Root Cause Analysis for Maintenance Engineers: How to Identify, Analyze, and Eliminate Equipment Failures Step by Step

Maintenance Strategy & Reliability Series

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ROOT CAUSE ANALYSIS FOR MAINTENANCE ENGINEERS: HOW TO IDENTIFY, ANALYZE, AND ELIMINATE EQUIPMENT FAILURES STEP BY STEP

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Written by Mohammed Hamed Ahmed Soliman.

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Disclaimer:

All diagrams, illustrations, worksheets, and visual materials in this book were created or customized specifically for this publication and are intended for educational and professional use only.

Preface

Maintenance is not failing because of lack of tools.

It is failing because of wrong thinking.

Across industries, companies invest heavily in systems, software, and technologies—yet the same failures repeat. Equipment breaks down again. Maintenance costs rise. Reliability remains unstable.

This book is part of a larger vision:

Maintenance Strategy & Reliability Series

A structured series designed to bridge the gap between theory and real industrial practice.

This series addresses the most critical areas of modern maintenance and reliability, including:

- Maintenance Strategy Optimization
- Risk-Based Inspection (RBI)
- Failure Modes and Effects Analysis (FMEA)
- Equipment-Specific Maintenance Strategies
- Reliability-Centered Maintenance (RCM)
- Total Productive Maintenance (TPM)
- Applications of Artificial Intelligence in

Maintenance

Each book in this series focuses on a specific problem—but all of them are connected by one core idea:

Maintenance is a system.

And systems fail when their logic is broken.

Why This Book?

This book focuses on one of the most misunderstood and misused practices in maintenance:

Root Cause Analysis (RCA)

In many organizations, RCA has become:

- A report to close
- A form to fill
- A meeting to attend

But rarely:

- A tool to actually eliminate failures

This book is different.

It is:

- Direct
- Problem-driven
- Practical

It does not aim to teach definitions.

It aims to change how you think.

What You Will Learn

This book will help you:

- Stop fixing symptoms and start eliminating causes
- Understand different types of failures and how they behave
- Distinguish between RCA and other tools like FMEA
- Apply a structured, step-by-step RCA method
- Analyze real industrial failures with practical logic
- Avoid the most common mistakes that make RCA useless

Who This Book Is For

- Maintenance Engineers
- Reliability Engineers
- Maintenance Managers
- Asset Integrity Professionals

And anyone who is tired of seeing the same failure... again and again.

A Final Thought

If you keep fixing the same problem repeatedly,

you are not solving it.

You are maintaining failure.

About the Author

Dr. Mohamed Hamed is a Professor of Industrial and Systems Engineering and a senior engineering consultant with extensive experience in maintenance, reliability, and asset management.

He is affiliated with the The American University in Cairo and has contributed to international research and professional practice through organizations such as Institute of Industrial and Systems Engineers and IEOM Society International.

Academic & Professional Background

Dr. Hamed combines strong academic depth with real industrial experience.

He has authored over 100 scientific publications in areas including:

- Maintenance Strategy
- Reliability Engineering
- Failure Analysis
- Asset Management Systems
- Industrial Optimization

Practical Experience

Beyond academia, Dr. Hamed has worked closely with real industrial systems, solving complex maintenance and reliability problems across different sectors.

His work focuses on:

- Diagnosing chronic equipment failures
- Designing practical maintenance strategies
- Bridging the gap between planning and execution
- Transforming maintenance from reactive to proactive systems

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His Approach

What makes his work unique is a simple philosophy:

Real problems are not solved by theory alone.

They are solved by logic, data, and disciplined thinking.

Why This Book

This book is the result of years of observing the same pattern:

- Failures repeating
- Teams reacting
- Systems not improving

It was written to provide engineers with a clear, structured, and practical way to break that cycle.

Dedication

To those who shaped how I think, work, and persist.

To Professor Attia Gomaa, my supervisor at The American University in Cairo,

for his guidance, discipline, and belief in structured thinking.

To Professor Jeffrey K. Liker, author of *The Toyota Way*,

whose work redefined how the world understands systems, leadership, and continuous improvement.

To Professor Eslam Soliman, Assiut University, PhD University of New Mexico,

who first encouraged me to write—and to believe that practical knowledge must be shared.

To my wife, Esraa,

for her patience, support, and strength through every long night and demanding phase.

To my children,

who remind me every day why meaningful work matters.

And to every engineer who refuses to accept repeated failure as normal.

Introduction
Maintenance Strategies Framework
Where Does RCA Really Fit?

Before we talk about Root Cause Analysis,

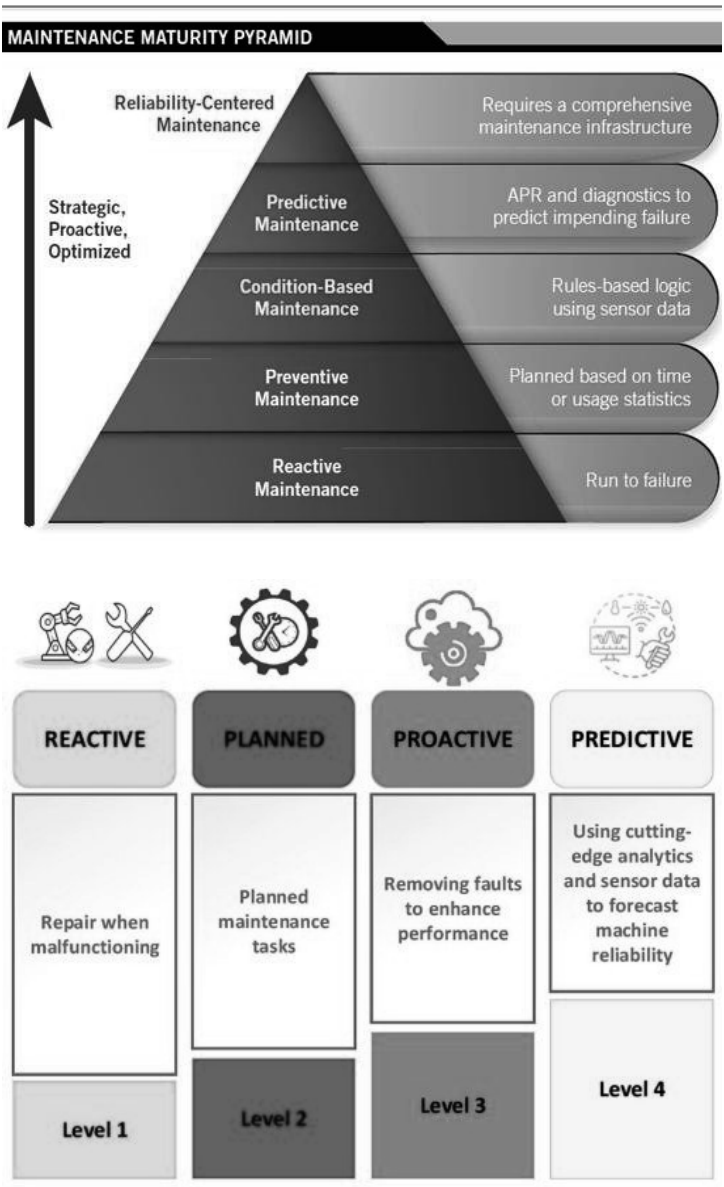
we need to understand one critical question:

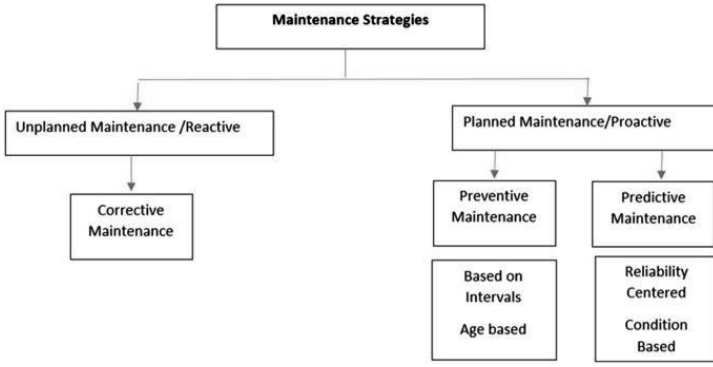
Where does RCA fit in the maintenance world?

Because RCA alone does not improve reliability.

It is part of a bigger system.

The Evolution of Maintenance Thinking


MAINTENANCE MATURITY PYRAMID
Strategic, Proactive, Optimized
Reliability-Centered Maintenance
Requires a comprehensive maintenance infrastructure
Predictive Maintenance
APR and diagnostics to predict impending failure
Condition-Based Maintenance
Rules-based logic using sensor data
Preventive Maintenance
Planned based on time or usage statistics
Reactive Maintenance
Run to failure
REACTIVE
PLANNED
PROACTIVE
PREDICTIVE
Repair when malfunctioning
Planned maintenance tasks
Removing faults to enhance performance
Using cutting-edge analytics and sensor data to forecast machine reliability
Level 1
Level 2
Level 3
Level 4



Maintenance strategies did not appear at once.

They evolved over time.

From reacting to failure...

to predicting it...

to preventing it completely.

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1. Reactive Maintenance

(Corrective / Firefighting)

The oldest and most common approach.

Fix it when it breaks.

Characteristics:

- No planning

- No prevention
- High downtime
- High cost
- High stress

Typical Actions:

- Replace failed components
- Emergency repair
- Restart equipment

Insight:

Reactive maintenance does not manage failure.

It waits for it.

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2. Preventive Maintenance

(Scheduled Maintenance)

A step forward.

Maintain equipment before it fails.

Characteristics:

- Time-based maintenance

- Planned shutdowns
- Work orders
- Routine inspections

Examples:

- Lubrication schedules
- Periodic replacement
- Planned inspections

Limitation:

You may replace parts that are still healthy.

Or miss failures that occur between intervals.

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3. Predictive Maintenance

(Condition-Based Maintenance)

Now we start listening to the machine.

Monitor condition... act when needed.

Tools:

- Vibration analysis
- Thermal imaging

- Oil analysis
- Ultrasonic testing

Advantage:

- Detect early signs of failure
- Reduce unnecessary maintenance

◈ Insight:

Predictive maintenance detects failure early...

but does not eliminate its cause.

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4. Proactive Maintenance

(Eliminating Root Causes)

This is where real reliability begins.

Remove the cause... not the symptom.

Includes:

- Root Cause Analysis (RCA)
- Failure Modes and Effects Analysis (FMEA)
- Risk-Based Inspection (RBI)

Focus:

- Why failures happen
- How to eliminate them permanently

Insight:

Predictive tells you something is wrong.

Proactive makes sure it never happens again.

Integrated Strategies

(RCM & TPM)

Some methodologies combine everything.

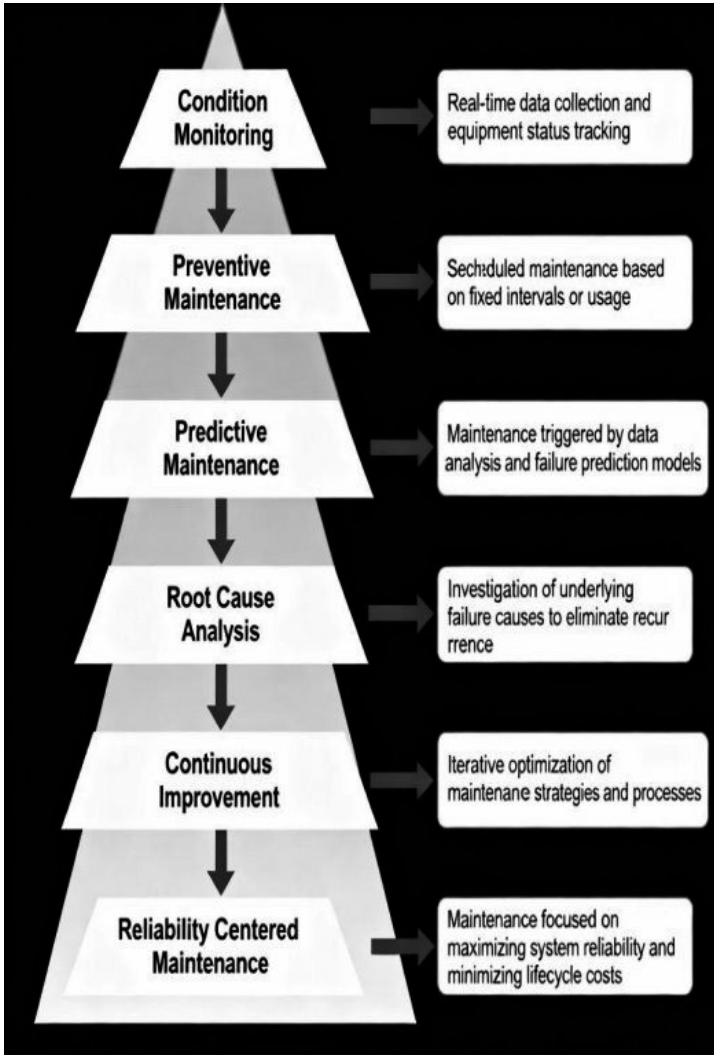
Reliability-Centered Maintenance (RCM)

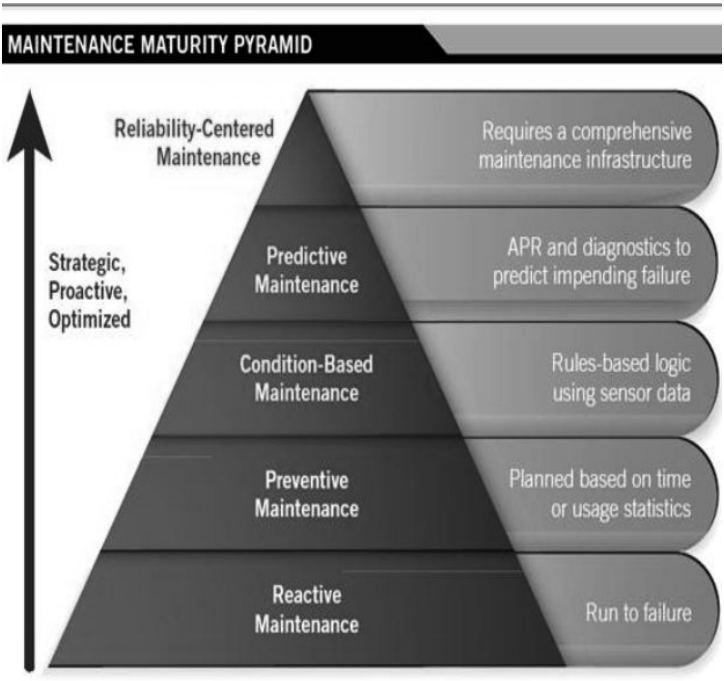
- Combines:
    - Preventive
    - Predictive
    - Proactive
- Focus:
    - Function
    - Failure consequences
    - Optimal strategy

Total Productive Maintenance (TPM)

- Involves:
    - Operators
    - Maintenance teams
- Focus:
    - Zero breakdowns
    - Continuous improvement

Where This Book Fits


Condition Monitoring
Real-time data collection and equipment status tracking
Preventive Maintenance
Sechduled maintenance based on fixed intervals or usage
Predictive Maintenance
Maintenance triggered by data analysis and failure prediction models
Root Cause Analysis
Investigation of underlying failure causes to eliminate recur rrence
Continuous Improvement
Iterative optimization of maintenane strategies and processes
Reliability Centered Maintenance
Maintenance focused on maximizing system reliability and minimizing lifecycle costs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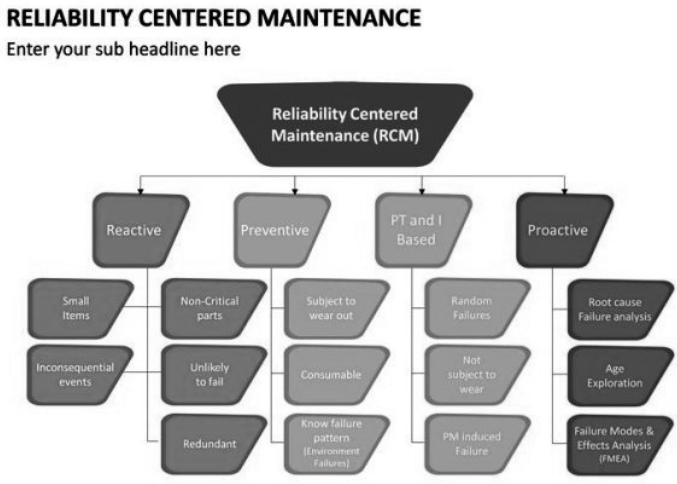

This book focuses on:

Root Cause Analysis (RCA)

Which belongs to:

Proactive Maintenance

Why RCA Matters

Because without RCA:

- Predictive detects... but failures repeat
- Preventive acts... but blindly
- Reactive keeps firefighting

Final Insight: