MAINTENANCE ENGINEERING AND MANAGEMENT:
THE PRINCIPLES GUIDE

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PREFACE

Welcome to "MAINTENANCE ENGINEERING AND MANAGEMENT: The Principles Guide," a comprehensive exploration of the fundamental principles, strategies, and methodologies that underpin the dynamic field of maintenance in engineering and management. This ebook serves as a guide for professionals, students, and enthusiasts seeking a profound understanding of the intricate world of maintenance practices.

Maintenance, a critical aspect of industrial operations, is essential for sustaining and enhancing the reliability, availability, and performance of assets. As industries evolve, so do the challenges and opportunities within the realm of maintenance engineering and management. This chapter is designed to provide a solid foundation for navigating these challenges and harnessing the full potential of maintenance practices.

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Authors

SINOPSIS

"MAINTENANCE ENGINEERING AND MANAGEMENT: The Principles Guide" covers the fundamental principles, strategies, and methods of the dynamic field of maintenance engineering and management. This chapter is helpful for professionals, students, and hobbyists seeking a deep understanding of maintenance procedures in an era of asset reliability and performance.

Introduction to core principles provides a theoretical foundation for effective maintenance strategy decision-making. Readers will learn about preventative, predictive, reliability-centered, and total productive maintenance (TPM). Readers learn how to evaluate, plan, and execute industry-standard maintenance tasks.

Analysis of Industry 4.0 technologies' impact on maintenance engineering shows how data analytics, IoT, and AI have transformed the field. The chapter covers organizational difficulties like cultural resistance and technology integration with inventive solutions.

This eBook provides a basis for professionals optimizing asset performance, students studying academics, and industry enthusiasts navigating maintenance. Explore maintenance excellence ideas and practical techniques to manage asset maintenance in today's fast-changing industrial context.

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Chapter 1: Maintenance Organization

1.1 Introduction

Organizing is about putting resources like people, materials, and technology together to achieve an organization's goals. This arrangement is known as the organization structure, a system involving the interaction of inputs and outputs. It includes task assignments, workflow, reporting relationships, and communication channels.

There's no one-size-fits-all structure; organizations continuously evolve to respond to changes in technology and processes. Historical figures like Frederick W. Taylor and the Gilbreths contributed to modern organization management.

Maintenance, traditionally reactive, is crucial. Poor maintenance can impact profitability significantly, making contemporary management revise maintenance organization approaches.

Maintenance costs are vital, consuming 2–10% of revenue in manufacturing and up to 24% in transport. Modern management sees maintenance as integral to productivity, quality, and reliability amid automation, flexible manufacturing systems, lean manufacturing, and just-in-time operations.

Designing maintenance systems lacks a universal methodology. Experience and judgment, supported by formal tools, shape maintenance systems. Considerations include strategy, defining the maintenance structure, and planning for day-to-day decisions. Maintenance organizing is a basic part of maintenance management, involving planning, organizing, implementing, and controlling activities.

The management, part of the Maintenance Management Function (MMF), organizes, provides resources, and leads to accomplish tasks. Organizing, a vital part of the management process, clarifies job relations, ensuring effective and efficient plan execution.

When creating a maintenance organization, important factors must be considered. These include the capacity of maintenance, whether to centralize or decentralize, and whether to keep maintenance in-house or outsource it. Designing the organization involves criteria like defining roles, maintaining effective supervision, and minimizing costs.

Maintenance managers play a crucial role, needing the ability to create a division of labor, coordinate tasks, and select the right people. Continuous training and incentive schemes contribute to organizational success in terms of performance efficiency.

The main goal is to find the right balance between plant availability and maintenance resource utilization. Two common organization structures are Centralized and Decentralized. While a decentralized structure might have lower utilization, it can respond quickly to breakdowns, achieving higher plant availability. Often, a mix of these structures is practical.

A maintenance organization comprises three essential components: resources (people, spares, tools), administration (hierarchy of authority), and a Work Planning and Control System. This system involves planning, scheduling, and feedback mechanisms to guide maintenance efforts toward defined objectives.

Maintenance is like a continuously evolving organism within the production system. It requires continuous modifications to match changing requirements and align resources with workload. Coordination is vital for timely execution of maintenance activities, which include preventive and condition monitoring tasks.

The Work Planning and Control System in maintenance management ensures coordination and control of maintenance activities. This involves applying general management principles to functions like planning, organizing, directing, and controlling. The control system plays a crucial role in managing maintenance costs and plant condition.

1.2 Role and objectives of maintenance management

1.2.1 Objectives and benefits

The goals and advantages of a maintenance organization within a plant or overall organization are significantly influenced by several key factors:

1. Type of Business:
   - The nature of the business matters, whether it's high-tech, labor-intensive, or involved in production or services.
2. Objectives:
   - The organization's goals, which could include maximizing profits, expanding market share, or pursuing social objectives.
3. Size and Structure:
   - The size and structure of the organization play a crucial role in shaping the maintenance setup.
4. Organizational Culture:
   - The culture of the organization, encompassing its values, practices, and norms, also influences the maintenance approach.
5. Range of Responsibility:
   - The extent of responsibility assigned to the maintenance function within the organization.

Organizations pursue various objectives such as profit maximization, specific quality standards, cost reduction, ensuring a safe environment, and developing human resources. Maintenance plays a crucial role in achieving these objectives, and it's essential that maintenance goals align with those of the organization.

Maintenance's primary responsibility is to provide services that support the organization's objectives. Responsibilities include keeping assets in good condition, performing various maintenance activities efficiently, conserving spare parts, commissioning new plants, and operating utilities while conserving energy.

These responsibilities impact the structure of the maintenance organization, which is determined after planning its capacity. The level of centralization or decentralization influences maintenance capacity. Key issues in forming the maintenance organization's structure include capacity planning, deciding on centralization or decentralization, and choosing between in-house or outsourcing approaches.

1.2.2 Maintenance Capacity Planning

Maintenance capacity planning is about figuring out what resources are needed for maintenance to run smoothly and meet department objectives. This includes the right number and skills of craftsmen, administrative support, equipment, tools, and space.

A key challenge is determining the number and types of craftsmen required since maintenance workloads can be uncertain. Accurate forecasts for future maintenance work are crucial for setting up the right maintenance capacity. To optimize manpower, organizations might have fewer craftsmen than needed, but this can lead to a backlog of unfinished work. The backlog can be managed during periods of lower maintenance demand.

Long-term estimations in maintenance capacity planning are crucial but often not well-developed in practice. Techniques for forecasting and planning maintenance capacity are explored in detail in another section of this handbook.

1.2.3 Centralization and Decentralization Management

Whether maintenance is organized centrally, decentrally, or in a hybrid way depends on the organization's philosophy, maintenance workload, plant size, and craftsmen's skills.

Advantages of Centralization:

1. Flexibility and Resource Utilization:
    - Provides flexibility and better use of resources like highly skilled crafts and special equipment, resulting in increased efficiency.
2. Efficient Line Supervision:
    - Allows for more effective line supervision.
3. Effective On-the-Job Training:
    - Facilitates more effective on-the-job training.
4. Modern Equipment Purchasing:
    - Permits the purchasing of modern equipment.

Disadvantages of Centralization:

1. Crafts Utilization:
    - Crafts may be underutilized due to increased travel time to and from jobs.
2. Supervision Challenges:
    - Supervising crafts becomes more challenging, leading to less maintenance control.
3. Less Specialization:
    - Achieves less specialization on complex hardware since different persons work on the same hardware.
4. Increased Transportation Costs:
    - Incurs more transportation costs due to the remoteness of some maintenance work.

1.2.4 In-house versus Outsourcing

When deciding how to build maintenance capacity, management weighs options like in-house hiring, outsourcing, or a mix of both. The criteria for choosing among these options involve strategic, technological, and economic factors. Key criteria include:

1. Long-Term Dependability:
    - The source's availability and dependability over the long term.
2. Capability to Achieve Objectives:
    - The source's capability to meet the organization's maintenance objectives and carry out tasks.
3. Costs:
    - Consideration of short-term and long-term costs.
4. Organizational Secrecy:
    - Potential leakage of organizational secrets.
5. Impact on Personnel Expertise:
    - Long-term impact on the expertise of maintenance personnel.
6. Special Agreements:
    - Any special agreements by manufacturers or regulatory bodies setting specifications for maintenance and environmental emissions.

Examples of tasks suitable for outsourcing include routine tasks requiring specialized skills readily available in the market, such as the installation and periodic inspection and repair of automatic fire sprinkler systems, air conditioning systems, heating systems, and mainframe computers.

1.3 Types of maintenance organizations and their responsibilities

To design or redesign their maintenance organization, organizations can consider the issues and criteria mentioned earlier. To consistently provide the capabilities needed, three types of organizational designs are worth considering:

1.3.1 Centralized Maintenance:

Strengths:

- Allows economies of scale.
- Enables in-depth skill development.
- Helps departments achieve functional goals.

Weaknesses:

- Slow response time to environmental changes.
- May cause delays in decision-making.
- Leads to poor horizontal coordination.
- Involves a restricted view of organizational goals.
- Suitable for: Small to medium-size organizations.

1.3.2 Decentralized Maintenance:

Strengths:

- Allows adaptability and coordination in production units.
- Efficient centralized overhaul group.
- Facilitates effective coordination within and between departments.

Weaknesses:

- Potential for excessive administrative overheads.
- May lead to conflicts between departments.

1.3.3 Matrix Structure (Hybrid):

Strengths:

- Allows coordination for dual demands from the environment.
- Facilitates flexible sharing of human resources.

Weaknesses:

- Causes maintenance employees to experience dual authority.
- Time-consuming, requires frequent meetings and conflict resolution.
- Requires management with good interpersonal skills and extensive training to address weaknesses.

1.3.4 Maintenance Organization Classifications:

Decentralized:

- ***Suited for***: large plants at different locations where inter-unit communication is challenging.
- ***Control***: Maintenance organization under the direct control of a chief engineer in charge of production.
- ***Advantages***:
  - ❖ Speedy decisions due to better communication.
  - ❖ Better understanding of each other's problems.
  - ❖ Interchangeability of workforce.
  - ❖ Better training opportunities.

Centralized:

- ***Suited for***: Small factories with freer departmental communication.
- ***Control***: Maintenance organization under a chief maintenance engineer/manager.
- ***Responsibilities***: Specified responsibilities and accountability for both production and maintenance personnel.
- ***Challenges***: Need for proper specification to avoid blame games.

Partially Decentralized:

- ***Suited for***: Projects with units at faraway locations.

- ***Control***: Maintenance personnel at production units handle day-to-day maintenance, centralized work at the central maintenance workshop.
- ***Flexibility***: Adjustments possible to suit the working environment and needs.

1.3.5 Types of Responsibilities/Roles:

1) Primary Functions:

- Maintenance of Existing Plant Equipment: Repair and preventive maintenance.
- Maintenance of Existing Plant Buildings and Grounds: Repairs to buildings, external property, and minor alterations.
- Equipment Inspection and Lubrication: Traditional responsibility but operators can assist in routine tasks.
- Utilities Generation and Distribution: Falls within maintenance engineering, can be a separate function.
- Alterations and New Installations: Depends on plant size, company size, and policy. Handled by outside contractors or a separate organization.

2) Secondary Functions:

a) Storekeeping:

i) Differentiation: Mechanical stores and general stores are differentiated.

ii) Administration: Mechanical stores administration falls within the maintenance engineering group due to its close relationship with other maintenance operations.

b) Plant Protection:

i) Subgroups:

(1) Guards or watchmen.

(2) Fire control squads.

(3) Incorporation: Common practice to include these functions with maintenance engineering.

(4) Importance: Fire-control group inclusion is crucial as its members are usually drawn from the craft elements.

c) Waste Disposal:

  i) Combination: Usually combined with yard maintenance as specific assignments of the maintenance department.

d) Salvage:

  i) Special Unit: If a significant part of plant activity involves off-grade products, a special salvage unit is recommended.

  ii) Mechanical Salvage: If salvage involves mechanical equipment (e.g., scrap lumber, paper), it should be assigned to maintenance.

e) Insurance Administration:

  i) Includes: Claims, process equipment and pressure-vessel inspection, liaison with underwriters' representatives, handling insurance recommendations.

  ii) Reason: Normally included with maintenance since most information originates here.

f) Other Services:

  i) Catchall: Maintenance engineering often handles various odd activities that other departments can't or don't want to manage.

  ii) Caution: Care needed not to dilute primary maintenance responsibilities with these secondary services.

  iii) Importance: Clearly define responsibilities, establish limits of authority and responsibility agreed upon by all concerned.

1.4 Sources and analysis of maintenance costs

1.4.1 Definition:

A. *Comprehensive Definition:* Includes costs related to lost opportunities in uptime, rate, yield, and quality due to non-operating or unsatisfactorily operating equipment. Also, consider costs associated with equipment-related safety degradation.

B. *Simplified Definition:* Often described as the labor and materials expense required to maintain equipment/items in a satisfactory operational state.

1.4.2 Importance of Maintenance Costs:

A. *Profitability Impact:* Maintenance cost can significantly impact an organization's profitability.

B. *Basic Profit Formula:* Profit = Income – Expenses. Reducing maintenance expenses becomes crucial for increasing profit and avoiding unnecessary expenditure.

C. *Associated Factors:*

1.4.1 Downtime

1.4.2 Idle equipment or personnel due to breakdown

1.4.3 Missed delivery dates

1.4.4 Transportation costs

1.4.5 Overhead costs

1.4.6 Maintenance labor (operator expertise and experience)

1.4.7 Asset condition (age, type, and condition)

1.4.8 Losses due to inefficient machine operations

1.4.9 Capital requirement for machine replacement.

1.4.3 Reasons for Analyzing Maintenance Costs:

- ***Maintenance Cost Drivers:*** Identify factors influencing maintenance costs.
- ***Budget Preparation:*** Essential for financial planning.
- *Input in Design:* Provide insights into the design of new equipment/systems.
- ***Life Cycle Cost Studies:*** Contribute to understanding equipment life cycle costs.

- ***Cost Control:*** Facilitate cost management.
- ***Equipment Replacement Decisions:*** Aid in decisions regarding equipment replacement.
- ***Benchmarking:*** Compare maintenance cost effectiveness to industry averages.
- ***Optimal Preventive Maintenance Policies:*** Contribute to the development of effective preventive maintenance strategies.
- ***Comparison of Approaches:*** Compare competing maintenance approaches.
- ***Feedback to Management:*** Provide valuable insights to upper-level management.
- ***Productivity Improvement:*** Contribute to enhancing overall productivity.

1.4.4 Balance in Maintenance Commitment:

- ***Frequency vs. Production:*** A balance is needed; frequent maintenance can improve production, but excessive maintenance may disrupt cost-effective operations.
- ***Illustration:*** Figure 1.2 depicts the relationship between maintenance commitment and maintenance cost.

1.4.5 Maintenance Cost Types:

(a) Direct Cost:

- *Definition:* Costs necessary to keep equipment operable.
- *Components:* Include periodic inspection, preventive maintenance, servicing, repair, and overhaul costs.

(b) Standby Cost:

- *Definition:* Total cost of operating and maintaining standby equipment used when primary facilities are undergoing maintenance or are inoperable.

(c) Lost Production Cost:

- *Definition:* Costs incurred due to lost production when primary equipment is down and no standby equipment is available.

(d) Degradation Cost:

- *Definition:* Costs resulting from the deterioration in the lifespan of equipment due to inadequate or inferior maintenance.

1.4.6 Cost Analysis Methods:

(a) Life Cycle Cost Analysis:

- *Definition:* Sum of all costs incurred during the lifetime of an item, including procurement and ownership costs.
- *Usage:* Widely employed in procuring expensive systems or equipment due to market pressure.
- *Purpose:* Evaluates the total cost of a product or system over its entire life span, considering development, operation, maintenance, and disposal costs.
- *Factors Considered:* Reliability issues, such as frequency of failure and time to repair, impacting life cycle cost.

(b) Aim of Life Cycle Costing:

- *Objective:* Determine the total cost of equipment over its entire life, considering all costs from specification to disposal.
- *Trade-offs:* Optimize total cost through trade-offs among different cost elements.
- *Quality Importance:* Emphasizes the importance of product quality over initial cost.

(c) Data for Life Cycle Cost Model:

- *Inputs:* Purchase price, mean time between failures (MTBF), mean time to repair (MTTR), material and labor costs for failures, preventive and corrective maintenance labor costs, installation and training costs, warranty coverage period, and inventory carrying costs.

(d) Advantages of Life Cycle Cost Analysis:

- Selection of equipment with lower operating and maintenance costs, reducing overall ownership costs.
- Savings redirected for other purposes.
- Excellent tool for comparing project costs, contractor selection, equipment replacement decisions, cost reduction, and planning.

(e) Disadvantages of Life Cycle Cost Analysis:

- *Challenges:* Time-consuming, expensive, and data collection can be tedious.
- *Data Accuracy:* Availability and accuracy of data can be questionable.

Conclusion: Despite challenges, life cycle cost analysis is a valuable tool for informed decision-making, cost control, and overall project planning.

1.5 Effective maintenance organization assessment and Key Performance Indicators (KPIs) for system improvement

Assessing the effectiveness of a maintenance organization is crucial for optimizing operational efficiency and ensuring equipment reliability. Key Performance Indicators (KPIs) play a vital role in this assessment, providing measurable metrics for continuous improvement. Here's a quick note on these essential aspects:

1.5.1 Effective Maintenance Organization Assessment:

- ***Objective***: Evaluate the efficiency and functionality of the maintenance organization.
- ***Components***:
    1. *Organization Structure:* Assess the clarity of roles, responsibilities, and reporting structures.
    2. *Capacity Planning:* Determine the required resources for efficient maintenance, considering manpower, tools, and space.
    3. *Centralization vs. Decentralization:* Evaluate the organizational approach based on philosophy, size, and skills.
    4. *In-house vs. Outsourcing:* Consider strategic, technological, and economic factors in building and maintaining maintenance capacity.
- ***Outcome***: Identifies strengths, weaknesses, and areas for improvement in the maintenance organization.

1.5.2 Key Performance Indicators (KPIs) for System Improvement:

- ***Objective***: Establish measurable metrics to gauge the performance and progress of the maintenance system.
- ***Essential KPIs***:
    1. *Downtime:* Measure the time equipment is non-operational, indicating efficiency and reliability.
    2. *Preventive Maintenance Compliance:* Track adherence to scheduled preventive maintenance tasks.
    3. *Response Time:* Evaluate how quickly maintenance teams respond to issues.
    4. *Equipment Reliability:* Measure the frequency of breakdowns and failures.

v. *Cost of Maintenance:* Assess the financial impact of maintenance activities on profitability.

- ***Continuous Improvement***: Regularly analyze KPI data to identify trends, set benchmarks, and implement strategies for ongoing enhancement.
- ***Benefits***: Provides a quantitative basis for decision-making, enhances accountability, and fosters a proactive approach to maintenance management.

In conclusion, an effective maintenance organization assessment, coupled with well-defined Key Performance Indicators, establishes a foundation for continuous improvement, ensuring that maintenance activities align with organizational goals and contribute to overall operational excellence.

Exercise chapter 1

1. What is the primary purpose of maintenance organization assessment?

   a) financial forecasting

   b) Ensuring equipment reliability

   c) Marketing strategy

   d) Employee satisfaction

2. Which factor heavily influences the decision to organize maintenance in a centralized, decentralized, or hybrid form?

   a) Marketing trends

   b) Organizational philosophy

   c) Employee preferences

   d) Government regulations

3. What is a potential disadvantage of a centralized maintenance structure?

   a) Improved line supervision

   b) Less utilization of crafts

   c) Quick response to breakdowns

   d) Efficient on-the-job training

4. What is the term for an organizational structure that combines both centralized and decentralized elements?

   a) Synchronized structure

   b) Hybrid structure

   c) Unified structure

   d) Segmented structure

5. In maintenance capacity planning, what is critical for determining the required resources?

   a) Projected profits

   b) Long-term estimations

c) Unpredictable forecasts

d) Minimal workforce

6. What is the objective of maintenance in achieving an optimum balance between plant availability and maintenance resource utilization?

a) Maximize downtime

b) Minimize workforce

c) Optimize cost

d) Increase breakdowns

7. What does the term "life cycle cost" refer to in maintenance analysis?

a) Initial purchase cost only

b) Total cost over an item's entire life

c) Annual maintenance cost

d) Short-term operational expenses

8. What is the drawback of life cycle cost analysis?

a) Provides inaccurate data

b) Time-consuming and expensive

c) Limited applicability

d) Biased towards new equipment

9. Which KPI measures the time equipment is non-operational?

a) Preventive Maintenance Compliance

b) Response Time

c) Downtime

d) Equipment Reliability

10. What does "MTBF" stand for in the context of life cycle cost analysis?

a) Maximum Time Before Failure

b) Minimum Time Between Failures

c) Mean Time Before Fixing

d) Maintenance Time Beyond Failures

11. In maintenance organization, what is the main responsibility concerning existing plant equipment?

a) Commissioning new plants

b) Managing utilities

c) Maintenance of existing plant equipment

d) Overhauling machinery

12. Which maintenance cost includes costs due to lost production when primary equipment is down?

a) Standby cost

b) Direct cost

c) Degradation cost

d) Lost production cost

13. What is the primary focus of primary functions in maintenance organization responsibilities?

a) Equipment installation

b) Salvage operations

c) Daily maintenance work

d) Insurance administration

14. What is the primary purpose of the Standby cost in maintenance?

a) Track equipment degradation

b) Evaluate efficiency in preventive maintenance

c) Cover costs of operating standby equipment during primary equipment downtime

d) Assess costs of standby personnel

15. Which maintenance organization type is best suited for large plants located at different places?

a) Centralized

b) Partially decentralized

c) Decentralized

d) Hybrid

16. What is the main consideration in selecting sources for building and maintaining maintenance capacity?

a) Personal preferences

b) Technological advancements

c) Strategic considerations

d) Government regulations

17. What is the primary objective of KPIs in maintenance management?

a) Increase equipment age

b) Provide a quantitative basis for decision-making

c) Minimize preventive maintenance

d) Reduce workforce

18. What is the potential disadvantage of a decentralized maintenance structure?

a) Excessive administrative overheads

b) Efficient coordination

c) Quick response to breakdowns

d) Improved specialization

19. What does the term "cascade system" refer to in maintenance organization?

a) Fully centralized structure

b) Hybrid structure with centralized challenges

c) Fully decentralized structure

d) Maintenance outsourcing

20. What is the primary objective of life cycle cost analysis in maintenance?

a) Minimize initial purchase cost

b) Optimize cost over an item's entire life

c) Reduce preventive maintenance costs

d) Maximize equipment age

Answer

1: b) Ensuring equipment reliability

2: b) Organizational philosophy

3: b) Less utilization of crafts

4: b) Hybrid structure

5: b) Long-term estimations

6: c) Optimize cost

7: b) Total cost over an item's entire life

8: b) Time-consuming and expensive

9: c) Downtime

10: b) Minimum Time Between Failures

11: c) Maintenance of existing plant equipment

12: d) Lost production cost

13: c) Daily maintenance work

14: c) Cover costs of operating standby equipment during primary equipment downtime

15: c) Decentralized

16: c) Strategic considerations

17: b) Provide a quantitative basis for decision-making

18: a) Excessive administrative overheads

19: b) Hybrid structure with centralized challenges

20: b) Optimize cost over an item's entire life

Chapter 2: Maintenance Strategies

2.1 Functions of maintenance and selection of strategies

2.1.1 Introduction: Key Points

High Maintenance Expenditures:

- Estimated one-third of maintenance expenditures are wasted in today's process industry.
- Maintenance averages 14% of the cost of goods sold in many industries.

Strategic Focus on Maintenance:

- DuPont report (2012) highlights maintenance as the largest single controllable expenditure in many plants.
- Maintenance budget often exceeds annual net profit.

Optimizing Return on Maintenance:

- Optimizing the return on maintenance is a key strategy for most process plants.
- Various maintenance strategies are outlined in this course to develop an overall plant maintenance strategy.

Traditional Maintenance Practices:

- Past practices view maintenance as actions associated with equipment repair after failure.
- The dictionary defines maintenance as "the work of keeping something in proper condition; upkeep."

Preventive Maintenance Concept:

- Maintenance should involve actions to prevent device or component failure and repair normal equipment degradation.
- The goal is to keep equipment in proper working order.

Consequences of Absence of Strategy:

- Without a well-thought-out maintenance strategy, operations may face equipment failures leading to lost production and expensive repairs.
- Patterns may emerge, such as repeated equipment failures and lack of maintenance standards.

Symptoms of Ineffective Maintenance:

- Common symptoms include repetitive equipment failures, uniform maintenance schedules, and absence of standards or best practices.

Importance of Maintenance Strategy:

- A good maintenance strategy addresses symptoms, improving process operations and reducing costs.
- Maintenance strategy's importance is likened to that of a quality program for business results

2.1.2 Maintenance Strategy

Definition:

- Maintenance strategy refers to an elaborate and systematic plan of maintenance action.
- It is a long-term plan covering all aspects of maintenance management, guiding the direction for maintenance functions.

Common Maintenance Strategies:

- Common strategies include corrective, time-based, condition-based, and reliability-centered maintenance.
- Decision-making involves selecting care and repair methodologies for maximizing equipment life and performance at minimal cost.

Understanding Equipment Failures:

- Successful maintenance management strategies require understanding how equipment fails.

- Knowing equipment weaknesses and strengths allows for proper care, ensuring maximum service at the least cost.

2.2 Categorization of maintenance types based on functions and advantages

Maintenance Functions:

- Maintenance functions ensure proper functioning of machines and equipment related to production and key organizational functions.
- Functions include inspection, testing, servicing, adjusting, aligning, calibrating, installing, replacing, repairing, overhauling, and rebuilding.

Functions Explained:

- Inspect: Evaluate item serviceability by comparing characteristics with established standards.
- Test: Verify serviceability and detect incipient failure by measuring characteristics against prescribed standards.
- Service: Periodic operations to maintain an item in proper operating condition.
- Adjust: Maintain within prescribed limits by bringing into proper position or setting operating characteristics.
- Align: Adjust specified variable elements for optimum or desired performance.
- Calibrate: Determine and make corrections to instruments or test equipment for precision measurement.
- Install: Emplace, seat, or fix an item into position for proper functioning.
- Replace: Substitute a serviceable part for an unserviceable counterpart.
- Repair: Application of maintenance services or actions to restore serviceability by correcting specific damage, fault, or malfunction.

- Overhaul: Effort to restore an item to a completely serviceable/operational condition as prescribed by maintenance standards.
- Rebuild: Restoration of unserviceable equipment to a like-new condition according to original manufacturing standards.

2.2.1 Key Stages in Implementing Maintenance Programs

Identification of Maintenance Needs:

- Assessing equipment and facility requirements to determine maintenance needs.
- Identifying critical assets and potential areas of concern.

Planning and Strategy Development:

- Developing a comprehensive maintenance plan and strategy.
- Outlining preventive, corrective, and predictive maintenance approaches.

Resource Allocation:

- Allocating necessary resources, including manpower, tools, and materials.
- Ensuring availability of adequate budget for maintenance activities.

Implementation of Maintenance Tasks:

- Executing planned maintenance tasks according to the established strategy.
- Ensuring adherence to safety standards during maintenance activities.

Monitoring and Data Collection:

- Implementing systems to monitor equipment performance.
- Collecting relevant data on maintenance activities and asset condition.

Performance Evaluation:

- Assessing the effectiveness of maintenance tasks.
- Evaluating equipment reliability and overall system performance.

Continuous Improvement:

- Implementing improvements based on performance evaluations.
- Iteratively refining maintenance strategies for enhanced efficiency.

Documentation and Record Keeping:

- Maintaining comprehensive records of maintenance activities.
- Documenting changes, improvements, and equipment history.

Training and Skill Development:

- Providing training for maintenance personnel.
- Developing and enhancing skills relevant to the maintenance program.

Review and Adjustment:

- Periodically reviewing the maintenance program's effectiveness.
- Adjusting based on changing needs, technology, or organizational goals.

2.2.2 Steps for Effective Decision-Making

Prepare for the Analysis:

- Identify equipment or components requiring maintenance analysis.
- Anticipate potential issues and failure modes.

Select the Equipment to be Analyzed:

- Choose specific equipment or components for in-depth analysis.
- Prioritize critical assets based on their impact on operations.

Identify Functions:

- Define the primary functions of the selected equipment.
- Understand the role and purpose of each function.

Identify Functional Failures:

- Recognize potential failures in the defined functions.

- Analyze how these failures impact the overall system.

Identify and Evaluate Effects of Failure:

- Categorize the effects of each failure on system performance.
- Evaluate the severity and consequences of failures.

Identify Causes of Failure:

- Investigate root causes behind each failure.
- Understand factors contributing to equipment malfunction.

Select Maintenance Tasks:

- Choose appropriate maintenance tasks based on failure analysis.
- Decide whether corrective, preventive, or predictive maintenance is suitable.

2.2.3 Example: Maintenance of a Piston

- Problem: Seal damage
- Effect: Oil leaking
- Functions: Reduce damage to the piston pump
- Functional Failures: Reduced efficiency of the piston pump
- Effects of Failure: Repairable but leads to downtime.
- Causes of Failure: Worn-out seal not replaced.
- Maintenance Tasks: Corrective maintenance

2.2.4 Strategic Considerations

Identification of Maintenance Needs:

- Recognize requirements for repair, reconditioning, or component replacement.

Analysis of Maintenance Requirements:

- Evaluate the specific needs identified in the first step.

- Prioritize tasks based on urgency and impact.

Functional Procedures for Maintenance Task Selection:

- Develop systematic procedures for selecting maintenance tasks.
- Include work planning, scheduling, and efficient work order processing.

Reporting and Controlling Procedure:

- Establish a comprehensive system for reporting and controlling all maintenance activities.
- Ensure transparency and accountability in the maintenance process.

Supporting Services and Infrastructure:

- Develop necessary support services and infrastructure for smooth execution of maintenance functions.
- Ensure availability of tools, materials, and skilled personnel.

Cost Account Procedures:

- Determine cost accounting procedures to optimize maintenance expenditures.
- Budget effectively for maintenance activities.

Training and Quality Assurance Policy:

- Adopt a policy for training maintenance staff.
- Ensure a commitment to quality in all maintenance activities.

2.3 Maintenance Type

Maintenance encompasses various actions aimed at preserving or restoring equipment, machines, or systems to their specified operable condition. The choice of maintenance type depends on factors such as equipment criticality, operational requirements, and cost considerations.

2.3.1 Breakdown Maintenance

- Definition: Repairs or replacements performed after equipment failure.
- Objective: Restore functionality post-failure; often used when downtime or injury risk is minimal.
- Characteristics:
    i. No proactive maintenance: machinery is left unchecked until failure.
    ii. Emergency repairs entail higher costs in terms of labor, parts, and lost revenue.
    iii. Associated with unpredictability and potential danger to personnel and facilities.

2.3.2 Corrective Maintenance

- Definition: Repairs conducted after a system fault emerges.
- Objective: Identify, isolate, and rectify faults, restoring operational conditions.
- Initiation: Triggered by system failures, requiring a diagnosis to determine the cause.
- Examples: Replacing a failed electrical breaker, weld repairing a cracked process line, repairing a failed instrument transmitter.

2.3.3 Preventive Maintenance

- Definition: Scheduled tasks to prevent wear, tear, or sudden equipment failure.
- Objectives:
    - Protect assets and extend equipment lifespan.
    - Enhance system reliability and reduce replacement costs.
    - Decrease system downtime and lower the risk of injury.
- Elements:
    - Reliability assessment of components.

  - Maintenance of service records.
  - Scheduled component replacements.
  - Inventory management for critical components.
- Advantages:
  - Reduced need for standby equipment.
  - Lower repair costs and wear and tear.
  - Increased machine life and worker safety.

2.3.4 Predictive Maintenance (PdM)

- Definition: Techniques to predict equipment condition and schedule maintenance.
- Objectives:
  - Convenient scheduling of corrective maintenance.
  - Prevention of unexpected equipment failures.
  - Optimization of plant availability and resource planning.
- Process:
  - Setup: Identify critical equipment, assess failure probability, set up a database.
  - Test: Employ predictive technologies and record measurements.
  - Monitor: Analyze measurements for signs of change in operating conditions.
  - Repair: Investigate warning signs and conduct necessary repairs.
  - Schedule Repair: Plan repairs before actual failure to minimize downtime.
  - Advantages: Increased equipment lifetime, enhanced plant safety, optimized spare parts handling.

2.3.5 Reliability Centered Maintenance (RCM)

Definition: RCM is a process ensuring assets fulfill users' needs in their operational context, focusing on safety, maintenance levels, and capital plans.

Primary Principles:

- Function-Oriented: Preserves system or equipment function.
- Device Group Focused: Maintains overall functionality of a device group.
- Reliability Centered: Utilizes failure statistics for an actuarial approach, emphasizing the probability of failure at specific ages.
- Design Limitations: Aims to maintain inherent reliability, acknowledging changes are a design matter.
- Safety and Economics Driven: Prioritizes safety; cost-effectiveness follows.
- Failure Definition: Any unsatisfactory condition affecting function or quality.
- Logic Tree for Tasks: Uses a logic tree to screen and select maintenance tasks consistently.
- Applicable and Effective Tasks: Chosen tasks must address the failure mode, be cost-effective, and reduce the probability of failure.
- Acknowledges Maintenance Types: Includes interval-based, condition-based tasks, and run-to-failure; the latter is a conscious decision.

Requirements Analysis:

- Determines maintenance standards ensuring systems meet designed reliability.
- Analyzes:
    i. Device/System function.
    ii. Likely failures and their consequences.
    iii. Methods to reduce failure probability or consequences.
- Results in decisions on reactive, preventive, or predictive maintenance.

Failure:

- Cessation of proper function or performance.

- RCM examines failure at various levels, directing maintenance based on the consequences.

(i) Identify the functions:

- Examines device/system capability or purpose.
- Functions may be active, passive, or hidden (emergency components).

(ii) Identify failures:

- Proactively identifies potential failures and pre-failure conditions.
- Uses failure codes for historical data in maintenance management systems.

(iii) Identify consequences of failure:

- Emphasizes threats to safety, environment, or operating capability.
- Considers consequences of infrequently used, off-line, or hidden function failures.

(iv) Identify the failure process:

- Determines methods and root causes of failures.
- Considers wear, overload, fatigue, and other processes.

2.3.6 Reactive Maintenance

Definition: Also known as breakdown, repair, fix-when-fail, or Run-to-Failure maintenance. Repairs or replacements occur only after deterioration causes functional failure.

Stages of Life-Cycle Cost Commitment:

- No influence on failure occurrence; high unplanned maintenance and part inventories.

- Can be effective if a conscious decision based on RCM analysis comparing risk and failure cost with maintenance cost.

Methods for Each Type of Maintenance Suitable in Industries and Processes

2.3.7 Condition Based Maintenance System (CBM):

- Methodology:
    - Maintenance as needed, performed after indicators show equipment deterioration.
    - Involves real-time data to optimize maintenance resources.
    - Prioritizes and acts only when maintenance is necessary.
- Advantages:
    - Improved system reliability.
    - Decreased maintenance costs.
    - Reduced human error.
- Disadvantages:
    - High installation costs.
    - Unequal maintenance periods.
    - Increased parts needing maintenance.

2.3.8 Risk Based Maintenance (RBM):

- Evaluates commercial risks, analyzes costs and benefits, and develops maintenance plans.
- Benefits:
    - Increased revenue and operating results.
    - Longer asset life and lower replacement costs.
    - Improved cash-flow management.
- Factors for Implementation:

- Depends on the start point.
- Many problems have multiple solutions.

2.4 Total Productive Maintenance

2.4.1 Introduction:

Manufacturing organizations face challenges in today's competitive environment. To succeed, effective and efficient maintenance practices are crucial. Total Productive Maintenance (TPM) is a strategic program aimed at improving maintenance performance and overall organizational efficiency.

Historical Context:

- Organizations implement proactive lean manufacturing programs to enhance competitiveness.
- TPM is part of "World Class Manufacturing," alongside programs like Total Quality Management (TQM) and Just-in-Time (JIT).
- Originating in Japan, TPM combines American preventive maintenance with Japanese concepts of total quality management and total employee involvement.

2.4.2 Key Principles of TPM:

- Total: Involves everyone from top to bottom.
- Productive: Emphasizes maintaining production while minimizing troubles.
- Maintenance: Focuses on equipment upkeep by production operators.

Definitions of TPM:

- TPM optimizes equipment effectiveness, eliminates breakdowns, and promotes autonomous maintenance by involving the entire workforce (Nakajima, 1989).
- A partnership between maintenance and production organizations to improve quality, reduce waste, cut costs, increase equipment availability, and enhance maintenance status (Rhyne, 1990).
- A maintenance improvement strategy involving all employees and departments to optimize equipment reliability and manage plant assets efficiently (Robinson and Ginder, 1995).
- A comprehensive productive-maintenance program covering the entire equipment life cycle, with participation from all employees (McKone et al., 1999).
- A communication-driven methodology that requires collaboration and understanding among operators, maintenance, and engineers (Witt, 2006).

2.4.3 Japan Institute of Plant Maintenance (JIPM)'s Definition (1971):

Focused on the production sector:

- Aims to maximize equipment efficiency.
- Establishes a total PM system for the entire equipment life.
- Operates in all sectors involved with equipment.
- Based on participation from top management to frontline staff.
- Carries out PM through motivation management.

Expanded TPM Definition (Shirose, 1996):

Adapted for organization-wide implementation:

- Aims to create a corporate system maximizing production system efficiency.

- Establishes mechanisms to prevent all losses in the entire life cycle of the production system.
- Applied in all sectors, including production, development, and administration.
- Based on participation from all members.
- Achieves zero losses through overlapping small-group activities.

2.4.4 TPM Initiative

The Total Productive Maintenance (TPM) initiative is designed to enhance the competitiveness of enterprises. It employs a structured approach to shift the mindset of employees, bringing about a visible change in the work culture of organizations. TPM aims to engage all levels and functions within an organization to maximize the overall effectiveness of production facilities.

Key Aspects of TPM Initiative:

- Structured Approach to Change: TPM represents a structured approach to bring about change in the organizational mindset. It involves systematic steps and methodologies to instill a culture of continuous improvement.
- Inclusive Engagement: Unlike traditional preventive maintenance programs centered around maintenance departments, TPM seeks to involve employees from all levels and functions. This inclusivity ranges from plant-floor operators to senior executives.
- Work Culture Transformation: A primary goal of TPM is to transform the work culture within organizations. This transformation is not limited to specific departments but extends across the entire organizational hierarchy.
- World Class Manufacturing (WCM) Initiative: TPM is aligned with the concept of World Class Manufacturing. It aims to optimize the effectiveness of manufacturing equipment, contributing to the organization's overall competitiveness.

- Employee Involvement: TPM emphasizes the active participation of employees at all levels. This involvement ensures that everyone is committed to effective equipment operation, leading to improved overall efficiency.

2.4.5 Needs of TPM:

Total Productive Maintenance (TPM) addresses various needs within the contemporary manufacturing scenario. By harnessing the participation of all employees, TPM aims to improve production equipment availability, performance, quality, reliability, and safety. The implementation of TPM leads to several bottom-line achievements that contribute to the overall success of an organization. Here are the key needs that necessitate the implementation of TPM:

- World-Class Competitiveness: To become world-class, satisfy global customers, and achieve sustained organizational growth.
- Adaptation and Competitiveness: The need for organizations to change and remain competitive in a dynamic business environment.
- Lean Production Processes: The requirement to monitor and regulate work-in-process (WIP) out of 'Lean' production processes, emphasizing synchronization of manufacturing processes.
- Manufacturing Flexibility: Achieving enhanced manufacturing flexibility objectives to respond effectively to changing market demands.
- Cultural Improvement: The desire to improve the organization's work culture and mindset, fostering a proactive and collaborative environment.
- Productivity and Quality Improvement: To enhance productivity and quality, leading to improved overall organizational performance.
- Cost Reduction Opportunities: Tapping significant cost reduction opportunities, particularly in maintenance-related expenses.
- Maximizing ROI: Minimizing investments in new technologies and maximizing return on investment (ROI) from existing equipment.

- JIT Manufacturing Environment: Ensuring appropriate manufacturing quality and production quantities in a Just-in-Time (JIT) manufacturing environment.
- Reliability and Flexibility: Realizing paramount reliability and flexibility requirements to meet organizational goals.
- Regulating Inventory Levels: Regulating inventory levels and production lead-times to achieve optimal equipment available time or up-time.
- Optimizing Life Cycle Costs: Optimizing life cycle costs to enhance competitiveness in the global marketplace.
- Addressing External Challenges: Overcoming challenges posed by external factors such as tough competition, globalization, and increases in raw material and energy costs.
- Addressing Internal Challenges: Resolving internal challenges like low productivity, high customer complaints, high defect rates, non-adherence to delivery times, and addressing issues related to wages, salaries, and skill levels.
- Effective Use of Human Resources: Ensuring more effective use of human resources, supporting personal growth, and enhancing human resource competencies through adequate training and multi-skilling.
- Problem Resolution: Liquidating unsolved tasks, including breakdowns, setup time, and defects in the production process.
- Simplifying and Ensuring Safety: Making jobs simpler and safer for employees.
- Working Smarter: Encouraging a culture of working smarter, not harder, to improve employee skills and efficiency.

By addressing these needs, TPM contributes to the overall success and competitiveness of manufacturing organizations.

2.4.6 Basic Elements of TPM: The Eight Pillars

Total Productive Maintenance (TPM) is structured around eight fundamental pillars, each contributing to the overall success of TPM implementation. These pillars serve as the basic principles or elements of TPM. The Japan Institute of Plant Maintenance (JIPM) outlines these eight pillars in a systematic approach to enhance labor productivity, control maintenance processes, and reduce setup and downtimes. Here are the eight pillars of TPM:

1. ***Autonomous Maintenance (Jishu Hozen):*** This pillar involves empowering operators and frontline employees to take ownership of routine equipment maintenance. Operators conduct basic maintenance tasks, such as cleaning, inspection, lubrication, and tightening, to prevent equipment deterioration.
2. ***Focused Improvement (Kobetsu Kaizen):*** The focus is on continuous improvement through small-group activities aimed at addressing specific issues related to equipment performance, quality, and efficiency. This pillar emphasizes a proactive and collaborative approach to problem-solving.
3. ***Planned Maintenance (Keikaku Hozen):*** This pillar emphasizes systematic and scheduled maintenance activities to prevent unplanned breakdowns and extend equipment life. It includes setting up maintenance schedules, conducting regular inspections, and replacing components before they fail.
4. ***Quality Maintenance (Hinshitsu Hozen):*** Quality maintenance focuses on ensuring that equipment functions correctly to produce high-quality products. This pillar integrates quality control practices with equipment maintenance to eliminate defects and improve overall product quality.
5. ***Education and Training (Kenzai Katsudō):*** This pillar emphasizes the importance of training and developing the skills of all employees, from operators to management. Proper education and training foster a culture of continuous learning and improvement.
6. ***Safety, Health, and Environment (Anzen Katsudō):*** This pillar addresses safety, health, and environmental concerns in the workplace. Ensuring a safe and healthy work environment is vital for sustaining long-term productivity and employee well-being.

7. ***Office TPM (Bi Area Kaizen)***: Extending TPM principles beyond the shop floor, this pillar focuses on improving efficiency and eliminating waste in administrative and office processes. It involves applying TPM methodologies to office functions.

8. ***Development Management (Shuken Katsudō):*** This pillar concentrates on the strategic aspects of TPM implementation. It involves developing and managing a comprehensive plan for TPM, aligning it with organizational goals, and ensuring continuous improvement.

These eight pillars form the foundation of TPM, promoting a holistic approach to maintenance, productivity, and organizational culture. Successful TPM implementation involves integrating these pillars into the organization's practices and fostering a mindset of continuous improvement at all levels.

2.4.7 TPM Tools and Implementation Methodology:

Total Productive Maintenance (TPM) relies on a set of tools and methodologies to analyze and solve equipment and process-related problems. The following tools are commonly used in TPM:

- Pareto Analysis: Identifying and prioritizing problems by focusing on the most significant issues.
- Statistical Process Control (SPC - Control Charts): Monitoring and controlling processes using statistical methods.
- Problem Solving Techniques: Utilizing methods like brainstorming, cause-effect diagrams, and the 5-M approach (Man, Machine, Method, Material, Measurement) to address issues.
- Team-Based Problem Solving: Collaborative problem-solving involving cross-functional teams.
- Poka-Yoke Systems (Mistake Proofing): Implementing mechanisms to prevent errors in processes.
- Autonomous Maintenance: Operators performing basic maintenance tasks to prevent equipment deterioration.
- Continuous Improvement (Kaizen): Fostering a culture of continuous learning and improvement.

- 5S: A workplace organization method involving Sort, Set in order, Shine, Standardize, and Sustain.
- Setup Time Reduction (SMED): Minimizing the time required to change over equipment setups.
- Waste Minimization: Identifying and reducing various forms of waste in processes.
- Benchmarking: Comparing performance against industry benchmarks or best practices.
- Bottleneck Analysis: Identifying and addressing bottlenecks in production processes.
- Reliability, Maintainability, and Availability (RMA) Analysis: Evaluating and optimizing equipment reliability.
- Recognition and Reward Programs: Acknowledging and rewarding employees for TPM contributions.
- System Simulation: Using simulations to model and analyze processes.

2.4.8 TPM Implementation Methodology:

Nakajima proposed a 12-step TPM implementation methodology, divided into four phases:

1. Stage Preparation:

- Declaration by top management decision to introduce TPM: Announcing the decision to implement TPM.
- Launch education and campaign to introduce TPM: Educating managers and employees about TPM.
- Create organizations to promote TPM: Establishing organizational structures for TPM.
- Establish basic TPM policies and goals: Defining fundamental TPM policies and goals.
- Formulate master plan for TPM development: Developing a comprehensive plan for TPM implementation.

2. Preliminary Implementation:

- Hold TPM kick-off: Launching TPM with events involving suppliers, related companies, and affiliates.

3. TPM Implementation:

- Establishment of a system for improving the efficiency of the production system: Pursuing efficiency improvement in the production department.
- Improve the effectiveness of each piece of equipment: Conducting project team and small group activities at production centers.
- Develop an autonomous maintenance (AM) program: Implementing a step system, diagnosis, and qualification certification for autonomous maintenance.
- Develop a scheduled maintenance program for the maintenance department: Implementing improvement, periodic, and predictive maintenance.
- Conduct training to improve operation and maintenance skills: Providing group education and training for leaders and team members.
- Develop initial equipment management program level: Focusing on easy-to-manufacture products and easy-to-operate production equipment.
- Establish quality maintenance organization: Setting conditions without defects and maintaining and controlling quality.
- Establish systems to improve the efficiency of administration and other indirect departments: Supporting production and improving efficiency in related sectors.
- Establish systems to control safety, health, and environment: Creating systems for zero accidents and zero pollution cases.

4. Stabilization:

- Perfect TPM implementation and raise TPM performance: Sustaining maintenance improvement efforts, challenging higher targets, and applying for PM awards.

This structured approach aims to systematically implement TPM, involving all levels of the organization and promoting continuous improvement in equipment reliability and overall productivity.

2.4.9 Barriers in TPM Implementation:

Implementing Total Productive Maintenance (TPM) is a challenging task, and several barriers can hinder its successful adoption. These barriers can be classified into various categories:

1. Organizational Barriers:

- *Inability to bring about cultural transformations:* Resistance to cultural change within the organization.
- *Lack of commitment from top management:* Insufficient support from leadership in implementing TPM.
- *Inadequate understanding of TPM concepts:* Lack of awareness and comprehension among employees.
- *Ineffective communication about TPM:* Failure to communicate the principles and goals of TPM.
- *Resistance from middle management:* Reluctance to empower and recognize bottom-level operators.
- *Inadequate reward and recognition mechanisms:* Lack of effective systems to acknowledge TPM contributions.
- *Lack of adherence to TPM practices:* Difficulty in strictly following established TPM practices and standards.

2. Cultural Barriers:

- *Inability to align employees with organizational goals:* Lack of alignment between individual and organizational objectives.
- *Resistance to change:* Opposition to new and proactive management concepts.
- *Strong unions and rigid mindsets:* Challenges posed by rigid attitudes, especially in unionized environments.
- *Concerns about job security:* Resistance due to fears of job insecurity and technological advancements.
- *Low skill base:* Insufficient skills and knowledge among employees for adapting to changes.

3. Behavioral Barriers:

- *Resistance from employees:* Opposition to proactive and innovative management concepts.
- *Difficulty in succeeding as cross-functional teams:* Challenges in collaborative efforts across different functions.
- *Lack of motivation:* Insufficient motivation among employees to contribute to organizational development.
- *Functional orientation:* A focus on individual functions rather than a holistic approach.
- *Resistance to skill enhancement:* Reluctance to learn and acquire new skills.

4. Technological Barriers:

- *Little emphasis on improving production capabilities:* Insufficient focus on enhancing production capabilities.
- *Inadequate predictive maintenance infrastructure:* Lack of facilities for predicting and preventing maintenance issues.
- *Absence of computerized maintenance management systems (CMMS):* Inability to manage maintenance efficiently using technology.
- *Poor flexibility of production systems:* Inflexible production systems with long setup and changeover times.
- *Lack of training on emerging technologies:* Insufficient training opportunities for employees on new technologies.

5. Operational Barriers:

- *Acceptance of high defect levels:* Tolerance for defects without a commitment to achieving world-class production capabilities.
- *Non-adherence to standard operating procedures (SOP):* Failure to follow established procedures.
- *Limited empowerment of operators:* Insufficient authority granted to operators for equipment-related decisions.
- *Lack of planned maintenance check-sheets:* Absence of efficient routine maintenance procedures.
- *Resistance from production operators:* Unwillingness of operators to perform basic autonomous maintenance tasks.

6. Financial Barriers:

- *Requirement of significant additional resources:* Need for additional resources during the initial stages of TPM implementation.
- *Inability of top management to support initiatives:* Lack of support from top management due to resource constraints.
- *Absence of appropriate motivating mechanisms:* Lack of effective reward and recognition mechanisms.

7. Departmental Barriers:

- *Low synergy between maintenance and production departments:* Lack of coordination between different departments.
- *Reluctance of production operators:* Resistance from operators to accept autonomous maintenance initiatives.
- *Divisions between maintenance and production responsibilities:* Firm distinctions between maintenance and production functions.
- *Lack of trust in productive operator capabilities:* General mistrust in the abilities of operators to perform basic maintenance tasks.

2.4.10 Success Factors in TPM Implementation:

To overcome these barriers, organizations can focus on key success factors, including:

- *Top management contributions*
- *Cultural transformations*
- *Employee involvement*
- *Traditional and proactive maintenance policies*
- *Training and education*
- *Maintenance prevention and focused production system improvements*

A successful TPM implementation requires a long-term commitment, training, management support, and teamwork to achieve the benefits of improved equipment effectiveness. The development of TPM support practices, such as committed leadership, vision, strategic planning, cross-functional training, employee involvement, cultural changes, continuous improvement, motivation, and evolving work-related incentive mechanisms, is crucial for facilitating TPM implementation programs and realizing world-class manufacturing attributes.

Exercise Chapter 2

a. Compare and contrast the strengths and weaknesses of preventive maintenance (PM) and predictive maintenance (PdM) strategies. Discuss scenarios where one strategy might be more effective than the other and provide real-world examples to support your analysis.

b. Explain the key principles of Reliability Centered Maintenance (RCM) and discuss the critical steps involved in implementing RCM in an industrial setting. How can organizations ensure the successful integration of RCM into their maintenance practices?

c. Discuss the core elements of Total Productive Maintenance (TPM) and how it differs from traditional maintenance approaches. Provide examples of industries or companies that have successfully implemented TPM and describe the impact on their overall operational efficiency.

d. Evaluate the role of asset management strategies in enhancing the lifecycle performance of equipment. How can organizations effectively balance reactive, preventive, and predictive maintenance to optimize asset reliability, minimize downtime, and maximize return on investment

e. Explore the integration of Industry 4.0 technologies, such as IoT sensors and predictive analytics, in modern maintenance strategies. How do these technologies transform traditional maintenance practices, and what challenges and opportunities do they present for industries adopting smart maintenance approaches?

Chapter 3: System Approach to Maintenance

3.1 Introduction:

- Maintenance management system is a systematic approach for planning, organizing, monitoring, and evaluating maintenance activities and costs.
- A successful maintenance system combines knowledge and skilled staff to prevent health and safety issues, minimize environmental damage, extend asset life, reduce breakdowns, and lower operating costs.

3.2 Maintenance Control System

3.2.1 List of Activities:

- Aimed at increasing productivity, efficiency, and profitability while minimizing losses and wastages.
- Objectives include achieving operational reliability and optimal personal safety at minimal cost.
- Facilitated through design changes, improved lubricants, enhanced suspension systems, calibration, alignment, etc.

3.2.2 Work Order and Work Permit System:

- Work order authorizes and directs individuals or groups for specific tasks, including maintenance, repair, and new work.
- Work order system covers all maintenance jobs, whether repetitive or one-time, with formal estimation, planning, and scheduling.
- Key details in a work order: requested and planned completion dates, work description and reasons, planned start date, labor and material costs, affected items, work category, and appropriate approval signatures.
- Purpose of Maintenance Work Order System:
    i. Requesting written work instructions.

ii. Assigning the best, safe method with estimated time.

iii. Reducing costs through man-hour and material control.

iv. Performing predictive and preventive maintenance.

v. Improving planning and scheduling.

vi. Serving as a data source for reporting time standard development and control.

3.2.3 Job Cards and Procedures:

- Completed job cards, initiated by maintenance personnel, are sent to the computer section or planning/documentation section for processing.
- Information from job cards provides feedback to maintenance engineers/plant engineers.
- Job cards focus on essential details for each job, taking the form of cards, sheets, or computer-generated printouts, manually or electronically prepared.
- It includes a schedule of tasks and is completed for every job undertaken.

3.2.4 Job Execution:

- Job execution involves the actual performance of maintenance and repair work, following a work request and a planned schedule.
- Schedules, charts, and job cards are distributed to different agencies or individuals.
- Divide by 2 types.

a. In-House Workforce:

- In-house workforce records labor, material, supplies, parts, and equipment usage on a daily employee activity sheet (Figure 3.1).
- This document serves as a record of worker activities for the day.

b. Contracted Work:

- An inspector is assigned to periodically check and inspect work progress.
- Nothing should be closed or covered without prior inspection to ensure quality and compliance.

3.2.5 Monitoring:

- Constant follow-up and monitoring throughout the execution of repair and maintenance are crucial.
- Monitoring roles include gathering information on deviations, delays, communicating with follow-up agencies, reporting constraints, and providing leads for technical advancements.
- Methods involve daily brief meetings and repair coordinators updating PERT/CPM/bar charts, noting deviations, and communicating corrective actions.

3.2.6 Feedback:

- Feedback involves collecting data on work execution status, system availability, work backlog, and work quality.
- Functions include inter/intra-departmental communication, immediate feedback on repair job status, ongoing work, suspended/stopped work reports, work completion reports, manpower engagement reports, and cost reports.

3.2.7 Control System:

- A control system, based on monitoring and feedback, optimizes time and cost in repair and maintenance.
- Control methods include continuous or periodic checking, inspection of condition/status, comparison of condition/status, and budgetary control.

3.3 Codification and Cataloguing:

3.3.1 Advantages:

- Proper and uniform codification facilitates inventory control and management.
- Systematic discipline aids users, stock controllers, purchase authorities, and organizations in correctly identifying, issuing, purchasing, and selecting items.
- Identification numbers enable transactional economy and automated data processing.
- Codification reduces variety, prevents overstocking, and lowers purchase costs by revealing duplicate and interchangeable items.
- Aids in rationalization, standardization, and promotes the use of standard items.
- Reveals interchangeability of items within and between services.

3.3.2 Codification of Equipment and Components:

- Awareness among all concerned persons about codes and the codification system is crucial.
- For standard bought-out components/items, a new number may be given, conforming to national or international codes, with cross-linking documented.
- Used not only for maintenance but also by material management, finance, project departments, and others.
- Categories of codification extensively used for maintenance functions include drawing codification, equipment codification, parts/spares codification, maintenance defects, and maintenance jobs codification.

3.3.3 Drawing Codification:

- Linked with material (equipment and spares/parts) catalogue/codification.
- In a new plant/industry, initial drawing cataloguing is based on supplier parts catalog.

- Subsequently, the plant's own catalogue/codification may necessitate adjustments to drawing codification.
- Ideally, drawing codification should precede equipment and parts catalogue.

Drawing Codification Logic:

The ten-digit drawing code system comprehensively describes parts or items. The breakdown is as follows:

- Discipline (a):
    - for operation items,
    - the fourth digit for mechanical items,
    - the seventh digit for electrical items.
- Shop Number (b): Ranges from 0 to 9.
    - Equipment Number (c and d): Combined digits c and d indicate the equipment number in the shop (01 to 99).
    - Assembly/Sub-assembly Number (e and f): Combined digits e and f indicate the assembly/sub-assembly number (01 to 99).
    - Part Number (g and h): Combined digits g and h indicate the part number of that assembly/sub-assembly (01 to 99).

Common Items Codification:

- For common items, the first two digits (a and b) describe the type of item. e.g., 63 for EOT Cranes, 64 for machine tools, 62 for transport vehicles (Rail & Road), etc.

Drawing Code Conversion:

- By adding the last two digits (i and j), the total ten digits are converted to a drawing code.

- Place (i) uses two digits ‘0’ or ‘9’. ‘0’ indicates a single item in the drawing, while ‘9’ indicates multiple items.
- The last digit in place of (j) is generally ‘0,’ indicating the first drawing. For revisions, the last digit changes to 1, 2, or more.

Deviation for Electrical Circuit Diagrams:

- Alphabets (A to Z) replace digits (0 to 9) in shop places.
- Three digits are used for sheets on main drawings.
- Alphabets (A to Z) replace digits (0 to 9) for revision, allowing more than 10 revisions.

3.3.4 Categories and Functions:

3.3.3.1 Codification:

The codification process involves the following steps:

- Item Identification: Identifying items based on characteristics, usage, and manufacture and assigning an approved item name and description.
- Classification: Classifying items into appropriate classes in accordance with the system.
- Allotment of a Number: Assigning a unique item identification number to items.
- Recording of Identification Data: Keeping a record of the identification data of all codified items for compiling a catalogue and checking for similar items.

3.3.5 Cataloguing:

The cataloguing system and organization depend on the size and magnitude of the task. Key aspects include:

- Arrangement: Catalogues list items in alphabetical sequence based on nomenclature, ensuring no ambiguity.

- Grouping: Items are grouped and classified based on technical, functional, user, or technical-cum-user affinity.
- Short Reference or Code: Each item is allotted a catalogue number, providing a short reference or code for decoding the item's description.
- Logical Structure: Catalogues consist of logical groups and classes for standardization.
- Additional Information: Specifications, titles, references, drawing authority, and supplier/manufacturer identity and reference may be included in a catalogue.

This standard cataloguing system ensures a clear and organized representation of items for efficient management and reference.

3.4 Instruction Manual and Operating Manual:

3.4.1 Information Required from Manuals:

Manuals are crucial technical communication tools that assist users in learning and using a particular program or device. There are two main types: instruction manuals and operating manuals.

- Instruction Manual: Accompanies a technical device, providing guidance on installation and operation. It includes technical descriptions, machine data, and maintenance information.
- Operating Manual: Describes processes and systems used by a company. For larger or special equipment, separate operating manuals are provided, focusing on guiding users through machine operation with specific procedures.

3.4.2 Sections of Instruction Manual:

Instruction manuals consist of various components, offering a step-by-step guide for users. Key sections include:

- Safety Regulation:

i. Emphasizes safety tips, hazard alerts, and precautions to protect users, prevent equipment damage, and avoid legal issues.

ii. Safety regulations aim to ensure freedom from failure, damage, accidents, and harm.

iii. They are presented as lists of safety tips and hazard alerts to protect users, prevent equipment damage, and mitigate legal risks.

- Machine Brief Introduction (Technical Data):

  i. Provides an overview of the machine, including technical specifications.

    - Part-by-Part Explanation: Delivers a breakdown of the machine's components, elucidating the function and purpose of each part.
    - Labeled Diagram of Product's Components: Includes a visual representation with labels, aiding users in identifying and understanding the various components.
    - List of Product's Specifications: Presents a detailed list outlining the specifications of the product, such as dimensions, capacity, and other relevant technical details.
    - Schematic Diagram: Provides a schematic representation, offering a simplified and visual explanation of the machine's internal structure and how its components interact

- Transportation:

  i. Guidance on safely transporting the equipment.

  ii. This section of the instruction manual is dedicated to guiding users on the proper transportation and handling of the equipment.

  iii. It outlines methods and procedures to safely move the equipment from one location to another within a facility or at a specific site.

  iv. The emphasis is on ensuring that the prescribed methods are followed to guarantee the safe and accurate handling of the equipment.

- Installation and Handling:
    i. Instructions on proper installation and handling procedures.
    ii. The installation procedure typically includes the following steps:
        - Choose a Suitable Location: Select a dry area away from drafts, air vents, or other equipment that may affect the equipment.
        - Place on Flat Surface: Set up the unit on a flat, preferably non-flammable surface.
        - Ensure Adequate Space: Allow enough space around the unit for access and cooling, with a suggested minimum of six inches on all sides.
        - Plug into Grounded Outlet: Connect the unit to a properly grounded electrical outlet.
        - Use Lifter for Insertion: If required, use a lifter to insert blocks into the designated well.
        - Readiness for Use: Following these steps, the unit is now ready for operation.
- Maintenance and Cleaning:
    i. Information on routine maintenance tasks and cleaning procedures.
    ii. The maintenance manual outlines user responsibilities, providing instructions and schedules.
    iii. Maintenance is categorized into instructions and schedules, contributing to long-term planning for effective system management. It addresses both operational and performance aspects, with diagnosis aiding in identifying issues and implementing corrective actions to restore or prolong optimal operation.
        - Periodic Maintenance Procedures:
            a) Clearly outlined in the manual.
            b) Guides users on maintaining each part at specific intervals.
            c) Enables precise scheduling of maintenance tasks.

- Step-by-Step Maintenance Instructions:
    a) Detailed procedures for every part or component.
    b) Helps users understand when and how to perform maintenance.
    c) Includes repair guidance if any part malfunctions.

3.5 Operating Policies of Effective Maintenance

3.5.1 Categories of Basic Operating Policies

Maintenance policies can be categorized into four general groups:

A. Policies with respect to work allocation

- In larger maintenance departments, planning beyond day-to-day allocation is essential for efficiency.
- Planning should be balanced, aiming for maximum overall efficiency without exceeding the cost of operating without it.
- Considerations include work unit, size of jobs scheduled, percent of total workload scheduled, and lead time for scheduling.

(i) Flow-of-Work Requests

- Formalize the method of requesting work from the maintenance department.
- Information must be routed to a central point for scheduling purposes.
- Job information for planning should include labor hours, craft skills, equipment requirements, and parts availability.
- Feedback on actual performance is crucial.

(ii) Determination of Priority

- Priority is crucial as the work demand often exceeds available resources.

- Prioritization can be handled at a lower level of management in consultation with production departments.
- Allocation of craft manpower to each production department helps in establishing work priority.

(iii) Coordinating and Dispatching

- A schedule should be used as a guide, with modifications made as needed.
- Rapid communication of changes to the workforce is essential.
- Changes or unexpected work should be funneled through the dispatch center.

(iv) Preventive versus Breakdown Maintenance

- Tailor preventive maintenance to the function of different equipment.
- Consider the cost of preparation for preventive maintenance against the cost of repair after a failure.
- Utilize compromise devices like mechanical custodians for smaller plants or units.

(v) Reliability Engineering

- Reliability engineering involves analyzing breakdown causes and making changes for increased reliability.
- Special groups or maintenance engineers can focus on cost-reduction efforts.
- Solicit aid from equipment suppliers and focus efforts on areas with the most significant return.

These strategies enhance overall efficiency, balance preventive and breakdown maintenance, and optimize reliability through ongoing analysis and improvement.

B. Policies with Respect to Workforce

(i). In-House Workforce or Outside Contractors

- Decision-making factors for using in-house staff or contractors include cost, type and amount of work, and the urgency of task completion.
- Cost analysis should consider not only maintenance expenses but also overall company costs, including downtime and performance quality.
- Factors like time requirements, skill availability, and potential knowledge transfer risks should be part of the decision-making process.
- Skill levels and equipment complexity influence the decision to set up an in-house shop for a specific craft.

(ii). Coverage

- In continuous operation industries, maintenance coverage during off-shifts is essential but requires balancing efficiency and workforce satisfaction.
- Considerations include the efficiency loss of off-shift work, coordination with production, and the availability of supplies and equipment during off-hours.
- The optimal solution often involves a compromise, determining the right amount of coverage based on safety, production needs, and economic justification.

(iii). Centralization versus Decentralization

- The debate between centralized and decentralized maintenance involves weighing advantages for each approach.
- Centralized maintenance offers diverse crafts, better equipment, specialized supervision, and improved training facilities.
- Decentralized maintenance provides reduced travel time, increased equipment knowledge, better application to jobs, improved maintenance-production relationships, and enhanced preventive maintenance.
- A compromise system, combining both approaches, often proves most effective, utilizing centralized groups for major work and decentralized groups for immediate attention to minor problems.

(iv). Recruitment

- Recruitment policies for maintenance personnel depend on local conditions, union contracts, and plant-specific needs.
- Union contracts may influence the selection process, but efforts should be made to consider age, aptitude, experience, education, and intelligence.
- Stable workforces are preferred, and agreements with unions can enhance the quality of candidates considered.
- Local conditions and the production work force's makeup impact recruitment decisions.

(v). Training

- Training methods vary from formal apprentice programs to on-the-job exposure and coaching.
- Factors influencing the degree of formality in training programs include plant size, labor attitudes, skilled labor availability, and management policies.
- The effectiveness of training programs relies on support from both management and the crafts group.
- Formal training programs should be justified by improved maintenance performance or proper staffing, and their scope should align with specific needs and goals.

C. Policies with Respect to Interplant Relations

(i). Participation by Maintenance Personnel in Selection of Production Equipment

- In some plants, engineering activities are consolidated, while in others, major construction or addition of equipment is handled by separate entities.

- Progressive companies involve maintenance representatives in the design and selection of new facilities to ensure ease of maintenance.
- Maintenance engineers contribute based on their experience and equipment performance records, suggesting modifications for reduced maintenance costs.
- Standardization of equipment is crucial for cost reduction, and maintenance engineering should play a major role in policy formulation.
- A project board, comprising representatives from different departments, facilitates communication and cooperation during new engineering ventures.

(ii). Authority to Shut Down Equipment for Maintenance

- The authority to dictate shutdowns for maintenance varies, with some plants granting this to the maintenance department, while others make it a joint decision with production.
- The maintenance department's recommendation for shutdown should be based on trust, and a collaborative approach between maintenance and production is essential.

(iii). Responsibility for Safety

- Safety is paramount, and the maintenance department plays a crucial role in ensuring a safe working environment.
- The responsibility for safety may be part of the maintenance function in smaller plants but is often handled by a separate safety department in larger plants.
- The maintenance department is responsible for implementing the safety program, including inspection of safety devices and immediate correction of deficiencies.

(iv). Instrumentation

- Responsibility for instrumentation in the maintenance department depends on the plant's characteristics and the complexity of instruments.

- In plants using simple instruments, responsibility may lie with the electrical group, while in industries with complex instrumentation, a separate department or the production department may handle it.
- The increased complexity of instruments may require technical personnel in a maintenance capacity, and responsibility could be transferred to those operating the plant.

D. Policies with Respect to Control

(i). Communications

- Effective communication is crucial in maintenance management, involving information flow upward, downward, and laterally across organizational levels.
- Communication should be minimized to ensure efficiency, with upward communication reaching only the necessary levels for effective action.
- Horizontal communication should be controlled to provide information essential for effective cooperation between different sections of the maintenance group.
- As the organization grows, procedural formality and specialization increase, necessitating clearly defined limits of authority for independent action at each level.
- Indiscriminate requirements for approvals can clutter communication channels, and flow diagrams can help identify unnecessary steps.

(ii). Use of Standard-Practice Sheets and Manuals

- Standard-practice sheets and manuals are essential for planning work, ordering materials, improving estimating accuracy, and training crafts personnel.
- The need for standard-practice sheets depends on the degree of equipment duplication, repair complexity, and skill/experience of personnel.
- Equipment suppliers' manuals are valuable resources, and efforts should be made to maintain a complete supply available to maintenance personnel.

- Clear and up-to-date drawings for electrical and piping layouts are crucial for planning repairs, replacements, or modifications.

(iii). Maintenance Control System

- Maintenance records provide documentation about equipment upkeep, helping businesses manage repair and preventative upkeep expenses.
- Essential for large industrial plants, maintenance records track repairs, service upkeep, and preventive maintenance, ensuring smooth plant operations.
- Maintenance records assist in diagnosing repeat problems, tracking equipment performance against warranties, and supporting legal cases related to faulty equipment.
- Developing a maintenance record plan involves creating an inventory of all equipment, assigning tracking numbers, and updating records when work is performed.
- Maintenance efficiency reports include backlog reports by craft, providing insights into the relationship between workforce size and backlog of requested work.
- Regular reports on maintenance costs per unit of production output, plant availability, and maintenance efficiency are crucial for assessing system success.
- Monitoring product quality, equipment failure, equipment history, and costs provides valuable insights for corrective action and decision-making in maintenance control.

3.6 Maintenance Manual and Department Manual

3.6.1 Overview

- ***Maintenance Manual***: Detailed instructions for repairing, maintaining, and overhauling specific equipment, providing in-depth information, drawings, and blow-up views for both minor and major repairs. Also known as a "workshop manual" and typically supplied by equipment manufacturers.

- ***Department Manual***: Document for the maintenance department, usually separated into mechanical, electrical, and civil maintenance sections. Its purpose is to outline the organizational structure, define responsibilities and authorities of different sections and executives up to area or section in-charges, and provide an overview of the department's capabilities.
- Areas Covered:
  I. ***Activities***: Brief descriptions of different sections and areas within the maintenance department.
  II. ***Organization Structure***: Hierarchical structure from the chief of the maintenance organization to section in-charges.
  III. ***Responsibility and Authorities***: Defined for personnel up to section in-charge, outlining decision-making levels.
  IV. ***List of Maintenance Procedures***: Standard operating procedures (SOP) or standard maintenance procedures (SMP) for various sections/areas.
  V. ***Instructions***: Guidance for different captive shops and services within the department.
  VI. ***List of Records***: Numerical records to be maintained by the department, including shift log reports, daily inspection reports, breakdown and delay reports, equipment history records, and job manuals.

3.6.2 Techniques of Maintenance Time Standard

- Maintenance Time Standard involves setting standard times for various maintenance jobs to aid in planning, scheduling, and cost control.
- Common arguments against setting maintenance time standards include the variety of jobs, non-repetitiveness, changing work conditions, and the uniqueness of many maintenance tasks.
- Maintenance time standards are feasible and beneficial for planning and controlling costs, if they consider job variety, changing conditions, and the unique aspects of maintenance work.

3.6.3 Level of Maintenance Operation Liaison

- Effective communication with operating personnel at all levels is crucial for maintenance operations. This horizontal communication ensures better cooperation, eliminates confusion, and reduces delays.
- Benefits at Different Levels:
    1. ***Lower Level***: Direct contact between workmen, supervisors, and junior executives leads to the issuance of service requisitions, regular inspections, immediate feedback, and joint discussions for improvement.
    2. ***Planning Level***: Liaison between maintenance planning personnel and operation planners helps adjust schedules based on additional service requests, work postponements, delays, and material availability.
    3. ***Senior Level***: Direct contact between senior maintenance and operation personnel leads to advice on technical matters, improved safety measures, minor budget adjustments, and steps for better equipment performance.
- Effective communication between maintenance and operation personnel results in reduced calls for maintenance, improved operator appreciation for technical features, improved economy and energy conservation, co-operation in fault finding and repair, identification of variations affecting equipment, improved record handling, cleanliness, and overall efficiency.
- Maintenance departments should establish similar liaison and effective communication with other departments/agencies, such as technical and engineering services, plan development/project departments, and materials departments.

Exercise Chapter 3

1. A system approach to maintenance involves considering the entire ___________ rather than individual components.
2. In the system approach, maintenance activities are aligned with overall ___________ goals and objectives.
3. The key principle of a system approach is to view maintenance as an integral part of the ___________ process.
4. System approach emphasizes the importance of understanding the ___________ and interactions within the maintenance process.
5. One benefit of the system approach is the ability to optimize ___________ resources and efforts.
6. The system approach considers not only equipment reliability but also its impact on overall ___________.
7. In the context of maintenance, a system approach requires a focus on both ___________ and preventive measures.
8. Applying a system approach involves considering the entire ___________ lifecycle, from acquisition to disposal.
9. The system approach to maintenance encourages a holistic view that includes people, processes, and ___________.
10. By adopting a system approach, organizations can achieve improved ___________ and cost-effectiveness in maintenance activities.

Answers:

1: System

2: Organizational

3: Management

4: Relationships

5: Operational

6: Performance

7: Reactive

8: Asset

9: Technology

10: Efficiency

Chapter 4: Maintenance Planning and Scheduling

4.1 Introduction

Planning is the process of determining what is needed to perform a task before starting it, while scheduling involves matching jobs with resources and arranging them to be done at specific times. Essentially, planning precedes scheduling. If even one job in a schedule of twenty is not fully planned beforehand, it can jeopardize the accuracy of the schedule. An unplanned or partially planned job may take longer than expected or use resources allocated for other jobs, disrupting the overall schedule.

4.2 Maintenance Planning

4.2.1 Concept and Steps

Maintenance planning involves determining future decisions and actions necessary to achieve goals efficiently. It helps minimize costs, reduce risks, and seize opportunities, enhancing the organization's competitive edge.

The steps in maintenance planning include:

a. Good planning is essential for effective scheduling.
b. Identify the job's content.
c. Develop a work plan outlining the sequence of activities and the best methods to complete the job.
d. Determine the crew size for the job.
e. Plan and order necessary parts and materials.
f. Check if special tools and equipment are required and obtain them.
g. Assign workers with the appropriate skills.
h. Review safety procedures.
i. Set priorities for all maintenance work.
j. Assign cost accounts.
k. Complete the work order.
l. Review the backlog and develop plans for its control.

m. Predict the maintenance load using effective forecasting techniques.

4.2.2 Types of Planning

(i) Long-range planning:

- Covers a period of 3 to 5 years.
- Sets plans for future activities and long-range improvements.

(ii) Medium-range planning:

- Covers a period of 1 month to 1 year.
- Specifies how maintenance workers will operate.
- Provides details on major overhauls, construction jobs, preventive maintenance plans, and plant shutdowns.
- Balances the need for staffing over the covered period.
- Estimates required spare parts and material acquisition.

(iii) Short-range planning:

- Covers a period of 1 day to 1 week.
- Focuses on determining all elements required for advance maintenance tasks.

4.2.3 Related Applications in Industries and Processes

The maintenance job priority system significantly influences maintenance scheduling, ensuring critical work is scheduled first. Coordination with operations staff is crucial to avoid assigning higher priorities to maintenance work than necessary, stressing maintenance resources. The priority system should be dynamic, reflecting changes in operation or maintenance strategies, typically having three to ten priority levels.

(i) Routine Maintenance:

- Periodic, planned, and scheduled operations covered by blanket orders.

(ii) Emergency or Breakdown Maintenance:

- Interrupts schedules to address unplanned events, planned and scheduled as they occur.

(iii) Design Modifications:

- Planned and scheduled to eliminate repeated breakdown causes.

(iv) Scheduled Overhaul and Shutdowns of the Plant:

- Planned and scheduled in advance.

(v) Overhaul, General Repairs, and Replacement:

- Planned and scheduled in advance.

(vi) Preventive Maintenance:

- Planned and scheduled in advance.

4.3 Maintenance Scheduling

4.3.1 Requirements for Scheduler

To effectively schedule maintenance, the scheduler needs:

- A job priority ranking reflecting the job's criticality.
- Availability of all materials for the work order in the plant.
- The production master schedule.
- Realistic estimates of what is likely to happen.
- Flexibility in the schedule.

Scheduling requires coordination with production personnel to release the machine during the specified time. It involves the importance of the work in relation to production requirements, machine downtime, and its impact on production and sales programs.

4.3.2 Types and Techniques Based on Functions and Processes

(i) Long-Range (Master) Schedule:

- Covers 3 months to 1 year.
- Based on existing maintenance work orders.
- Balances long-term demand with available resources.
- Allows identification and ordering of spare parts and materials.

(ii) Weekly Schedule:

- Covers 1 week.
- Generated from the master schedule.
- Considers current operations schedules and economic factors.
- Allocates 10% to 15% of the workforce for emergency work.
- Sequences work orders based on priority.

(iii) Daily Schedule:

- Covers 1 day.
- Generated from the weekly schedule.
- Prepared the day before.
- Interrupted for emergency maintenance.
- Prioritizes jobs.

4.3.2.1 Scheduling Techniques

Objective: Construct a time chart showing start and finish for each job, interdependencies among jobs, and critical jobs requiring special attention.

(i) Modified Gantt Chart:

- Efficient for managing projects with concurrent activities.
- Detects unplanned project growth (scope creep).

(ii) Critical Path Method (CPM):

- Identifies the critical path consuming the most resources (time).
- Focuses attention and resources on critical path activities.

(iii) Program Evaluation Review Techniques (PERT):

- Presents a graphic illustration of a project as a network diagram.
- Shows tasks as nodes connected by vectors.
- Differentiates dependent (serial) and parallel (concurrent) tasks.

(iv) Integer and Stochastic Programming:

- Stochastic programming deals with optimization problems involving uncertainty.
- Robust optimization finds solutions feasible for all known data within certain bounds.
- Integer programming models involve maximizing expectations based on probability distributions.

4.4 Maintenance Inventory

4.4.1 Concept and Advantages

Maintenance inventory refers to the list of physical features of capital assets requiring maintenance. A well-managed inventory system, including spares for production equipment, is crucial for reducing maintenance costs, minimizing worker and equipment downtime, and enhancing productivity. Inventory control has evolved, now playing a significant role in planning and control.

Advantages of Maintenance Inventory:

- Clear and frequent communication among maintenance, inventory management, and purchasing departments.
- A customer service-oriented approach by inventory management and purchasing departments.
- Active material planning by maintenance, inventory management, and purchasing departments.
- Efficient material flow from the storehouse to the customer site.
- Effective physical control of parts.
- Enhanced item accuracy.

4.4.2 Types and Techniques

Various types of inventories serve different purposes:

a. ***Raw Materials Inventory:*** Involves items purchased from suppliers for use in production processes.
b. ***Finished Goods Inventory:*** Concerned with finished product items not yet delivered to customers.
c. ***Supplies Inventory:*** Concerned with parts/materials supporting the production process.
d. ***Work-in-Process (WIP) Inventory:*** Involves partly-finished items that need further processing.

e. ***Transportation Inventory:*** Concerned with items being shipped through the distribution channel.
f. ***Replacement Parts Inventory:*** Maintains items for replacing worn-out items in company or customer equipment/systems.

Maintenance Management Decisions on Inventory:

a. ***Items/Materials to be Stored:*** Considers vendor reliability, cost, and storage impact.

b. ***Number of Items/Materials to be Stored:*** Decided based on usage and delivery lead time.

c. ***Item/Material Suppliers:*** Decisions based on factors like price, delivery, quality, and service.

d. ***Lowest Supply Levels:*** Based on historical records and projected needs.

e. ***Highest Supply Levels:*** Decided considering supply usage rate and past ordering experience.

f. ***Time to Buy and Pay:*** Influenced by vendor announcements, past records, and equipment repair histories.

g. ***Place to Keep Items/Materials:*** Emphasizes effective retrieval, usually favoring a single physical location.

h. ***Appropriate Price to Pay:*** Decided based on perceived supply and demand rather than actual factors.

Exercise

Case Study Question: Maintenance Planning and Scheduling

ABC Manufacturing Company operates a production facility with various equipment critical to its operations. The maintenance department plays a crucial role in ensuring the reliability and efficiency of these machines. Recently, the company has been facing challenges related to unexpected breakdowns and increased downtime, impacting overall productivity.

Task.

As a maintenance planning and scheduling expert, your task is to analyze the situation and propose a comprehensive plan to improve maintenance practices within the company. Address the following key points:

1. ***Assessment***.
   a. Identify the current maintenance practices and their shortcomings.
   b. Evaluate the impact of recent breakdowns on production and overall efficiency.
2. ***Maintenance Planning***.
   a. Propose a long-term maintenance planning strategy for the next year, considering different types of maintenance tasks.
   b. Define the criteria for determining the priority of maintenance tasks.
3. ***Scheduling***.
   a. Develop a weekly maintenance schedule based on the proposed long-term plan.
   b. Explain the factors that should be considered when scheduling maintenance tasks.
   c. Discuss how you would involve production personnel in the scheduling process to ensure alignment with production requirements.
4. ***Inventory Management***.
   a. Suggest an inventory management strategy for critical spare parts.
   b. Highlight the advantages of effective inventory control in reducing downtime.
5. ***Monitoring and Improvement***.
   a. Propose methods to monitor the effectiveness of the new maintenance plan.
   b. Outline a continuous improvement process to adapt the maintenance plan to changing circumstances.

Chapter 5: Computerized Maintenance Management System

5.1 Introduction

A Computerized Maintenance Management System (CMMS) is a vital software designed for planning, managing, and administering maintenance activities. It ensures both equipment condition and output quality. Selecting a CMMS involves a long-term relationship with the vendor, emphasizing the need for a thorough contract review.

5.2 Definition

CMMS, also known as Enterprise Asset Management (EAM), CMMIS, or IIMS, maintains a computerized database of information related to an organization's maintenance operations. It encompasses asset, inventory, and labor data, aiding maintenance workers in effective management.

Basic CMMS Components:

- Asset/Equipment data management
- Preventive maintenance
- Labour
- Work order system
- Scheduling/planning
- Vendor
- Inventory control
- Purchasing
- Budgeting
- Integrated report writer

5.2.1 Benefits

Benefits of PC-based CMMS

i. Elimination of paperwork, enhancing staff productivity
ii. Early detection of issues, reducing failures and complaints
iii. Efficient use of staff resources through planned maintenance

iv. Improved inventory control for better forecasting
v. Optimal equipment performance, minimizing downtime and extending equipment life.

Benefits of Web-based CMMS

i. Accessibility anywhere with an internet connection
ii. Lower overall cost, including licensing, installation, and maintenance.
iii. Easier upgrading with automatic updates
iv. Lower IT cost and greater convenience
v. Enhanced security and reliability
vi. Continuous data backup and ease of product demonstration
vii. Consistency in version usage, reducing potential bugs.

5.2.2 Concepts

Computerized Maintenance Management Systems (CMMS) software is designed to maintain a computerized database of information regarding an organization's maintenance operations. These packages are applicable to any organization involved in equipment, asset, and property maintenance, with some tailored to specific industry sectors (see Figure 5.1).

Key Functions of CMMS:

- Status Tracking: Enables facility managers, subordinates, and customers to monitor maintenance work status and associated costs.
- Reporting: Generates detailed or summary reports of maintenance activities.
- Facilities Key Performance Indicators (KPIs)/Metrics: Assists in evaluating operational effectiveness.
- Resource Management: Records, manages, and communicates day-to-day operations, providing crucial information for decision-making.
- Evolution of CMMS: From manual paper records to computer-based systems, CMMS has evolved to become an essential tool for modern facilities maintenance organizations.

In the pre-computer era, paper records were the norm, making the tracking of work and costlier report preparation a tedious process. The advent of computer software revolutionized this, allowing for more efficient recording, tracking, analysis, and reporting of maintenance data. With advancements in technology, computers have become more powerful, cost-effective, and user-friendly, providing robust tools for enhanced maintenance practices.

5.2.3 Goals of CMMS

- Optimize the use of scarce resources (manpower, equipment, material, funds).
- Manage facilities and equipment throughout their lifecycle, from acquisition to disposal.
- System Objectives:
    i. Resource Management: Address all resources involved in maintenance activities.
    ii. Inventory Management: Maintain a comprehensive maintenance inventory.
    iii. Work History: Record and maintain a detailed work history.
    iv. Work Tasks and Frequencies: Include work tasks and their frequencies.
    v. Versatility: Accommodate various methods of work accomplishment.
    vi. Interfacing: Effectively interface and communicate with related and supporting systems.
    vii. Mission Support: Support each customer's mission.
    viii. Customer Communication: Ensure communication with each customer.
    ix. Feedback Information: Provide feedback information for analysis.
    x. Cost Reduction: Reduce costs through effective maintenance planning.

A robust CMMS not only streamlines maintenance operations but also serves as a strategic tool for informed decision-making and resource optimization.

5.3 CMMS Approach and Scopes

5.3.1 Approach methods toward computerization

A modern Computerized Maintenance Management System (CMMS) serves as a comprehensive tool for facilities maintenance managers, aiding in work reception, planning, control, performance, evaluation, and reporting. Evaluation of management data requirements and electronic data needs should precede CMMS acquisition or upgrades, including a return on investment (ROI) analysis. The manager should acquire only what is necessary to achieve maintenance organization goals.

A. Operating Locations:

- CMMS may include an application for entering and tracking equipment locations, organizing them into logical hierarchies or network systems.
- Allows tracking of equipment lifecycles and performance at specific sites.

B. Equipment:

- Module for maintaining detailed records of each piece of equipment.
- Includes bill of material, preventive maintenance schedule, service contracts, safety procedures, measurement points, multiple meters, inspection routes, specification data, equipment downtime, and related documentation.

C. Resources:

- Separate module for tracking labor resources, including records for maintenance personnel, craft or trade categories, labor rates, skill levels, and qualifications.

D. Safety Plans:

- Capability for safety plans/planning, covering manual or automatic safety plan numbering, tracking hazards, associating precautions, hazardous materials, lock-out/tag-out procedures, and more.

E. Inventory Control:

- Module for tracking inventory movement, including stocked, non-stocked, and special order items.
- Allows tracking of item vendors, location, cost information, substitute or alternate items, and basic tool-room management features.

F. Work Request:

- Integral module for work requests, enabling easy input and assignment of requests such as trouble calls.

G. Work Order Tracking:

- Essential component for tracking work orders, providing instant access to detailed planning and scheduling information.

H. Work Management:

- Module for planning and dispatching, allowing labor assignments to be planned for future shifts and executed as soon as possible.

I. Quick Reporting:

- Provides a rapid means for opening, reporting on, and closing work orders, facilitating after-the-fact reporting on small jobs.

J. Preventive Maintenance:

- Manages preventive maintenance programs with capabilities such as supporting multiple criteria, generating work orders based on last generation or completion date, and permitting PM extensions.

K. Utilities:

- Module with detailed information on utilities consumption, distribution, use, metering, allocation to users, and cost.

L. Facility/Equipment History:

- Includes a history module containing maintenance histories of facilities and equipment, supporting proactive maintenance techniques.

M. Purchasing:

- May include a Purchasing module to initiate material requisition against work orders, track delivery, and manage costs.

N. Facilities Maintenance Contracts:

- Contracts module providing information on maintenance contracts, including past performance, current loading, planned work, specifications, quality assurance, and more.

O. Key Performance Indicators/Metrics:

- Utilizes CMMS to accumulate data for Key Performance Indicators (KPIs) to evaluate the organization's maintenance program.

P. Specialized Features:

- Some CMMS providers offer specialized capabilities for specific business sectors, functions, or requirements, such as tracking transportation, fleet inventory, IT equipment, and more.

Q. Application:

- Versatile application in managing facilities, from single facilities to complex/campuses, and for managing maintenance programs for equipment fleets.

5.3.2 Scopes of computerization

Sub-system or branches:

- CMMS functionality is grouped into subsystems for specific activity sets within the system.
- Sub-systems include equipment maintenance, inventory management, preventive maintenance, work order planning, human resource/craft skills, purchasing, and integrated reporting.

Master files:

- Common CMMS provides storage, manipulation, and retrieval of information in master files based on sub-systems.

- Master files include equipment or asset, inventory, types of maintenance and scheduling, and work order/manpower/human resource/craft skills.

Transaction file:

- Transaction files serve as audit trails and history for changes made in master files due to system modifications.
- Examples include changes in customer addresses, employee craft skills, and equipment or asset modifications.

5.4 Elements Needed

5.4.1 Classification Steps or Guidelines

A well-executed CMMS project can lead to increased efficiency, productivity, and profits. However, failure to plan and execute the project properly can result in revenue loss. Several factors contribute to the failure of CMMS projects:

i. Lack of Management Support:
    - Management commitment is crucial for the success of any large undertaking.
    - Upper-level management support is necessary for the commitment of resources and manpower.

ii. Employee Turnover:
    - Project teams may face challenges due to members resigning, being terminated, or transferred.

iii. Employee Resistance:
    - Employees may resist computerization, viewing it as a potential disruption to their work.
    - Management needs to communicate the benefits and the transitional nature of the process.

iv. Wrong CMMS Selection:
    - The selection of the appropriate CMMS based on organizational needs and requirements is crucial.

v. Advanced Functionality Justification:
    - Organizations often justify CMMS solutions based on advanced functionalities.
    - Many organizations fail to progress beyond the primary functionalities phase.

vi. Restrictive Hardware/Software:
   - Corporate policies may dictate hardware and software requirements, leading to limitations.

vii. Lack of Adequate Training:
   - Inadequate training during implementation can hinder effective system utilization.

viii. Lack of Follow-up and Monitoring:
   - Post-implementation follow-up is essential to ensure the continued success and efficiency of the CMMS.

ix. Inadequate Supplier Support:
   - The effectiveness of even the best CMMS depends on adequate vendor support.

Step-by-Step Process for Implementing a CMMS Project

(a) Form a Team:

- Establish a team consisting of members from the CMMS user community, including various departments.
- External resources, such as implementation consultants, can provide guidance.
- Appoint a project leader from the maintenance manager or a person familiar with company structure and maintenance functionalities.

(b) Management Commitment:

- Upper-level management must commit to the CMMS project, providing necessary resources and manpower.

(c) Prepare for Change:

- Ensure that employees understand the need for change and involve key maintenance personnel in developing new procedures.

(d) Order Software/Hardware:

- Acquire the necessary software and hardware based on the justification process.

(e) Scope of Project:

- Determine which CMMS modules to implement, considering factors such as equipment, preventive maintenance, work orders, and inventory.

(f) Planning:

- Properly plan the CMMS implementation project, addressing the "what," "why," "who," and "how" aspects.

(g) Installation and Configuration:

- Ensure necessary hardware and software are in place, and install and configure the CMMS application.

(h) Basic CMMS Training:

- Provide basic training on computer basics and the operating system for those who will operate the CMMS.

(i) Internal Training:

- Train CMMS users on internal processes, including equipment numbering schemes.

(j) Data Gathering:

- Check for existing electronic data and explore options for electronic data transfer.

(k) Data Entry:

- Choose data entry options, such as in-house, outside temporary help, or outside contractors.

(l) Advanced Training:

- Provide advanced training for users to enhance their proficiency with the CMMS.

(m) Follow-up/Monitor:

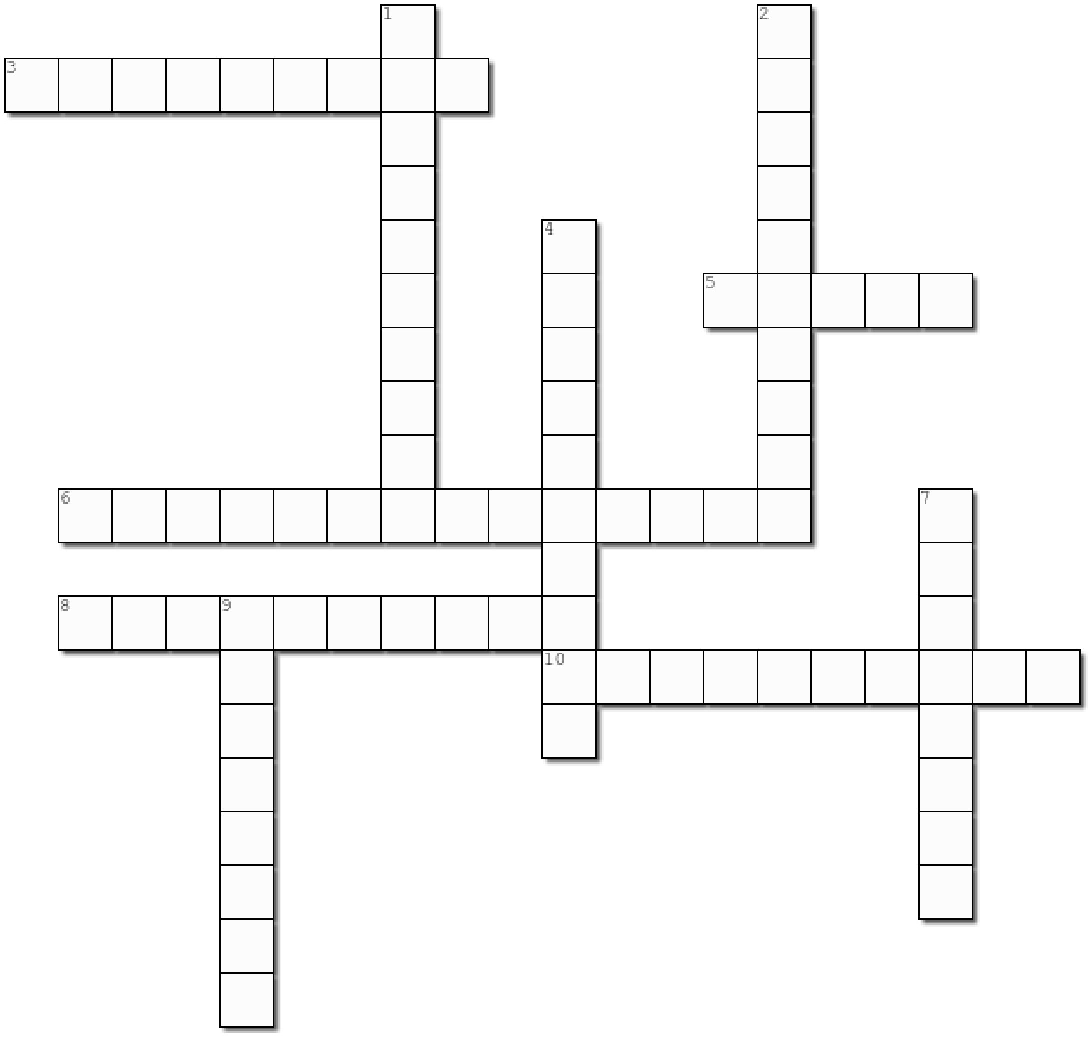
- Continuously monitor the CMMS to ensure it serves its purpose and meets goals.

(n) Continuous Improvement:

- Implement continuous improvement measures based on Key Performance Indicators (KPIs) for maintenance performance evaluation.

Exercise Chapter 5

Complete the crossword puzzle below



Across	**Down**
3. The stage where work order execution takes place **5.** The type of management commitment needed for a CMMS project to succeed. **6.** A person responsible for implementing the CMMS project. **8.** An essential element for the success of any large undertaking, including a CMMS project. **10.** A common reason for CMMS project failure, where employees may become hostile to the idea of computerization	**1.** An external resource that can guide you through CMMS implementation, helping avoid common pitfalls. **2.** The main element in all flow diagrams for maintenance information systems. **4.** The process of inputting data into a CMMS system. **7.** The phase where you determine the 'what,' 'why,' 'who,' and 'how' of the CMMS implementation. **9.** The phase where you justify a CMMS based on advanced functionalities.

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