175
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.032528
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\Departement specific KPIs	0.031992
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	0.031808
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.031802

V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	0.030329
V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	0.030152
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.029733
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.02958
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	0.028617
V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.027815
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	0.027601
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Stock data mismatch causing delays	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.027329
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	0.026464

V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	0.026412
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.025794
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.025772
V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.025215
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.024329
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.02375
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.023243
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	0.022694
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.021643

V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.021331
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPIs trigger escalation and review	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.020738
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System data not fully trusted	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Location discipline affects response speed	0.020087
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.018077
V2 - MRO Inventory Management Effectiveness\2.4 Supplier Relationship and Responsiveness\Key suppliers understand operational urgency	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.017671
V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.017327
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.016675
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Duplicate material codes	0.016557
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Criticality determines priority between cost and availability	0.016318

V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete technical specification in request	0.016235
V4 - Digital Integration within MRO Processes\4.1 System Bypass and Trust\System bypassed during urgency	V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	0.015806
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Incomplete failure descriptions	0.015768
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Minimum stock periodic review	0.015341
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Missing real time consumption data	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.2 Cost vs Availability Trade-off\Item value does not always reflect operational risk	0.013242
V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	V2 - MRO Inventory Management Effectiveness\2.3 Data Quality in Inventory Management\Material master data as root cause	0.013192
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.1 Cost Control Mechanisms\Framework and blanket agreements	0.012403
V1 - MRO System Structure and Quality\1.5 Performance Measurement and KPI Usage\KPI generation involves manual verification	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Forecast miss triggers downstream instanbility	0.012121
V2 - MRO Inventory Management Effectiveness\2.1 Spare Part Availability\Delay impact on operations	V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Aging reports as identification tool	0.012112

V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Reliability data not feeding into planning decisions	V4 - Digital Integration within MRO Processes\4.3 Data Completeness and Quality\Documentation lag after repairs	0.011647
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	0.01057
V2 - MRO Inventory Management Effectiveness\2.2 Demand Forecasting and Planning Accuracy\Planned demand is reliable but unplanned demand disrupts	V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Operator initiated failure detection	0.010562
V3 - MRO Inventory Holding-Cost Reduction Strategy\3.3 Obsolete and Slow Moving Stock\Old stock retained due to uncertainty	V4 - Digital Integration within MRO Processes\4.4 Cross Functional System Integration\Fewer manual steps if system connected	0.010536
V1 - MRO System Structure and Quality\1.1 Failure Detection and Reporting Flow\Triage between urgent and planned response	V4 - Digital Integration within MRO Processes\4.2 Real Time Visibility Gaps\Physical movement ahead of system update	0.010189

Appendix H Source Clustered by Word Similarity

Table H.1 Source Clustered by Word Similarity

File A	File B	Pearson correlation coefficient
Files\\P3_Warehouse_Inventory	Files\\P1_Maintenance_Engineer	0.534285
Files\\P2_Procurement_Officer	Files\\P1_Maintenance_Engineer	0.464067
Files\\P4_Supply_Planner	Files\\P3_Warehouse_Inventory	0.444225
Files\\P4_Supply_Planner	Files\\P1_Maintenance_Engineer	0.435376
Files\\P5_Reliability_Engineer	Files\\P4_Supply_Planner	0.417332
Files\\P3_Warehouse_Inventory	Files\\P2_Procurement_Officer	0.417318
Files\\P5_Reliability_Engineer	Files\\P3_Warehouse_Inventory	0.404792
Files\\P4_Supply_Planner	Files\\P2_Procurement_Officer	0.386734
Files\\P5_Reliability_Engineer	Files\\P1_Maintenance_Engineer	0.382211
Files\\P5_Reliability_Engineer	Files\\P2_Procurement_Officer	0.31571

Appendix I Matrix Coding Query

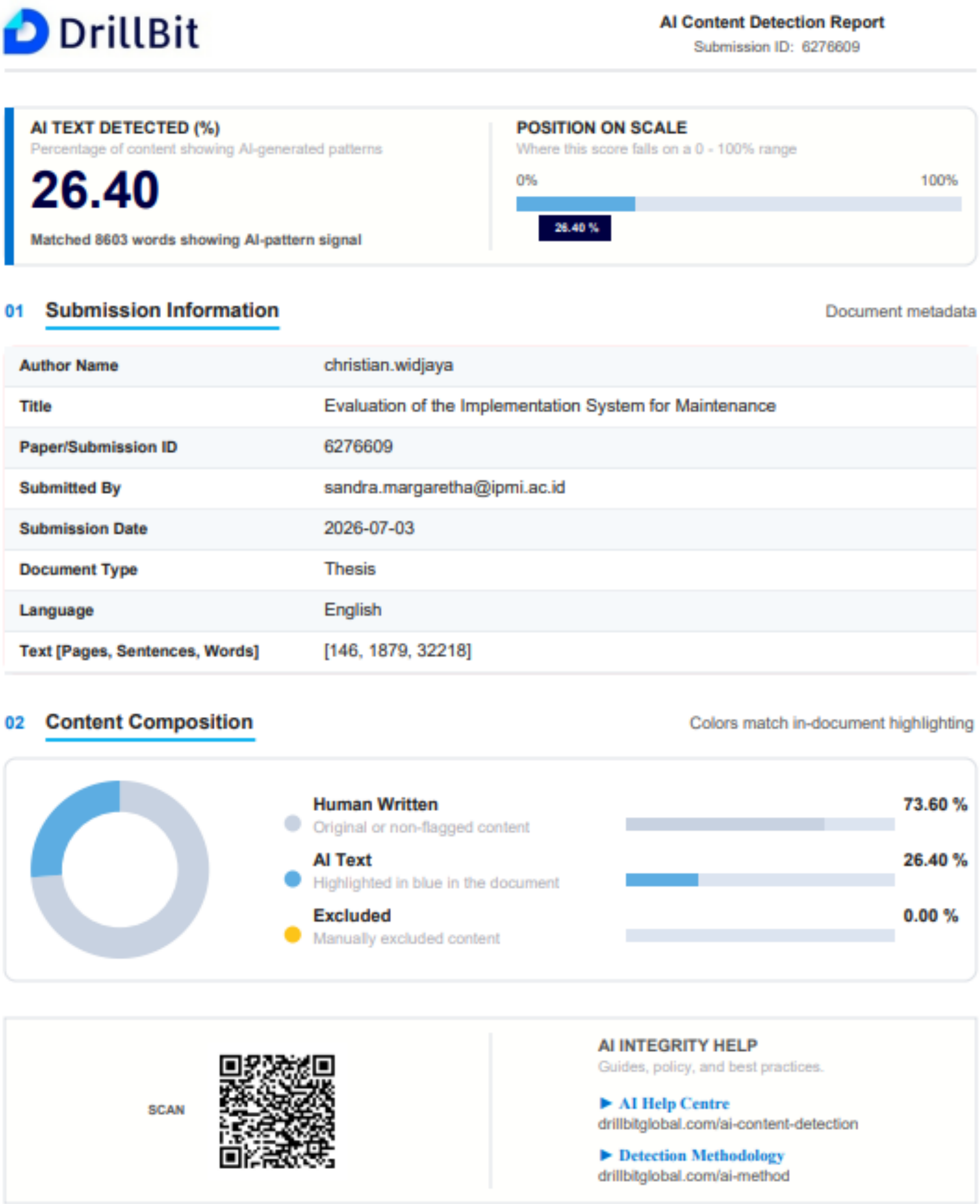
Table I.1 Matrix Coding Query

	I1_Maintenance_Engineer	I2_Procurement_Officer	I3_Warehouse_Inventory	I4_Supply_Planner	I5_Reliability_Engineer
1 : Operator initiated failure detection	0	0	0	0	0
2 : Technician initiated failure detection	1	0	0	0	0
3 : Triage between urgent and planned response	1	0	0	0	0
4 : Role boundaries blur during urgency	0	0	0	0	0
5 : Roles clear under normal conditions	0	0	0	0	0
6 : Unclear ownership of data accuracy	0	0	0	0	0
7 : Formal standards exist but field judgment overrides	0	0	0	0	0
8 : Standardization varies by item category	0	0	0	0	0
9 : Informal channels preferred for urgent matters	0	0	0	0	0
10 : Upstream information quality affects downstream speed	0	0	0	0	0
11 : Departement specific KPIs	2	1	1	1	1
12 : KPI generation involves manual verification	1	1	0	0	0
13 : KPIs trigger escalation and review	1	0	0	0	1
14 : Delay impact on operations	1	0	0	0	0
15 : Spare part shortage as primary bottleneck	1	0	1	0	0

16 : Stock data mismatch causing delays	3	0	1	0	0
17 : Forecast miss triggers downstream instanbility	0	0	0	2	0
18 : Planned demand is reliable but unplanned demand disrupts	0	0	0	1	0
19 : Duplicate material codes	0	0	0	0	0
20 : Location discipline affects response speed	0	0	0	0	0
21 : Material master data as root cause	1	0	0	0	0
22 : Key suppliers understand operational urgency	0	1	0	0	0
23 : Framework and blanket agreements	0	0	0	0	0
24 : Minimum stock periodic review	0	0	0	0	0
25 : Criticality determines priority between cost and availability	0	1	0	1	0
26 : Item value does not always reflect operational risk	1	0	0	0	0
27 : Aging reports as identification tool	0	0	1	0	0
28 : Old stock retained due to uncertainty	0	0	1	0	0
29 : System bypassed during urgency	2	0	0	0	0
30 : System data not fully trusted	0	1	0	0	0
31 : Missing real time consumption data	0	0	0	0	0
32 : Physical movement ahead of system update	1	0	0	0	0
33 : Documentation lag after repairs	1	0	0	0	0
34 : Incomplete failure descriptions	0	0	0	0	2

35 : Incomplete technical specification in request	0	2	0	0	0
36 : Fewer manual steps if system connected	0	0	0	0	0
37 : Reliability data not feeding into planning decisions	0	0	0	0	1

Appendix J AI Content Detection Report



DrillBit

AI Content Detection Report
Submission ID: 6276609

AI TEXT DETECTED (%)
Percentage of content showing AI-generated patterns
26.40
Matched 8603 words showing AI-pattern signal

POSITION ON SCALE
Where this score falls on a 0 - 100% range
0% 100%
26.40 %

01 Submission Information Document metadata

Author Name	christian.widjaya
Title	Evaluation of the Implementation System for Maintenance
Paper/Submission ID	6276609
Submitted By	sandra.margaretha@ipmi.ac.id
Submission Date	2026-07-03
Document Type	Thesis
Language	English
Text [Pages, Sentences, Words]	[146, 1879, 32218]

02 Content Composition Colors match in-document highlighting

Human Written Original or non-flagged content	73.60 %
AI Text Highlighted in blue in the document	26.40 %
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Guides, policy, and best practices.
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drillbitglobal.com/ai-content-detection
► Detection Methodology
drillbitglobal.com/ai-method

Figure J.1 AI Content Detection Report

Appendix K Plagiarism Detection Report

DrillBit

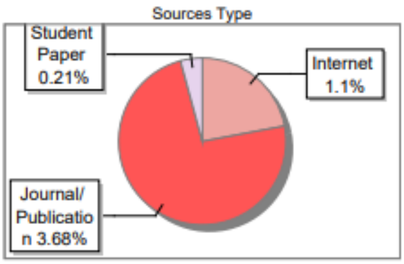
The Report is Generated by DrillBit Plagiarism Detection Software

Submission Information

Author Name	christian.widjaya
Title	Evaluation of the Implementation System for Maintenance,
Paper/Submission ID	6276672
Submitted by	sandra.margaretha@ipmi.ac.id
Submission Date	2026-07-03
Total Pages, Total Words	146, 32218
Document type	Thesis

Result Information

Similarity **5 %**



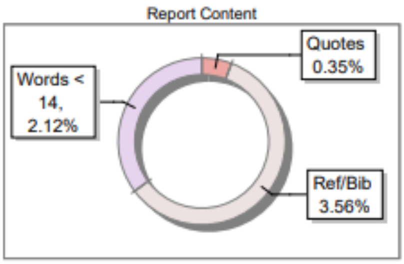


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Figure K.1 Plagiarism Detection Report