KEMENTERIAN PENGAJIAN TINGGI
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

MAINTENANCE MANAGEMENT

VOLUME 1

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We hereby declare that this module is our original work. To the best of our knowledg e it contains no materials previously written or published by another person. However , if there is any, due acknowledgement and credit are mentioned accordingly in the e-book.

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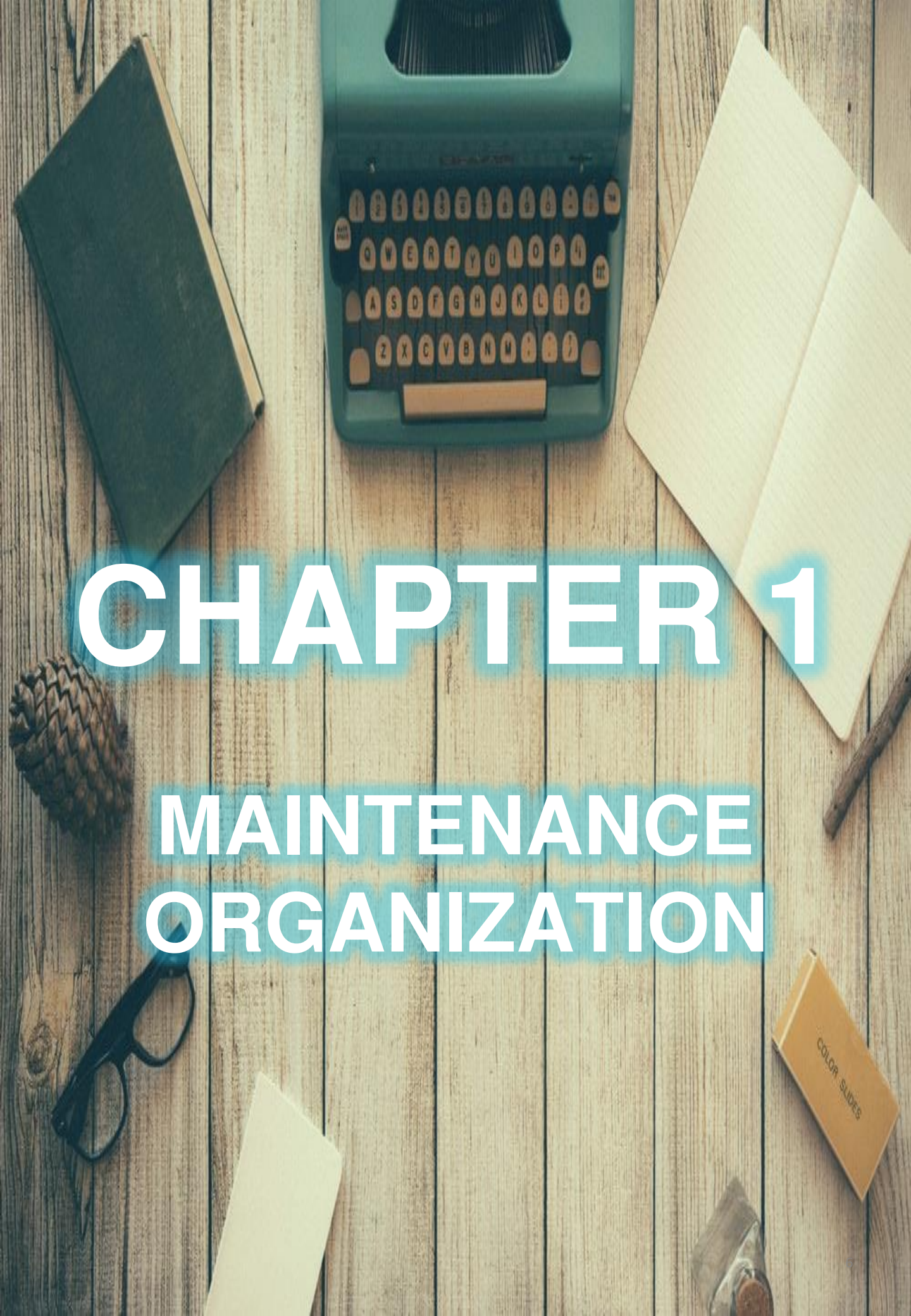
PREFACE

This E-Book prepares any mechanical engineering students about the fundamental of maintenance management in any industry, cooperation and company. This E-Book focuses on the Maintenance Organisation and Maintenance Strategies only.

There are notes, diagrams and examples with solutions to ease the readers and to test their understandings as well.

Hopefully the readers will get benefit from this E-Book



CHAPTER 1

MAINTENANCE ORGANIZATION

CHAPTER 1

MAINTENANCE ORGANIZATION

SUBTOPIC

1.0 Maintenance Organization

1.1 Apply the role of maintenance management

- 1.1.1 State objectives and benefits of maintenance organization.
- 1.1.2 Classify types of maintenance organizations.
- 1.1.3 Differentiate types of responsibilities/roles in maintenance management organization.

1.2 Organize types of maintenance organization.

- 1.2.1 Explain sources of maintenance cost
- 1.2.2 Classify types of maintenance cost.
- 1.2.3 Distinguish cost analysis methods.
- 1.2.4 Relate cost control, budget control and finance system

1.3 Construct the types of maintenance costs.

- 1.3.1 Analyze effective and non-effective maintenance organization.
- 1.3.2 Analyze maintenance performance or evaluation.
- 1.3.3 Classify maintenance audit such as maintenance operation audit, maintenance plan audit and technical audit
- 1.3.4 Apply key performance indicator (KPI) in review or Improvement of maintenance system and strategy

TOPIC 1.1

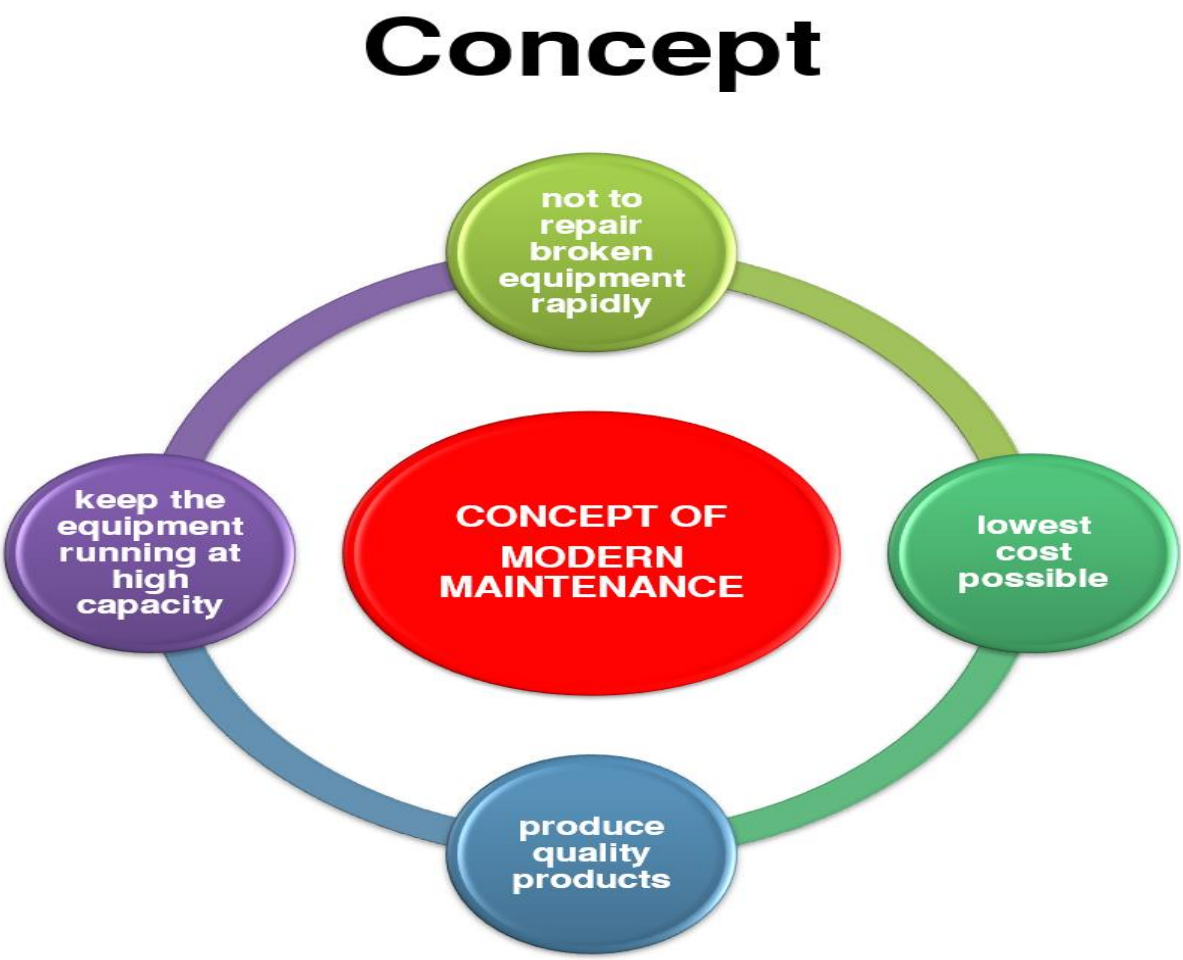
APPLY THE ROLE OF MAINTENANCE MANAGEMENT

1.0 Introduction

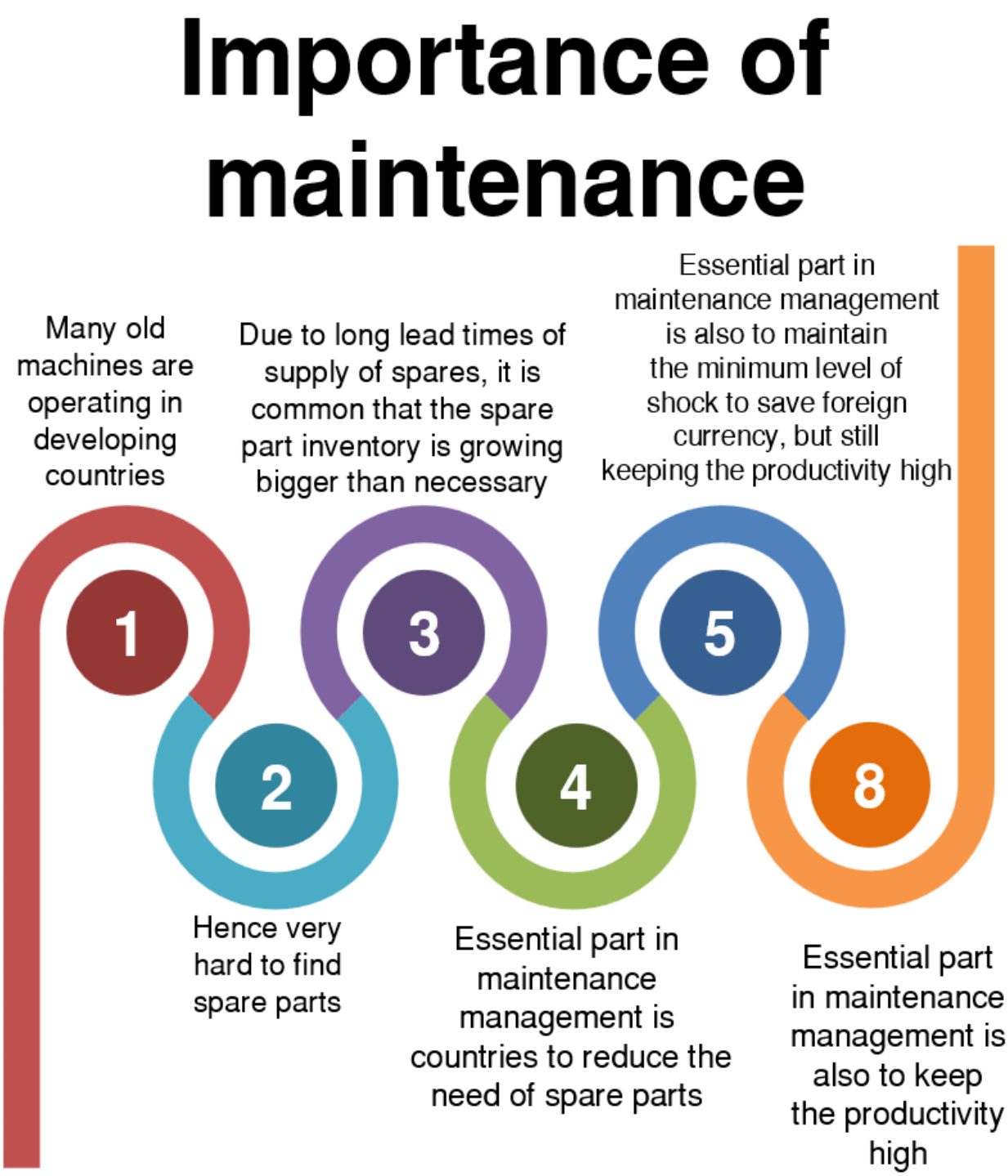
1.1 Definition:

In designing the maintenance organization there are important determinants that must be considered. The determinants include the capacity of maintenance, centralization versus decentralization and in-house maintenance versus outsourcing. A number of criteria can be used to design the maintenance organization. The criteria include clear roles and responsibilities, effective span of control, facilitation of good supervision and effective reporting, and minimization of costs

1.1.1 State objectives and benefits of maintenance organization



1.1.1 State objectives and benefits of maintenance organization



1.1.1 State objectives and benefits of maintenance organization

Definition

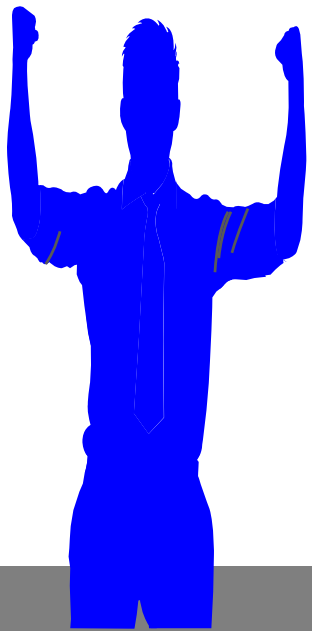
actions carried out to retain an item in, or restore it to an acceptable condition

Actions of servicing, repair, modification, overhaul, inspection and condition verification

Increase availability of a system

Keep systems equipment in working order

Purpose



Maximize performance	Prevent breakdown
Minimize production loss	Increase reliability of the systems

1.1.1 State objectives and benefits of maintenance organization

Principles Objectives

Objective 1
achieve product quality and customer satisfaction

Objective 2
Maximize useful life of equipment

Objective 3
Minimize cost

Objective 4
Maximize production capacity & profit through high utilization of facility

Objective 5
Must be consistent with cost, quality, delivery, safety of production

Objective 6
Must be comprehensive and include specific responsibilities

Specific Responsibilities

- ✓ Keeping assets and equipment in good condition
- ✓ Perform all maintenance activities including preventive, predictive; corrective, overhauls, design modification and emergency maintenance in an efficient and effective manner
- ✓ Conserve and control the use of spare parts and material;
- ✓ Commission new plants and plant expansions;
- ✓ Operate utilities and conserve energy.

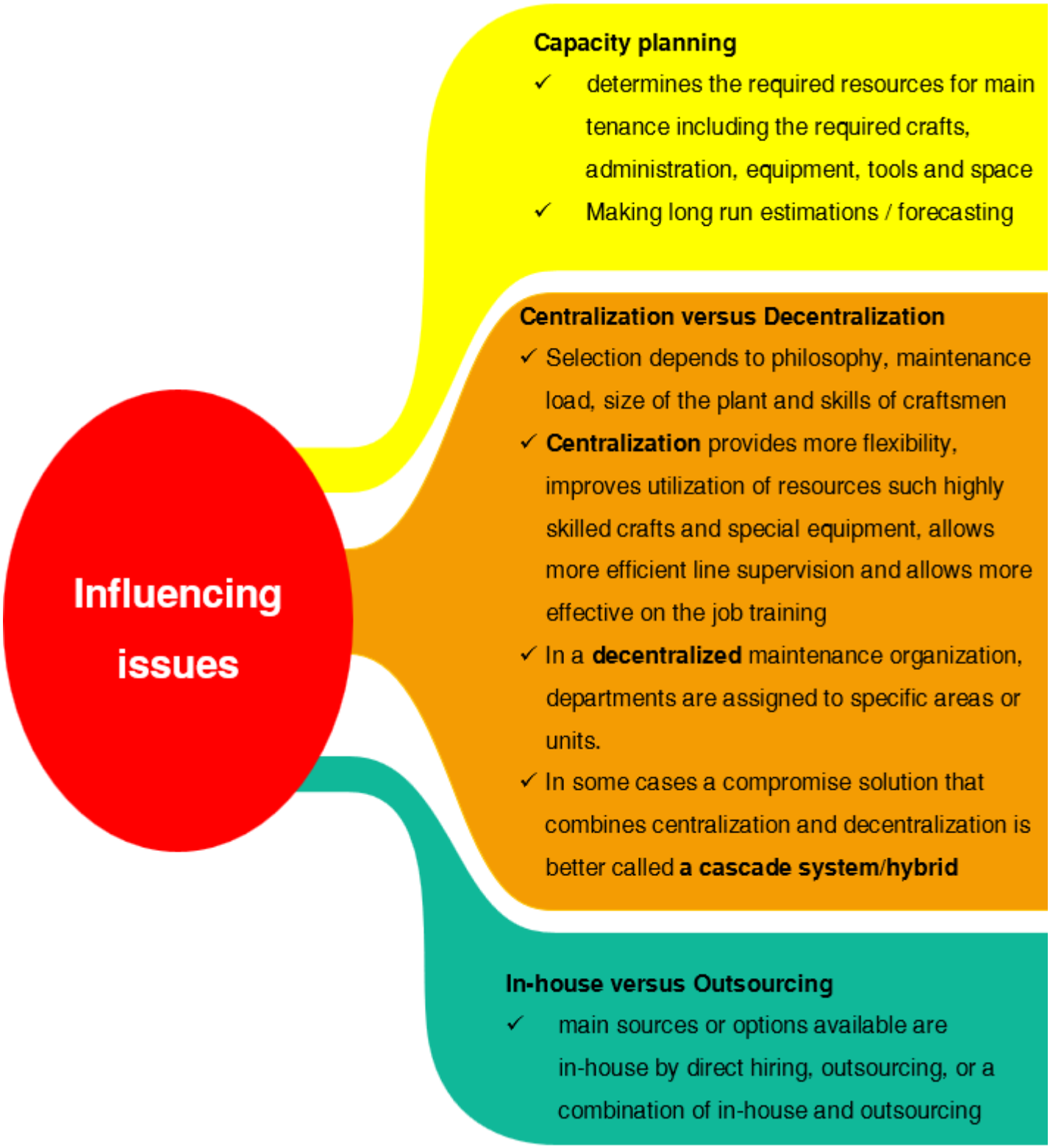
1.1.1 State objectives and benefits of maintenance organization

Benefits

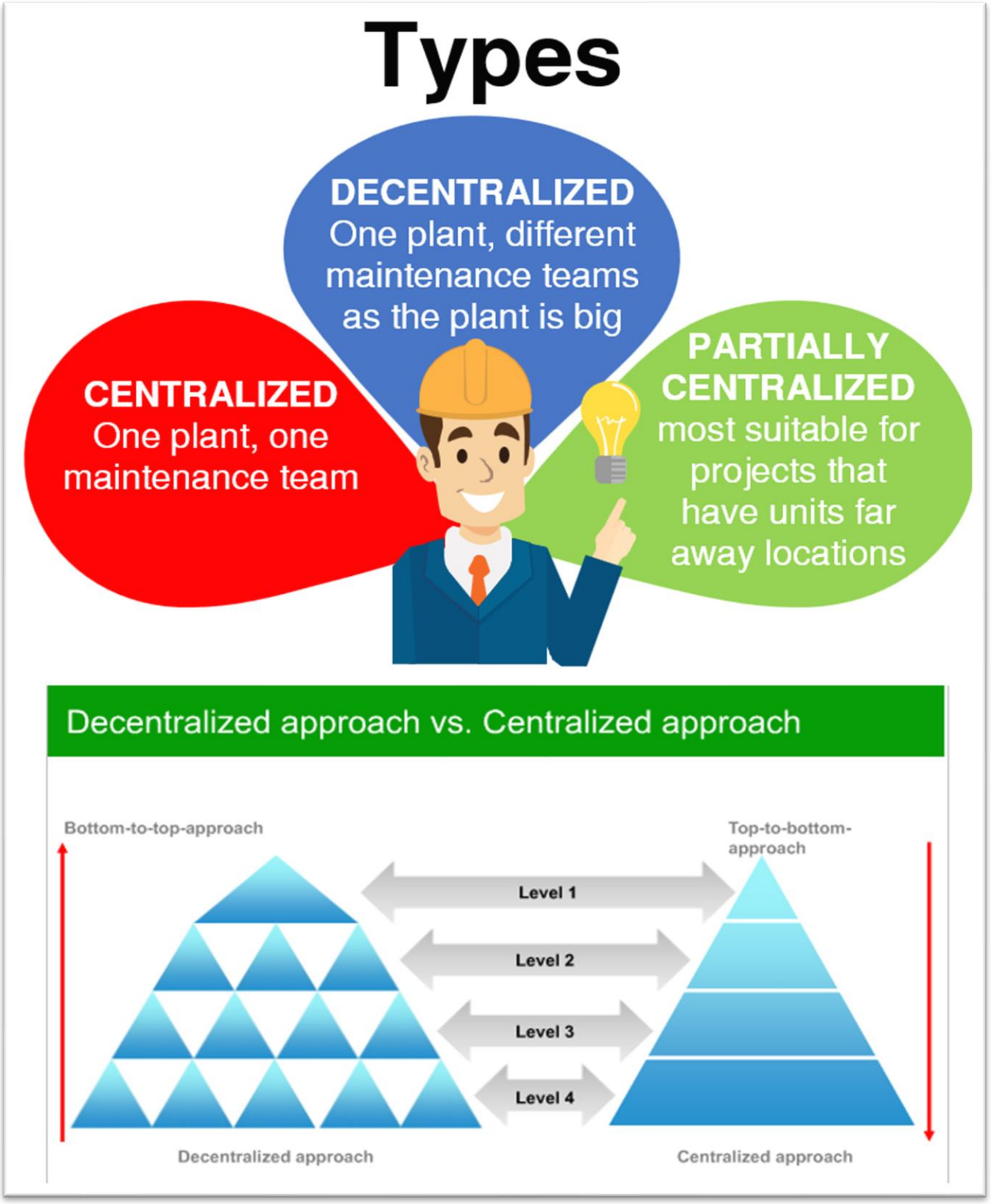
- production capacity of the facility remains unaffected due to well maintained machines and thus lesser breakdowns
- Production cost can be kept minimum
- Quality of products and services can be maintained due to reduced variation in output
- Increased safety of the workers due to reduction in accidents
- Delivery schedule of the custom ers can be maintained.
- Life of facilities and equipment increases.

1.1.1 State objectives and benefits of maintenance organization

The main issues that must be addressed when forming the maintenance organizations structure are shown in the diagram below:

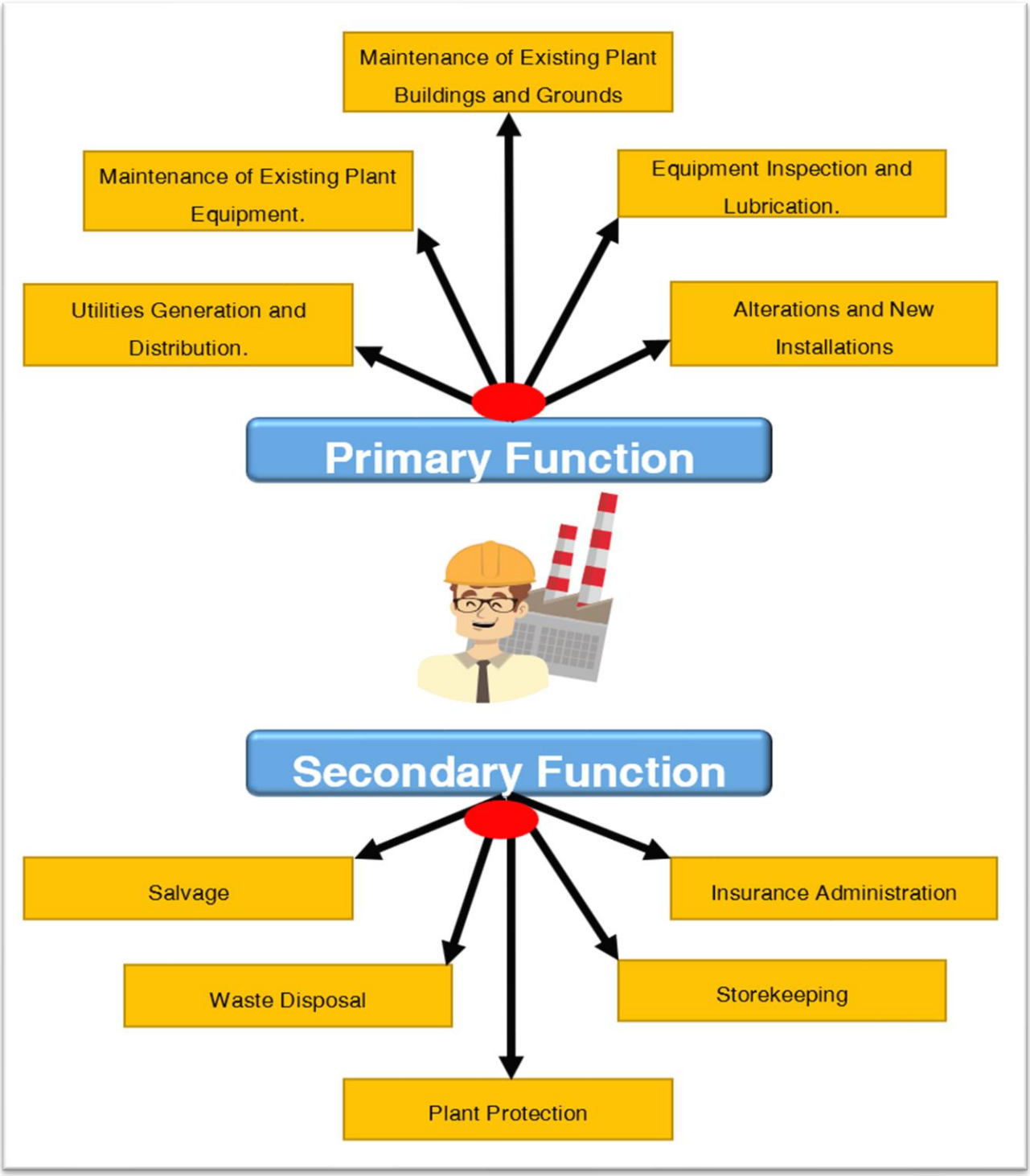


1.1.2 Classify types of maintenance organizations



1.1.3 Differentiate types of responsibilities/roles in maintenance management organization

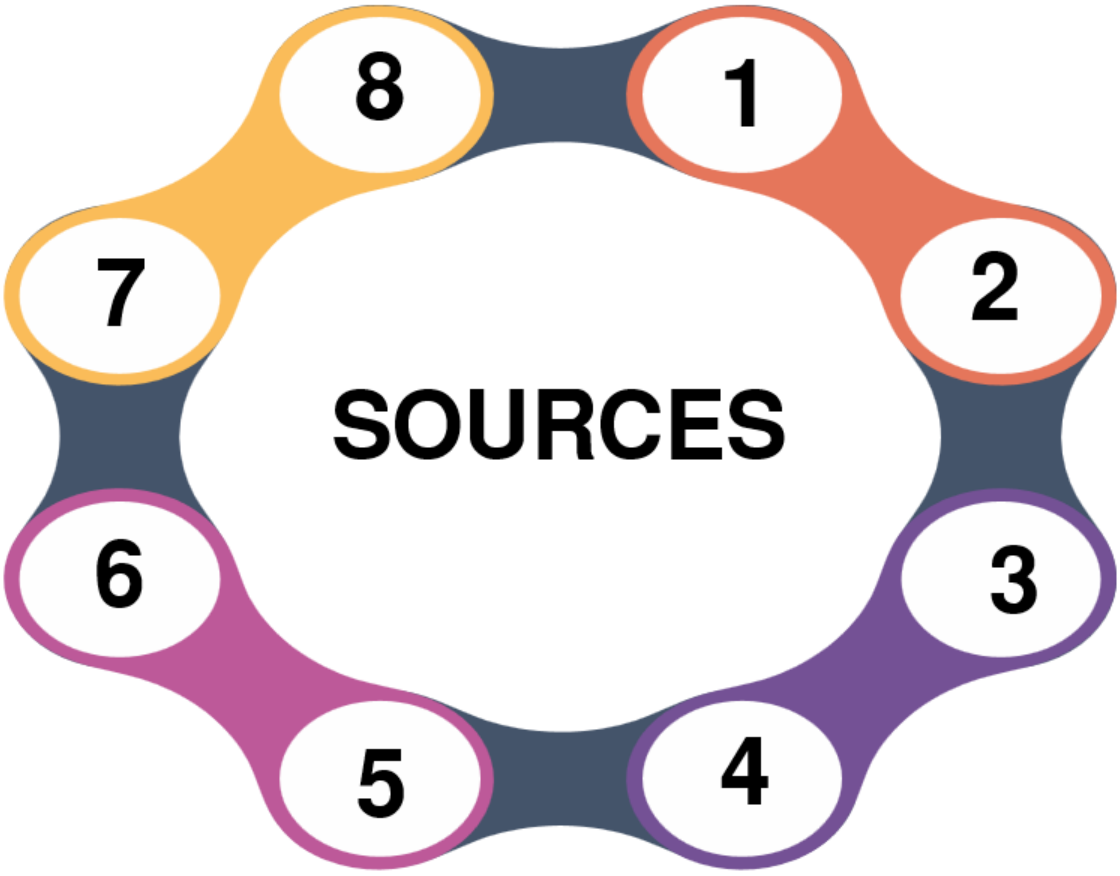
The main issues that must be addressed when forming the maintenance organizatio ns structure are shown in the diagram below:



TOPIC 1.2

ORGANIZE TYPES OF MAINTENANCE ORGANIZATION

1.2.1 Explain sources of maintenance cost



1. Downtime
2. Idle equipment or personnel due to equipment breakdown
3. Missed delivery dates of equipment (including out of stock)
4. Transportation due to remoteness of some of the maintenance work
5. Overhead cost
6. Maintenance labor (i.e., operator expertise and experience)
7. Asset condition (i.e., age, type, and condition)
8. Losses due to inefficient operations of machines

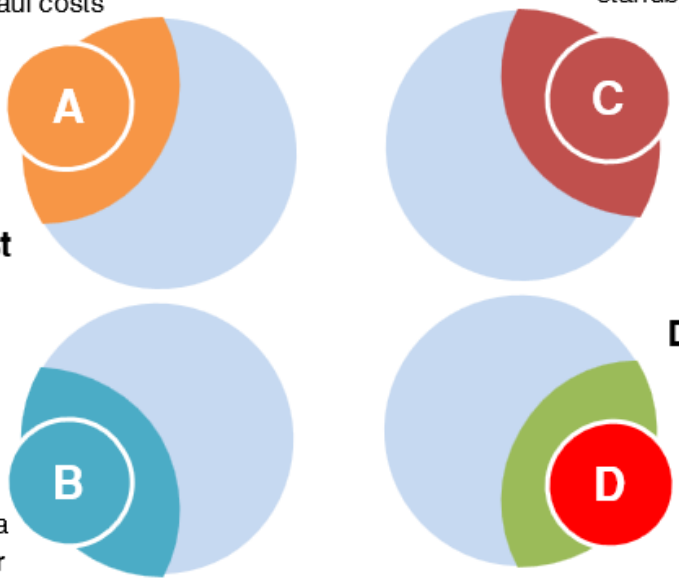
1.2.2 Classify types of maintenance cost

A - Direct Cost

costs required to keep equipment operable. These include periodic inspection and preventive maintenance, servicing costs, repair costs and overhaul costs

C - Lost production Cost

lost production because primary equipment is down and no standby equipment is available.

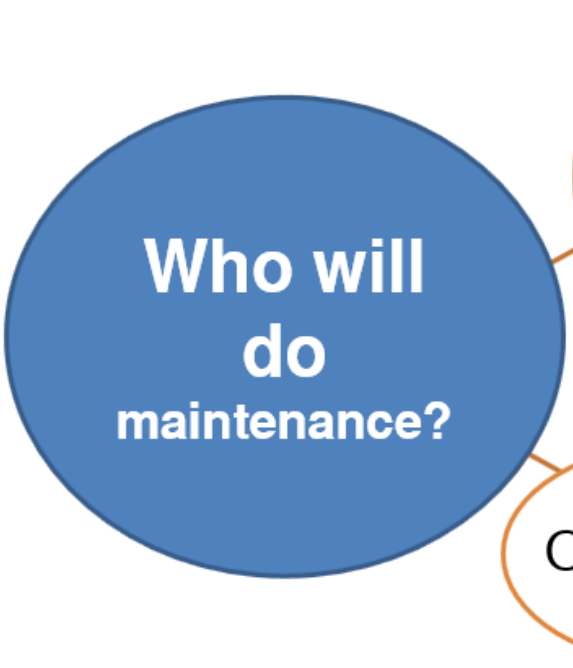


B - Standby Cost

The total cost of operating and maintaining standby equipment needed to be put in operation when primary facilities are either undergoing a maintenance activity or are inoperable for some reason.

D - Degradation cost

Those costs occurring in deterioration in the life span of equipment resulting from inadequate and/or inferior maintenance



WHY

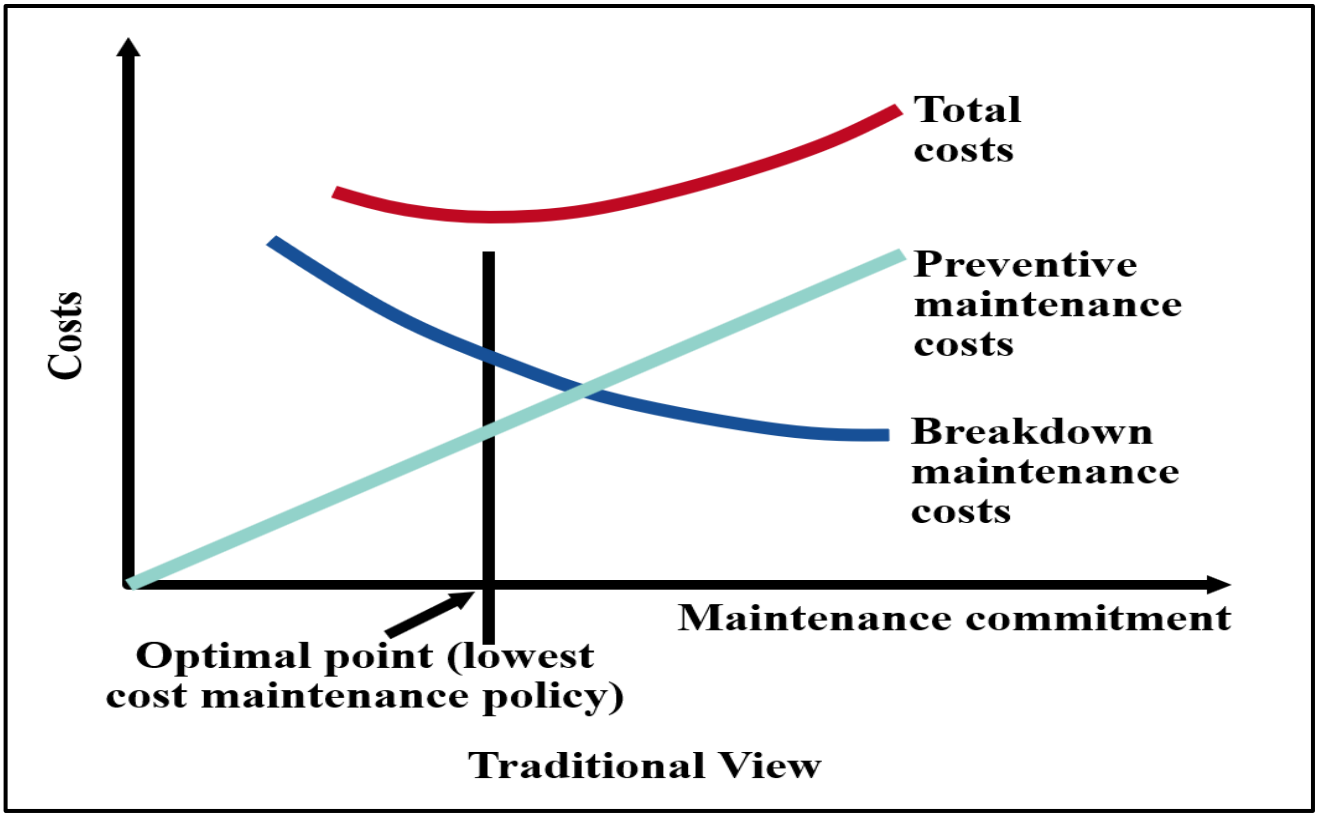
- flexible and invested to the team
- Free to schedule
- establishing control and stability
- easily control implementation
- in-house maintenance team usually has more years of service

WHY

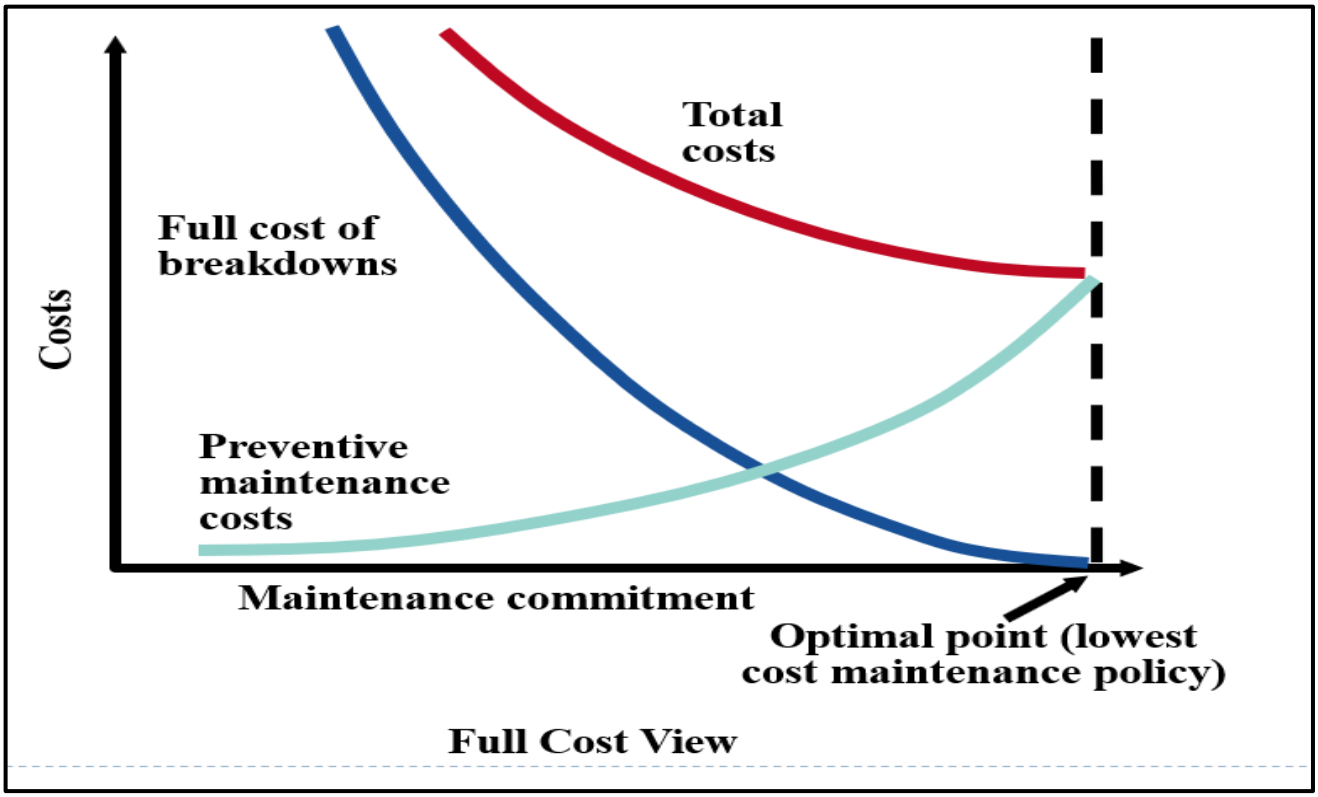
- Lack of in house expertise
- Too hazardous
- No experience
- Bound by contract
- Top management policy

1.2.2 Classify types of maintenance cost

Graphs related to maintenance cost



Traditional View



Full Cost View

EXAMPLE

Question

The record of computer breakdown for Company PCK for the past 20 months is shown below.

# of breakdown	# of months breakdown occurs
0	4
1	8
2	6
3	2
Total	20

- ✓ Each time computer breakdown - estimated loss is RM300
- ✓ Contract preventive maintenance by company DK - RM220 per month
- ✓ Should PCK contract out preventive maintenance to DK?

Solution

Step 1

- Calculate expected number of breakdown (based on past records) if the company continue without service contract.

Step 2

- Compute expected breakdown cost per month with no preventive maintenance contract

Step 3

- Compute the cost of preventive maintenance

Step 4

- Compare the two options and select the one which cost less

# of breakdown	Frequency
0	4/20 = 0.2
1	8/20 = 0.4
2	6/20 = 0.3
3	2/20 = 0.1

- Step 1

Expected # of breakdowns = ∑(# of breakdown) x (frequency)

= (0)(0.2)+(1)(0.4)+(2)(0.3)+(3)(0.1)

= 1.3 breakdown per month

- Step 2

Expected breakdown cost = (expected of breakdown) x (cost per breakdown)

= (1.3) x (300)

= RM390 per month

- Step 3 *Calculate Preventive Maintenance Cost*

= cost of expected breakdown + cost of service contract

= (1 breakdown per month x 300) + RM220 per month

= RM520 per month

- Step 4 Compare

Less expensive to suffer breakdown without service contract.

Breakdown = RM390

Service contract = RM520

Therefore, continue present policy.

1.2.3 Distinguish cost analysis methods

- Life cycle cost is the sum of all costs incurred during the life time of an item, that is, the total of procurement and ownership costs.
- life cycle costing is now often used in the procurement of expensive systems or equipment.
- Life cycle cost analysis examines the effect on cost of alternative equipment designs.
- In other words, life cycle cost analyses involve evaluating the total cost of a product or system over its entire life span.
- Life cycle cost will consider the cost of developing or acquiring the asset, the cost of running, operating and maintaining, and the cost of disposal.
- Life cycle costing plays an important role in maintainability analysis, particularly with respect to operation and maintenance costs.
- The aim of life cycle costing is to know the total cost of equipment accruing over its whole life period, which may include all the costs starting from the specification cost.
- It is also observed that reduction in one cost possibly will increase the other cost. The total cost has to be therefore optimized by making trade-offs among all elements of it.
- Normally it is observed that cheap items do not have sufficient economic life nor do they yield satisfactory performance over their whole life.

1.2.4 Relate cost control, budget control and finance system

- A good budget is characterised by the following:

- ✓ **Participation:** involve as many people as possible in drawing up a budget.
- ✓ **Comprehensiveness:** embrace the whole organisation.
- ✓ **Standards**: base it on established standards of performance.
- ✓ **Flexibility:** allow for changing circumstances.
- ✓ **Feedback:** constantly monitor performance.
- ✓ **Analysis of costs and revenues**: this can be done on the basis of product lines, departments or cost centres

TOPIC 1.3

CONSTRUCT THE TYPES OF MAINTENANCE COSTS

1.3.1 Analyze effective and non-effective maintenance organization

An effective maintenance system includes the following elements :

- Maintenance Policy
- Control of materials
- Preventive Maintenance
- Condition Monitoring
- Work Order
- Job planning
- Priority and backlog control
- Data recording system
- Performance measurement measures or indices

1.3.2 Analyze maintenance performance or evaluation

- Planned maintenance percentage (PPC)
- Overall Equipment Effectiveness (OEE)
- Mean time to repair (MTTR)
- Mean time between failure (MTBF)
- Preventive maintenance compliance (PMC)

POP QUIZ

- Based on 1.3.2, list down in detail for each items

1.3.3 Classify maintenance audit such as maintenance operation audit, maintenance plan audit and technical audit

❖ The maintenance audit is a review of the maintenance function from within the overall organisation taking into account all the various functions within the organisation. The purpose of a Maintenance Audit is to derive a Maintenance strategy

❖ Maintenance Audits can prove vital to your organisation. It is very important to measure the performance of the maintenance function whether you have an existing Maintenance strategy or not

❖ A dysfunctional maintenance function can adversely affect the following:

✓ Performance targets not being met due to breakdowns

✓ Low morale of engineering personnel

✓ Ratio of breakdown to Planned Maintenance very high

✓ Over- purchasing and double-purchasing of Maintenance Spares

✓ Purchasing of incorrect maintenance spares

✓ Unnecessary Planned Maintenance

✓ Machinery over-maintained

❖ The aim of a maintenance audit, which is the main consideration of this policy sector, is to determine whether the way forward is correctly defined and is being followed.

❖ The audit should measure the effectiveness of the normal practices and reveal whether im provements are required.

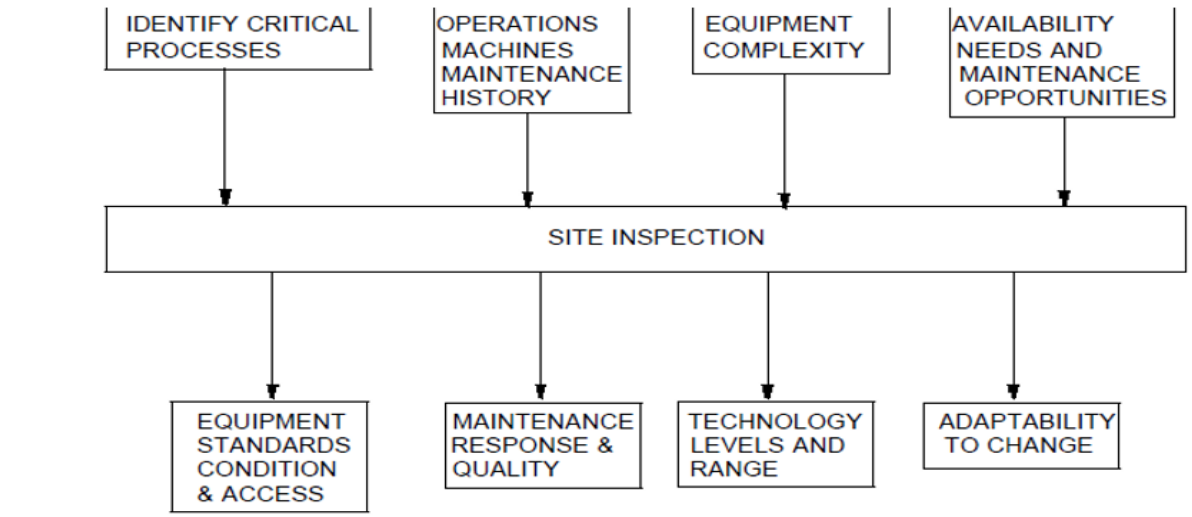
❖ Increasing awareness of the maintenance contribution.

❖ Technical audit (TA) is an audit performed by an auditor, engineer or subject-matter expert evaluates deficiencies or areas of improvement in a process, system or proposal.

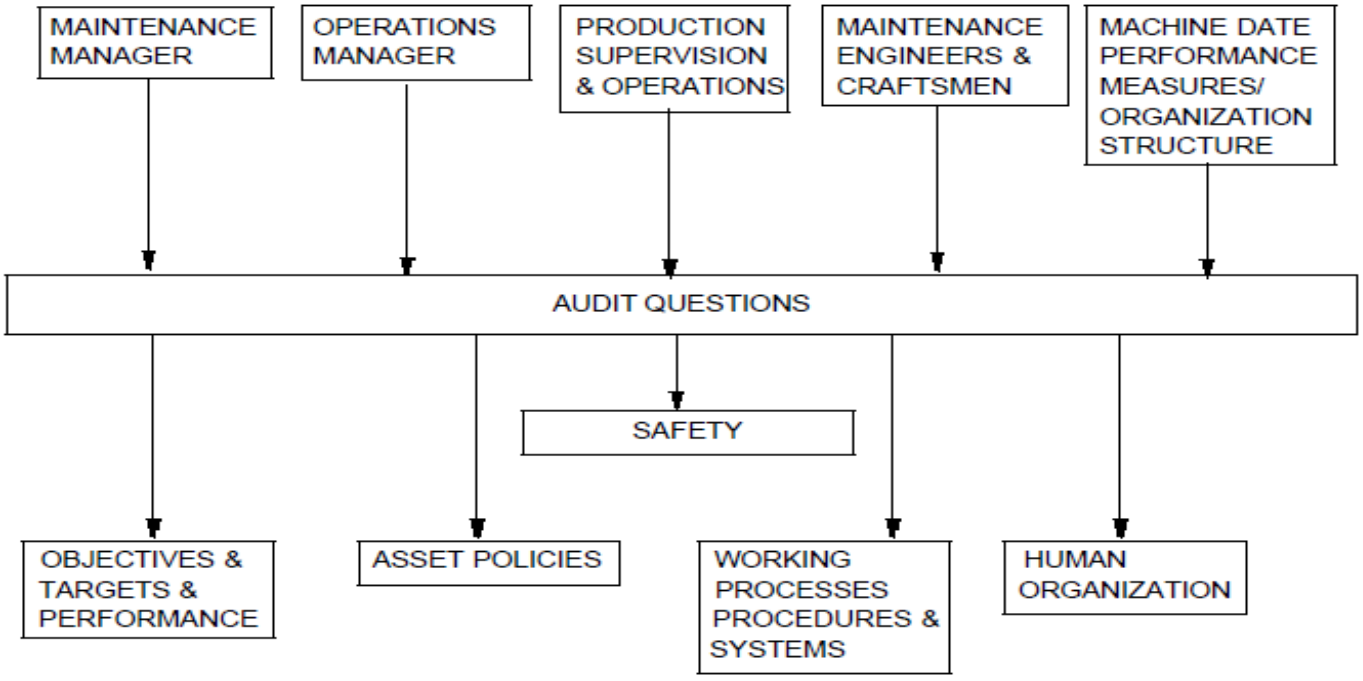
❖ Technical audit covers the technical aspects of the project implemented in the organization through verification of a supplier's manufacturing processes and quality control systems to provide confidence that your standards will be met or that any shortfalls will be resolved.

SCOPE OF AUDIT

OBJECTIVES	PRACTICES	STRATEGY
What are the aims and targets?	What developments are others making? What is it possible to achieve?	What changes are required? How should they be implemented?



QUESTIONS OF AUDIT



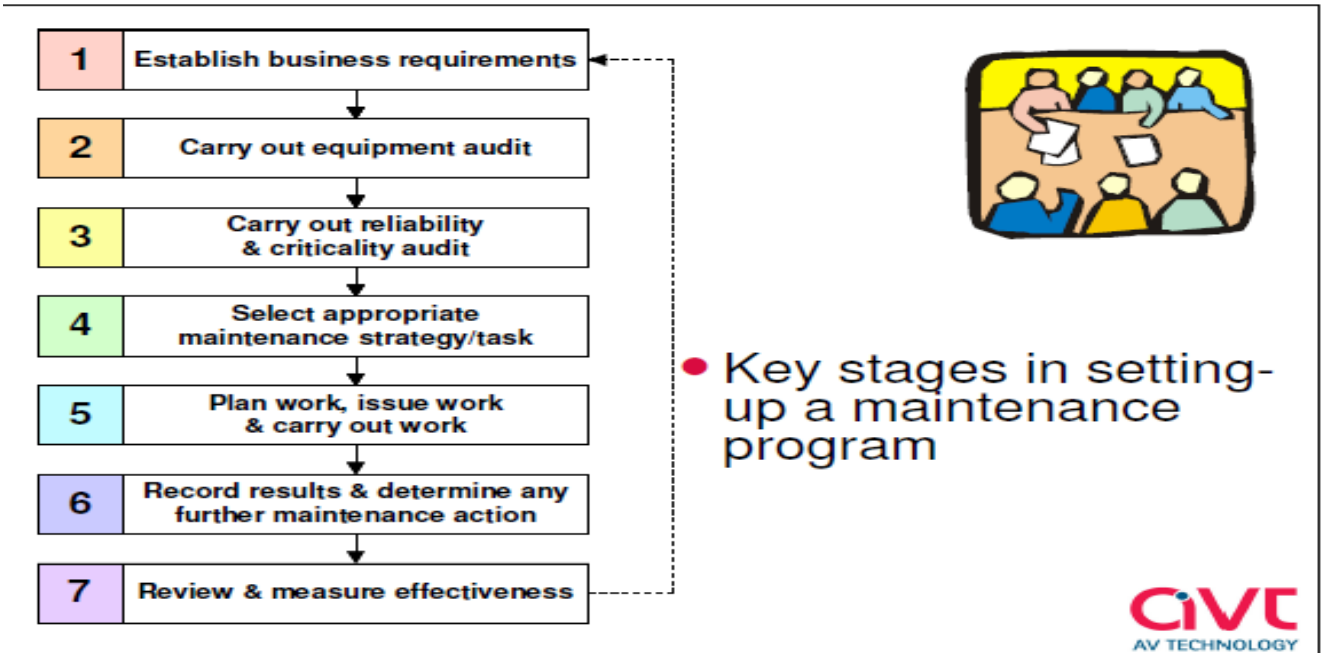
1.3.4 Apply key performance indicator (KPI) in review or improvement of maintenance system and strategy

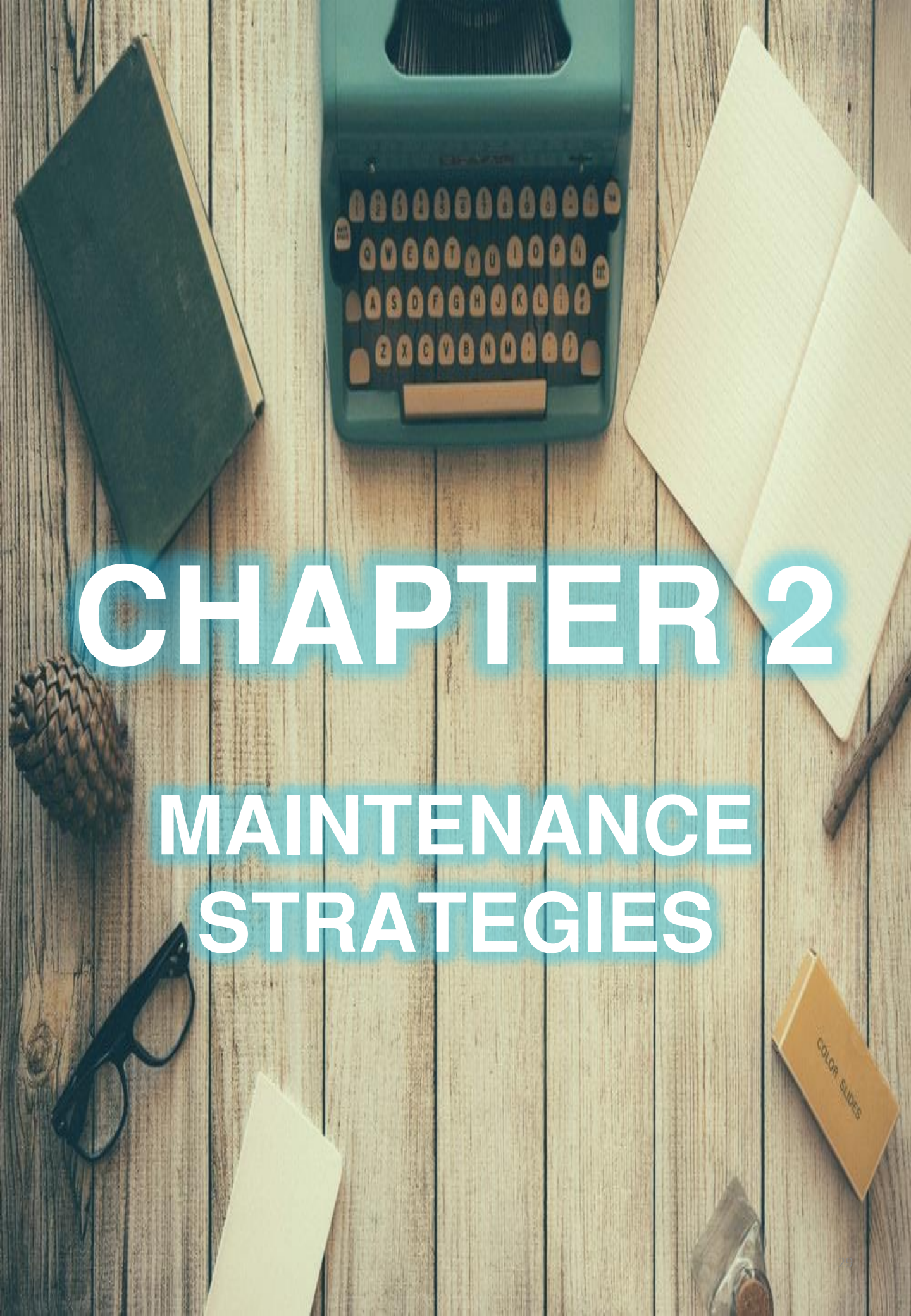
What are KPIs?

- ✓ KPIs measure parameters which describe an aspect of the current state of your operation
  - whether at departmental level or board level
- ✓ They can be compared over time to indicate changes or trends
- ✓ Their nature & range will vary from company to company

Maintenance Influencing Factors

- ✓ External Influencing Factors
  - Location, Society, Culture, Labour Cost
  - Market Situation, Laws, Regulations
- Internal Influencing Factors
  - Company Culture, Process Severity
  - Product Mix, Plant Size, Utilization Rate
  - Age of Plant, Criticality





CHAPTER 2

MAINTENANCE STRATEGIES

CHAPTER 2

MAINTENANCE STRATEGIES

SUBTOPIC

2.0 Maintenance Strategies

2.1 Determine maintenance strategies

- 2.1.1 State the functions of maintenance.
- 2.1.2 Identify the selection of maintenance strategies.
- 2.1.3 Determine system approach to maintenance functions.

2.2 Classify the types of the maintenance

- 2.2.1 Categorize the types of maintenance based on functions and advantages.
- 2.2.2 Apply methods for each type of maintenance above in suitable industries and processes.
- 2.2.3 Distinguish maintenance concept use or apply in industry such as Total Productive Maintenance (TPM).

2.3 Discover Condition Based Maintenance system (CBM) concepts.

- 2.3.1 Analyze methodology of CBM.
- 2.3.2 Distinguish risk based maintenance.

TOPIC 2.1

DETERMINE MAINTENANCE STRATEGIES

2.0 Introduction

2.1 Definition:

A maintenance strategy or option means a scheme for maintenance, i.e. an elaborate and systematic plan of maintenance action.

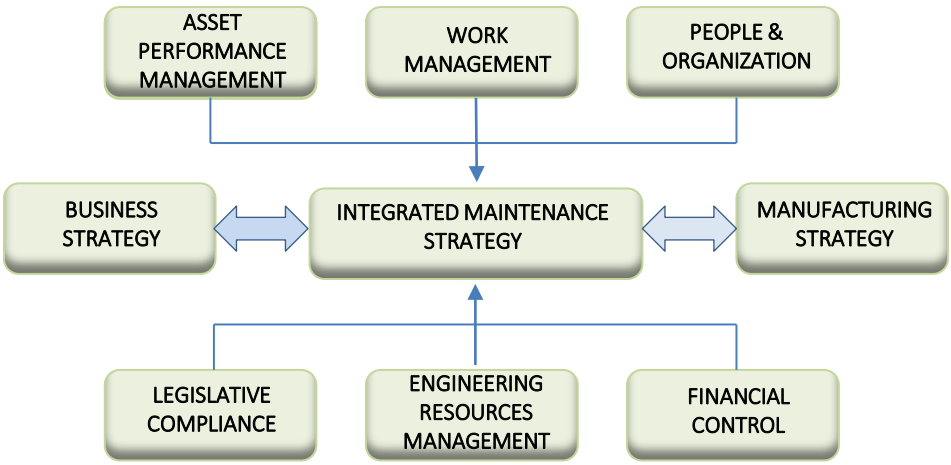


Figure 2.1.0 : Maintenance Strategy Model

2.1.1 Maintenance Function

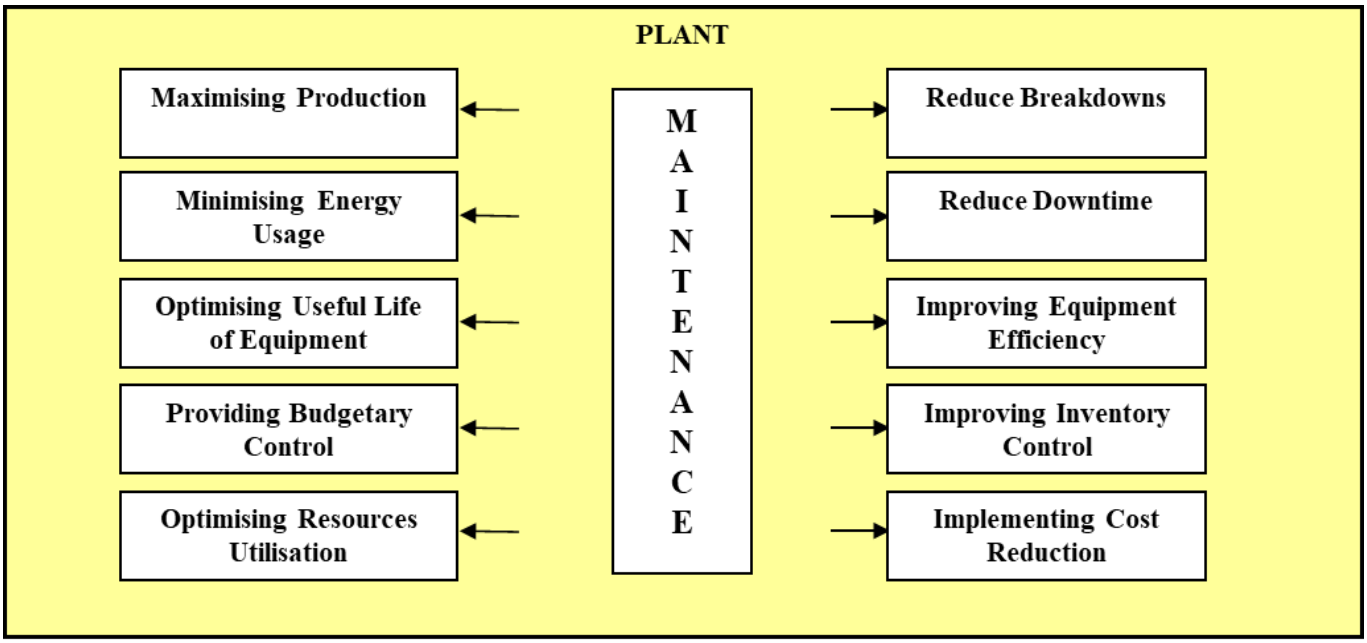


Figure 2.1.1 : Maintenance Function

2.1 Determine Maintenance Strategies

2.1.2 The Selection of maintenance strategies

Maintenance functions will be limited to and completely serviceable/operational condition as defined as follows:

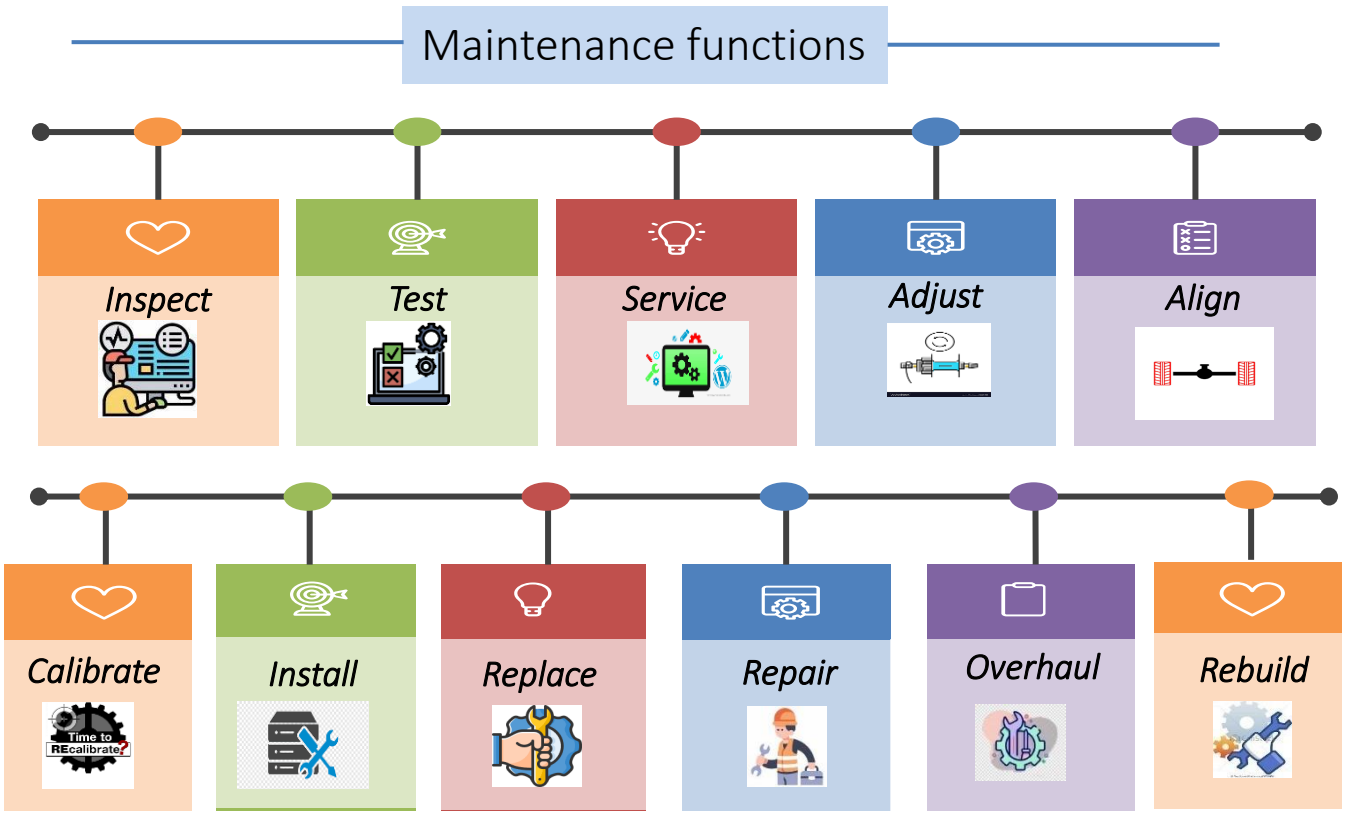


Figure 2.1.2 : Type of Maintenance Function

2.13 System Approach to maintenance function

i) Inspect

To determine the serviceability appropriate technical publications. Overhaul is normally the highest degree of and/or electrical characteristics with established standards through examination.

EXAMPLE

Figure 2.1.3 : Plant Inspection

ii) Test

To verify serviceability and to detect condition. Incipient failure by measuring the mechanical or electrical characteristics of an item and necessary for the restoration of unserviceable comparing those characteristics with prescribed equipment to a like new condition in accordance standards.

EXAMPLE

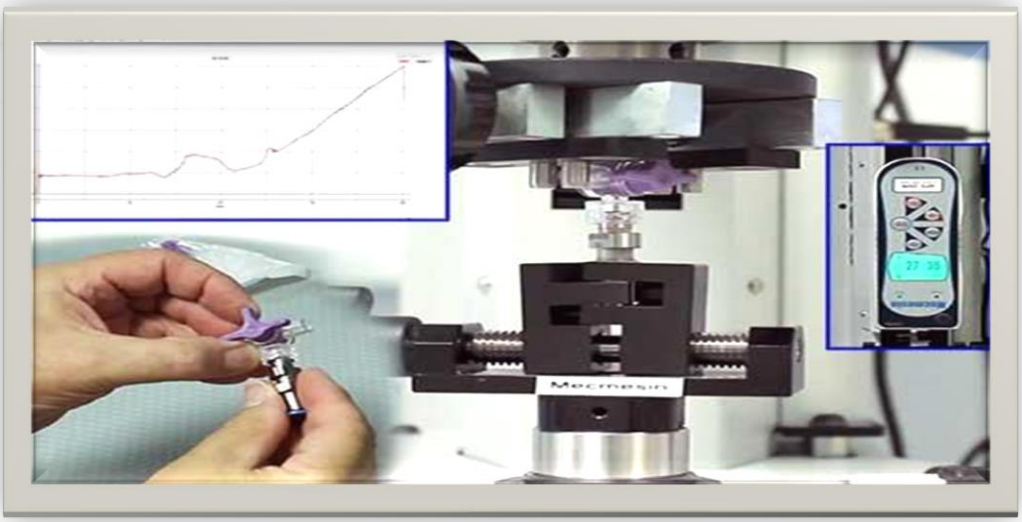


Figure 2.1.4 : Product Testing

iii) Service

Operations required periodically to build is the highest degree of materiel maintenance applied to Army equipment. The rebuild to clean (decontaminate), to preserve, to drain, operation includes the act of returning to zero to paint, or to replenish fuel, lubricants, hydraulic fluids, or compressed air supplies.

EXAMPLE

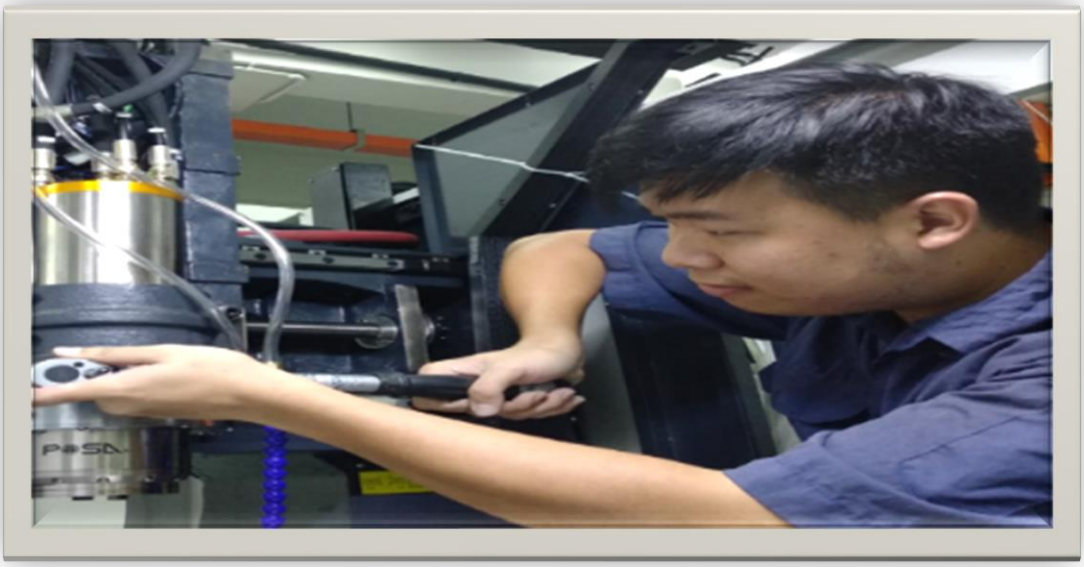


Figure 2.1.5 : Service

iv) Adjust

To maintain, within prescribed components. Limits, by bringing into proper or exact position, or by setting the operating characteristics to the specified parameters.

EXAMPLE

Figure 2.1.6 : Top Engine Adjustment

v) Align

To adjust specified variable elements group numbers, the purpose of which is to of an item to bring about optimum or desired identify components, assemblies, subassemblies, and modules with the next higher performance.

EXAMPLE

Figure 2.1.7 : Wheel Alignment

vi) Calibrate.

To determine and cause corrections to be made or to be adjusted on instruments or test measuring and diagnostic equipment used in precision measurement. Consists assemblies, subassemblies, and modules for which of comparisons of two instruments, one of which maintenance is authorized.

EXAMPLE

Figure 2.1.8 : Machine Calibration

vii) Install

The act of emplacing, seating, or maintenance functions, it is solely for purpose of fixing into position an item, part, module having the group numbers and component or assembly in a manner to allow the proper functioning of the equipment or system.

EXAMPLE

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Figure 2.1.9 : Machine Installation

viii) Replace

The act of substituting a serviceable like type part, subassembly, or module maintenance authorized to perform the function.

EXAMPLE

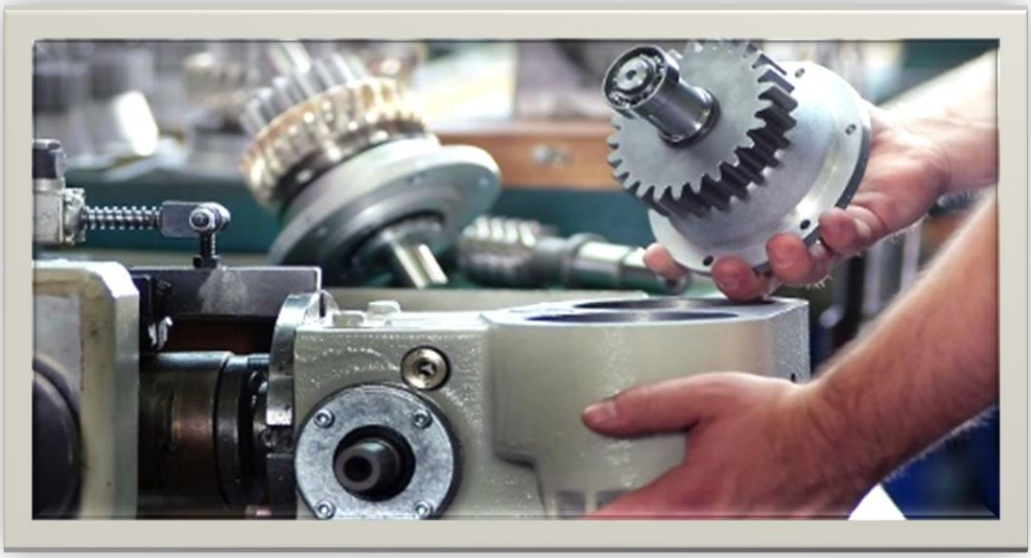


Figure 2.2.0 : Component Replaced

ix) Repair

The application of maintenance function at the indicated category services (inspect, test, service, adjust, align). If the number or complexity of calibrate, replace or other maintenance actions the tasks within the listed maintenance function - welding, grinding, riveting. This function does not (assembly, subassembly, component, module) include the trial and error replacement of end item or system to a serviceable condition running spare type items such as fuses, lamps, under typical field operating conditions.

EXAMPLE

Figure 2.2.1 : Engine Repair

x) Overhaul

That maintenance effort (service/action) necessary to restore an item to a prescribed by maintenance standards.

EXAMPLE

Figure 2.2.2 : Engine Overhaul

xi) Rebuild

Consists of those services/actions with original manufacturing standards.

EXAMPLE

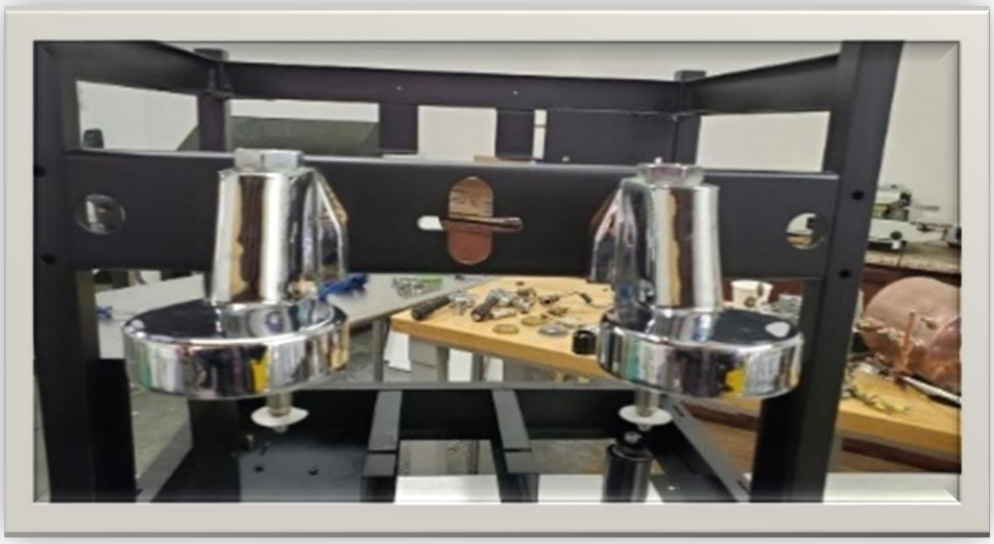


Figure 2.2.3 : Component Rebuild

TOPIC 2.2

CLASSIFY THE TYPES OF THE MAINTENANCE

2.2 Classify the types of the maintenance

2.2.1 The type of maintenance based on function and advantages

There are two maintenance approaches.

1. Reactive Maintenance

2. Proactive Maintenance

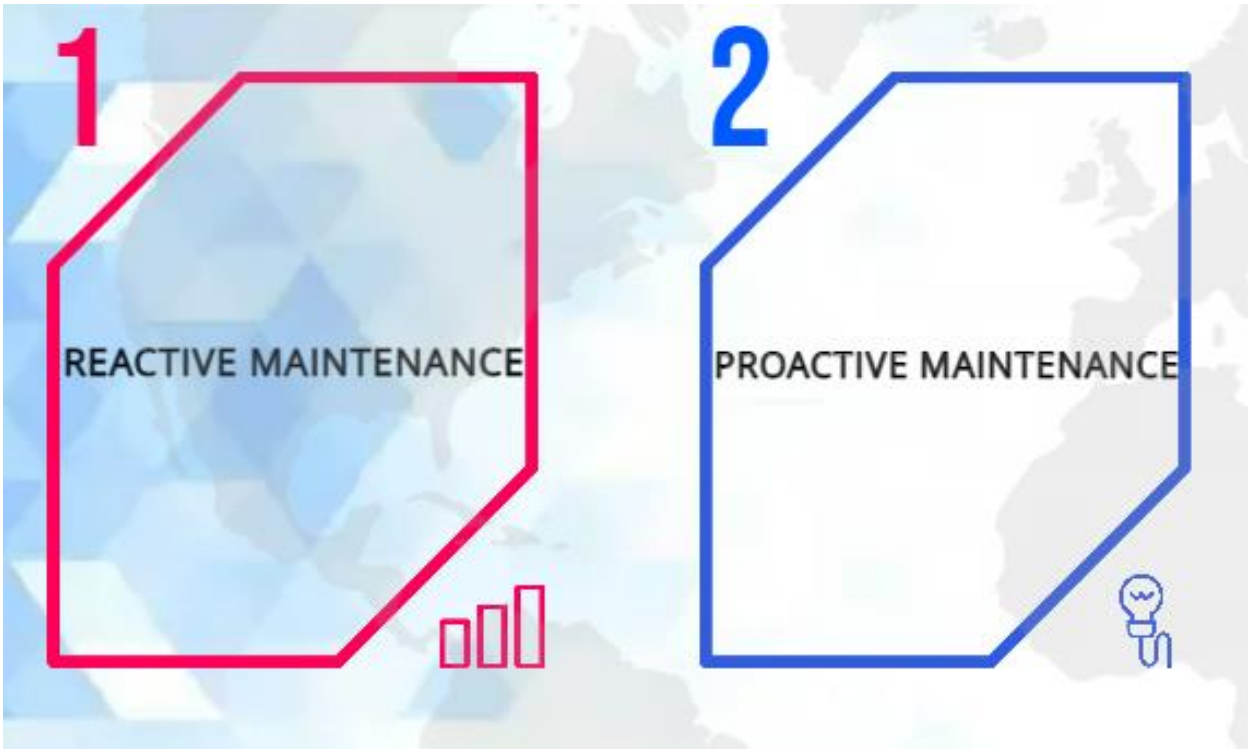


Figure 2.2.4 : Maintenance Approaches

2.2.2 Method for type of maintenance

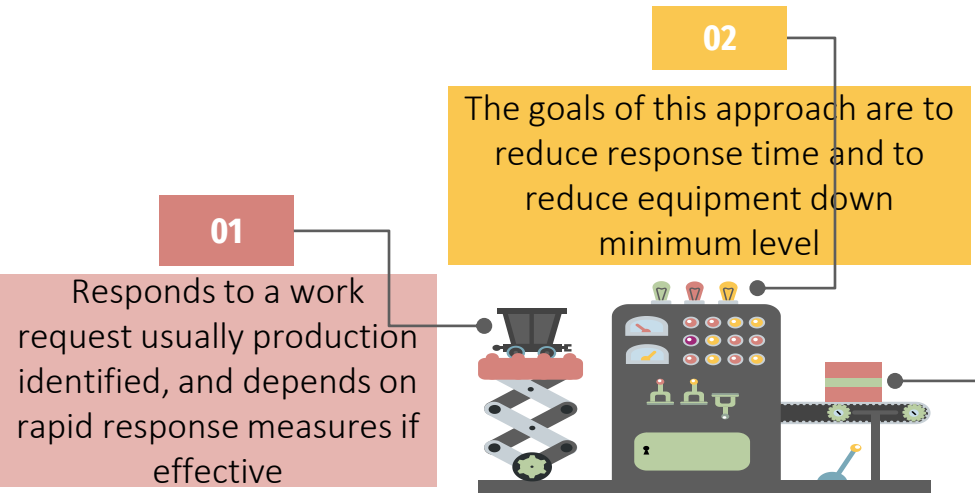


Figure 2.2.5 : Reactive Maintenance

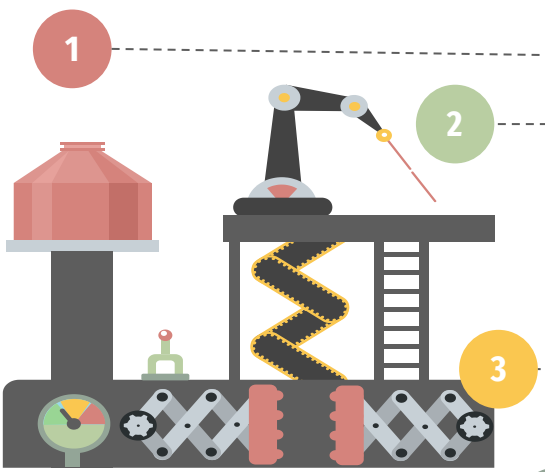


Figure 2.2.6 : Proactive Maintenance

Types of reactive maintenance are :

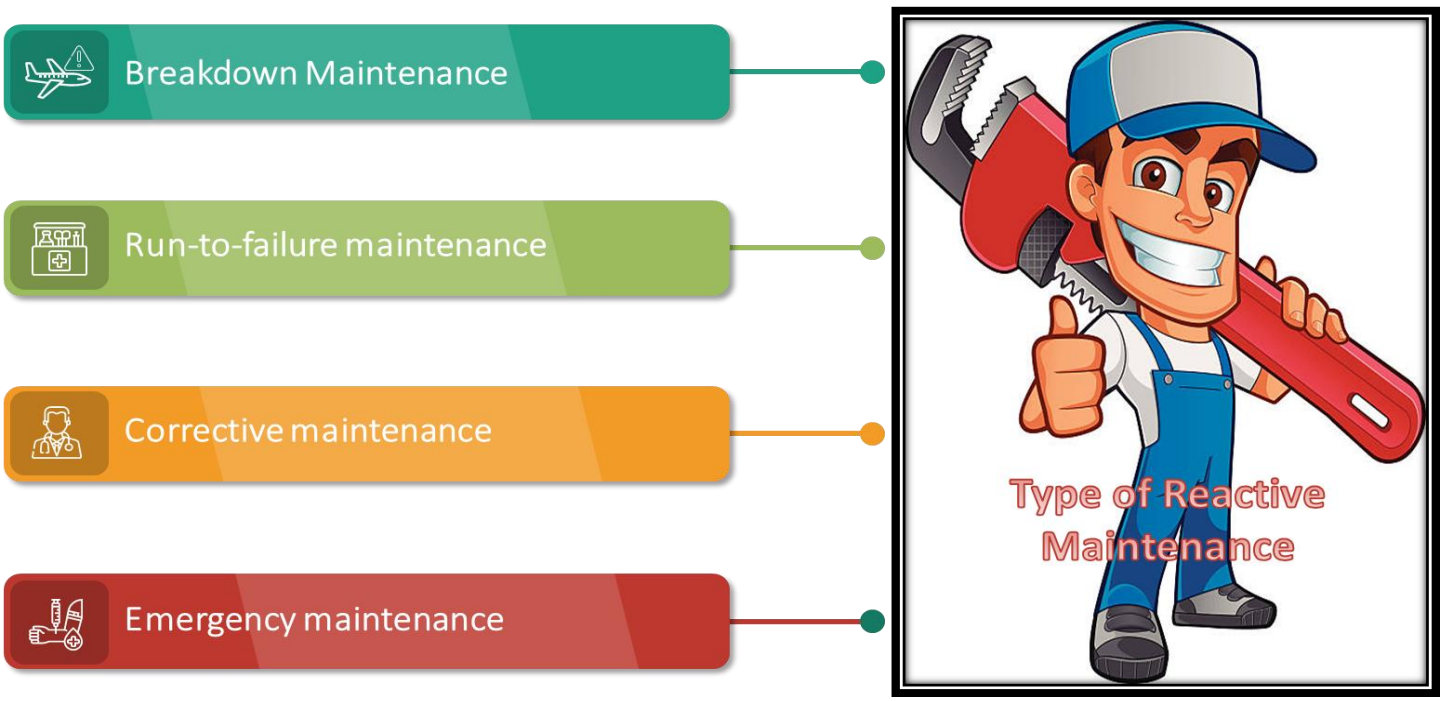


Figure 2.2.7 : Type of Reactive Maintenance

Breakdown Maintenance

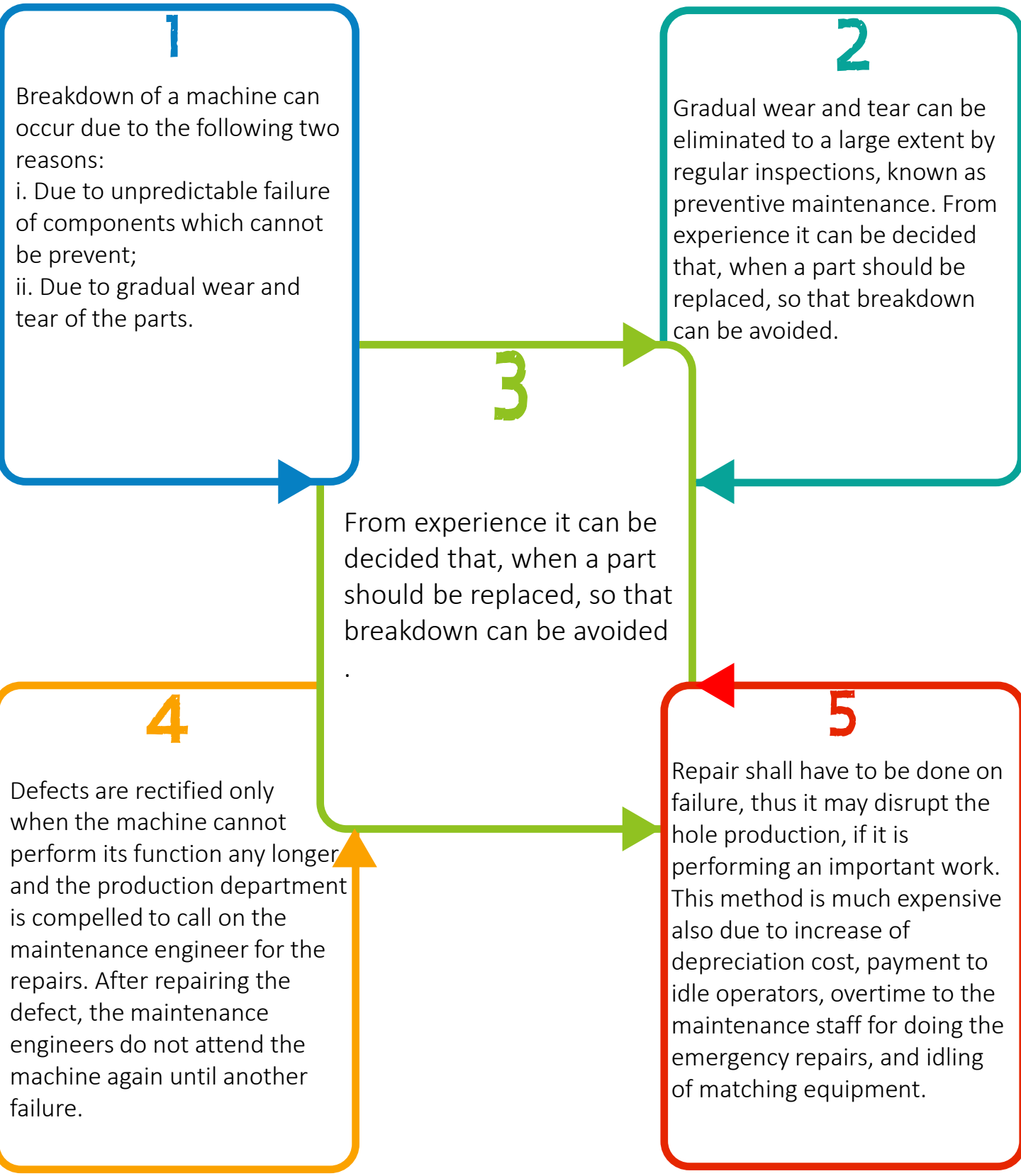


Figure 2.2.8 : Breakdown Maintenance

Figure 2.2.9 : Breakdown Maintenance Flowchart
https://safetyculture.com/topics/breakdown-maintenance/

first national REAL ESTATE
Lewis Prior Home Rentals

Maintenance Report Form

Date..... **Tenant Name**: .....

Property Address .....

Contact Mob).....W).....

AH)..... Email .....

MAINTENANCE DETAILS

Please describe the repair clearly, including appliance details, what room together with make and model number of appliance etc.

1.....

2.....

3.....

4.....

5.....

ACCESS DURING BUSINESS HOURS

Please Tick One Box Below

☐ **Access With Key-** we give permission for the tradesperson to access the property with an office key, if we are not home

☐ **Tradesperson To Contact Me-** Please Get Them To Contact Me For Access **During Business Hours** (Please Ensure we have ALL your contact details above)

Please Note - If you request the tradesperson to come after hours, and an after hours rate is charge to us by the tradesperson, we will forward this extra rate (amount above the normal day rate) in a tax invoice to the tenant, for payment within 14 days.

Please Ensure All Details Have Been Completed

Signed .....

Tenant Name.....

Dated...../...../.....

Office Use Only- Work Order Generated– Date ...../...../.....

Lewis Prior Home Rental 245 Diagonal Road Warradale Phone 8358 0999 Fax 8358 0111 Form LPFN 300.5

Figure 2.3.0 : Example of Breakdown Maintenance Report
https://templatelab.com/maintenance-report/

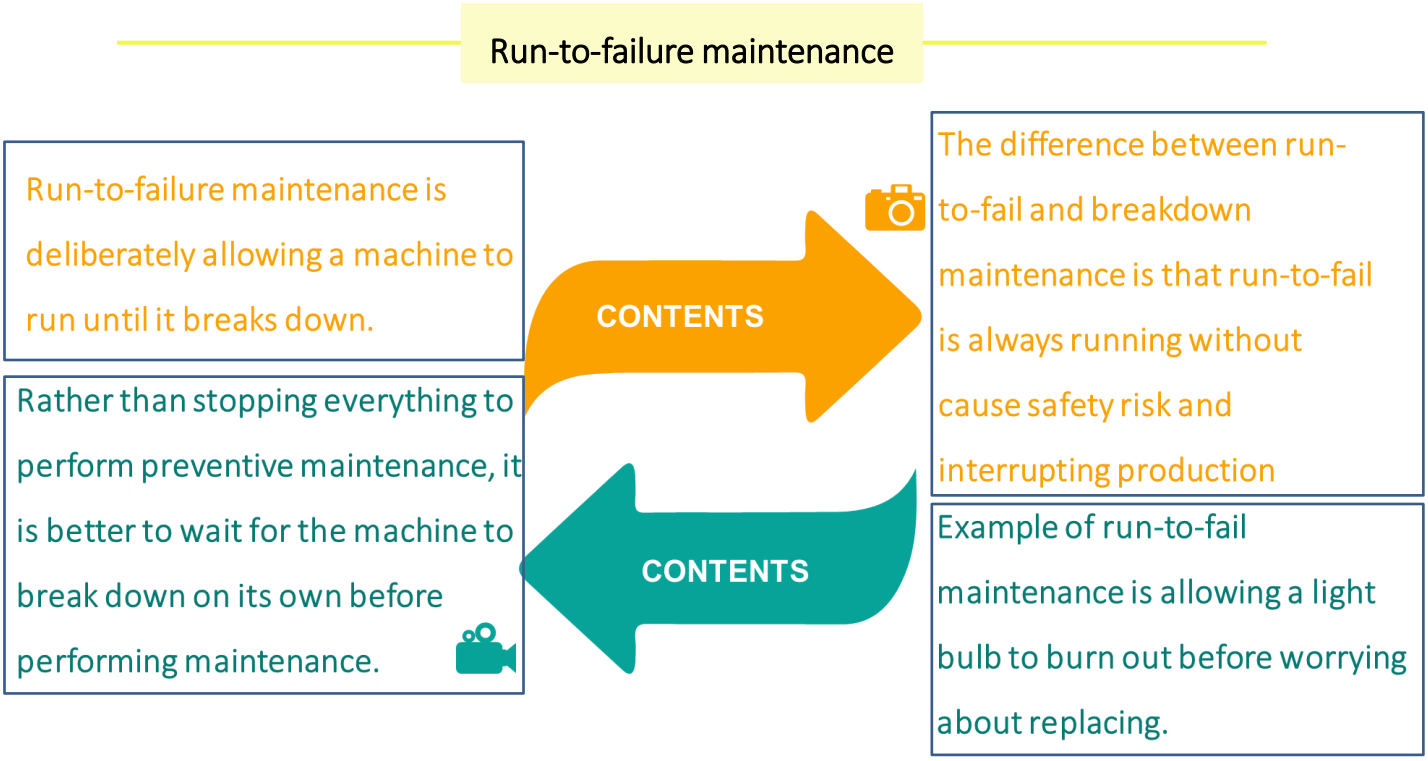


Figure 2.3.1 : Run-to-failure Maintenance

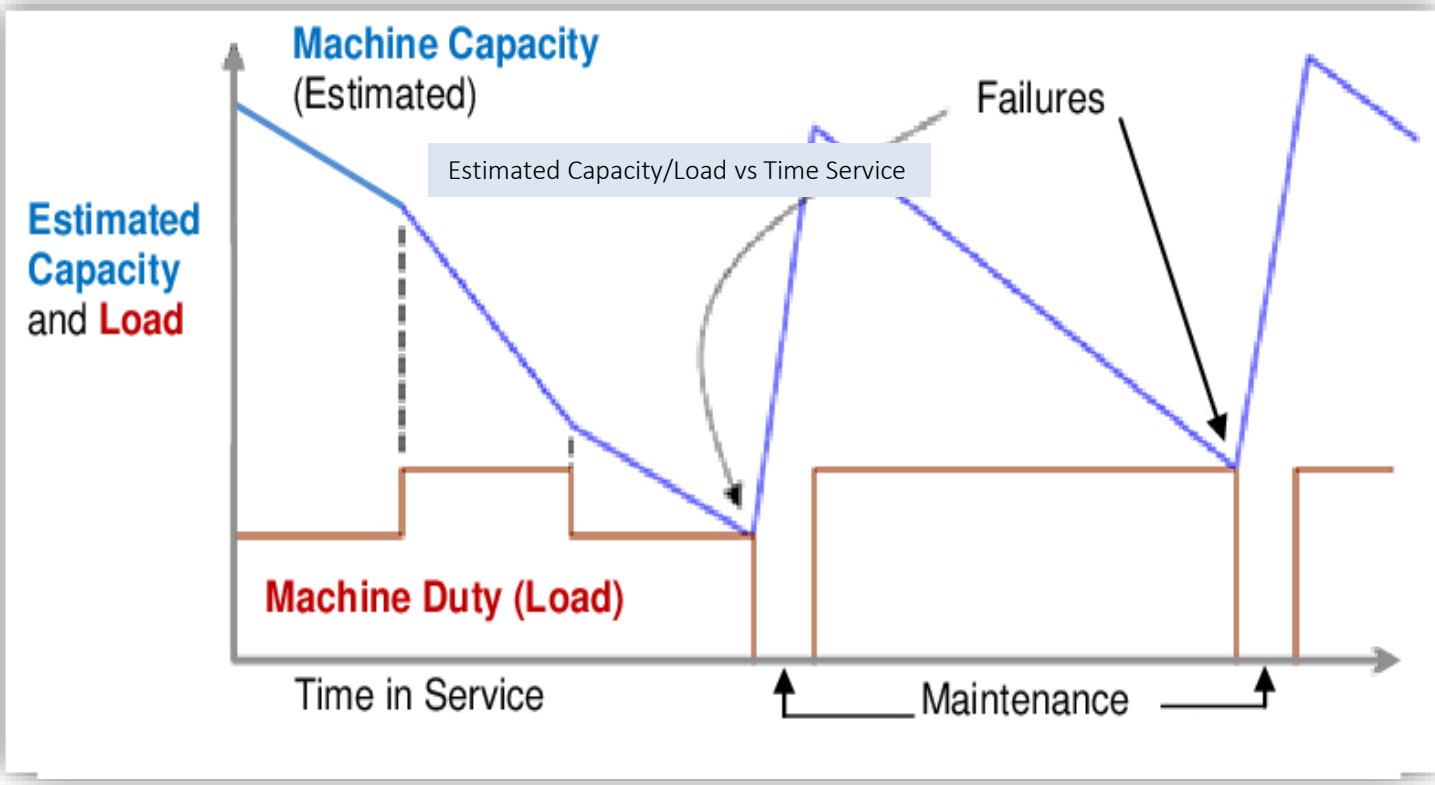


Figure 2.3.2 : Estimated Capacity and Load vs Time Service Graph
https://www.aladon.com/why-the-original-model-of-the-p-f-curve-is-the-correct-model/

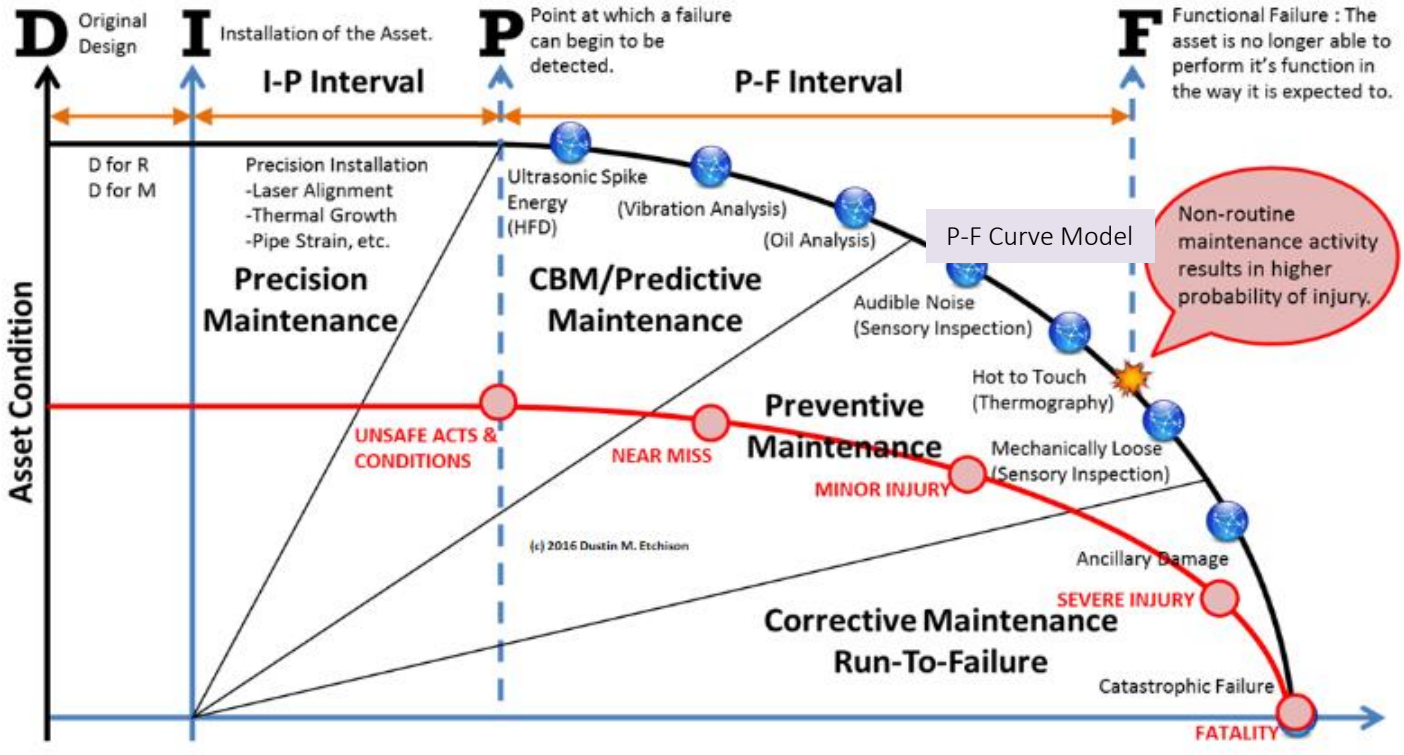


Figure 2.3.3 : Asset Condition vs Asset Failure Graph
https://www.aladon.com/why-the-original-model-of-the-p-f-curve-is-the-correct-model/

Corrective Maintenance

Point 1

Corrective maintenance refers to action only taken when a system or component failure has occurred.

Point 2

The task is usually effect repairs as soon as possible. Costs associated with corrective maintenance include repair costs (replacement components, labor, consumables), lost production and lost sales.

Point 3

To minimize the effects of lost production and speed up repairs, actions such as increasing the size of maintenance teams, the use of backup systems and implementation of emergency procedures can be considered, but only effective in the short-term

Point 4

For example, if heat exchanger tubes have leaked due to corrosion and production must proceed as a matter of urgency, it may be possible to plug the leaking tubes on a short-term basis.

Figure 2.3.4 : Corrective Maintenance

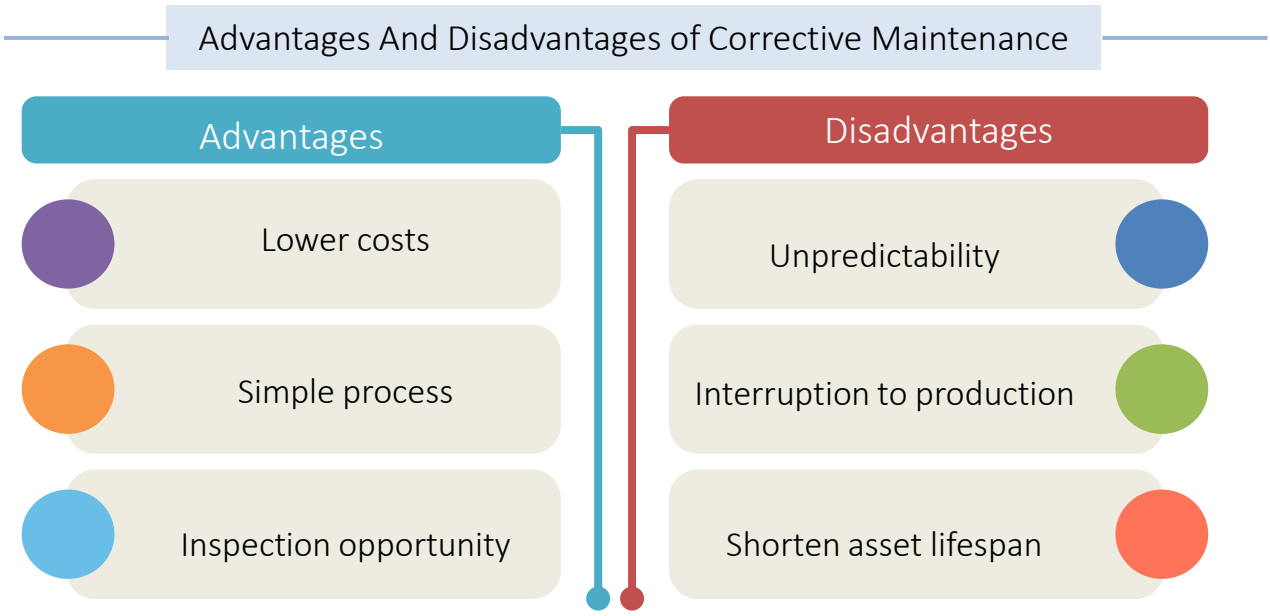


Figure 2.3.5 : Advantages and Disadvantages of Corrective Maintenance

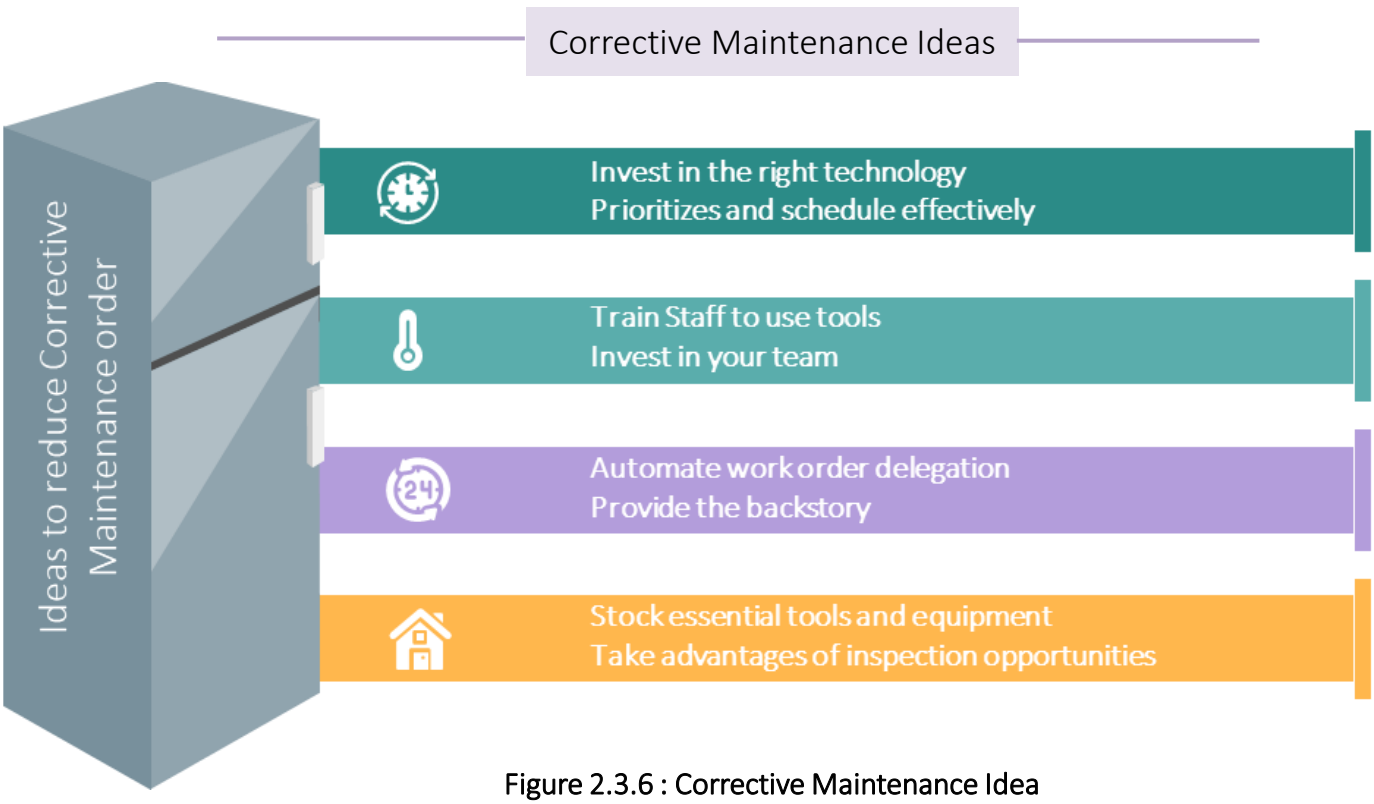


Figure 2.3.6 : Corrective Maintenance Idea

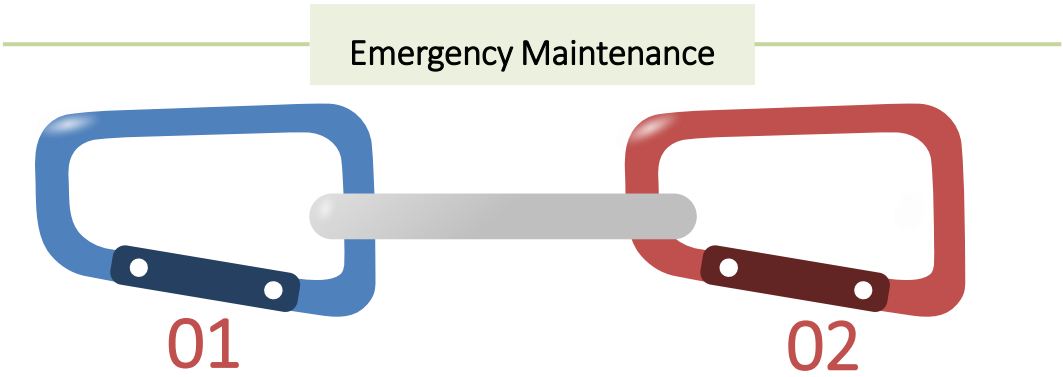
Corrective and Preventive Action Form

Parish / Community Name.....Suburb / State .....Date.....

Issue Type	Incident resulting in Injury ☐	Incident not resulting in Injury ☐	Issue raised from Internal / External Audit ☐	Issue raised by Regulator or other notices/external parties ☐		Other ☐ .....
	Improvement Suggestion ☐	System failure ☐	Training Issue ☐	Contractor Issue ☐	Volunteer Issue ☐	Employee Issue ☐
Raised by:		**Assigned to:**		**Date Required for Completion:**		
Description of Issue:						
Proposed immediate action (correction):						
Completed by:		**Date:**		**Remarks:**		
Investigation Required: Yes ☐ No ☐				**If Yes: Use *Investigation Form***		
Underlying root cause of Issue:						
Determined by:		**Date:**		**Remarks:**		
Proposed action for long term solution (corrective/preventive action):						
Completed by:		**Date:**		**Remarks:**		
Comments on effectiveness of action taken:						
Closed out by:		**Date:**		**Remarks:**		

GOAOA – Corrective and Preventative Action Template 1

Figure 2.3.7 : Corrective Maintenance Report Form
https://www.examples.com/business/corrective-action-report-examples.html



Requires a last-minute response to the sudden breakdown of an asset. However, emergency maintenance entails some type of threat to health and safety.

Never planned, and the best way to prevent emergency maintenance is by adhering to planned and preventive maintenance routines.

Figure 2.3.8 : Emergency Maintenance

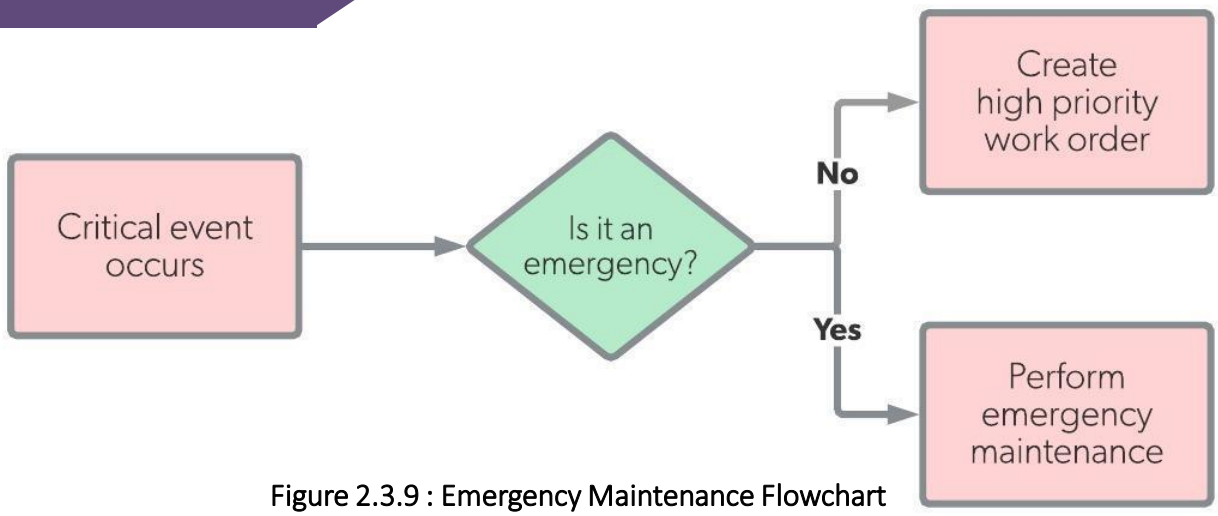


Figure 2.3.9 : Emergency Maintenance Flowchart

https://www.upkeep.com/learning/emergency-maintenance

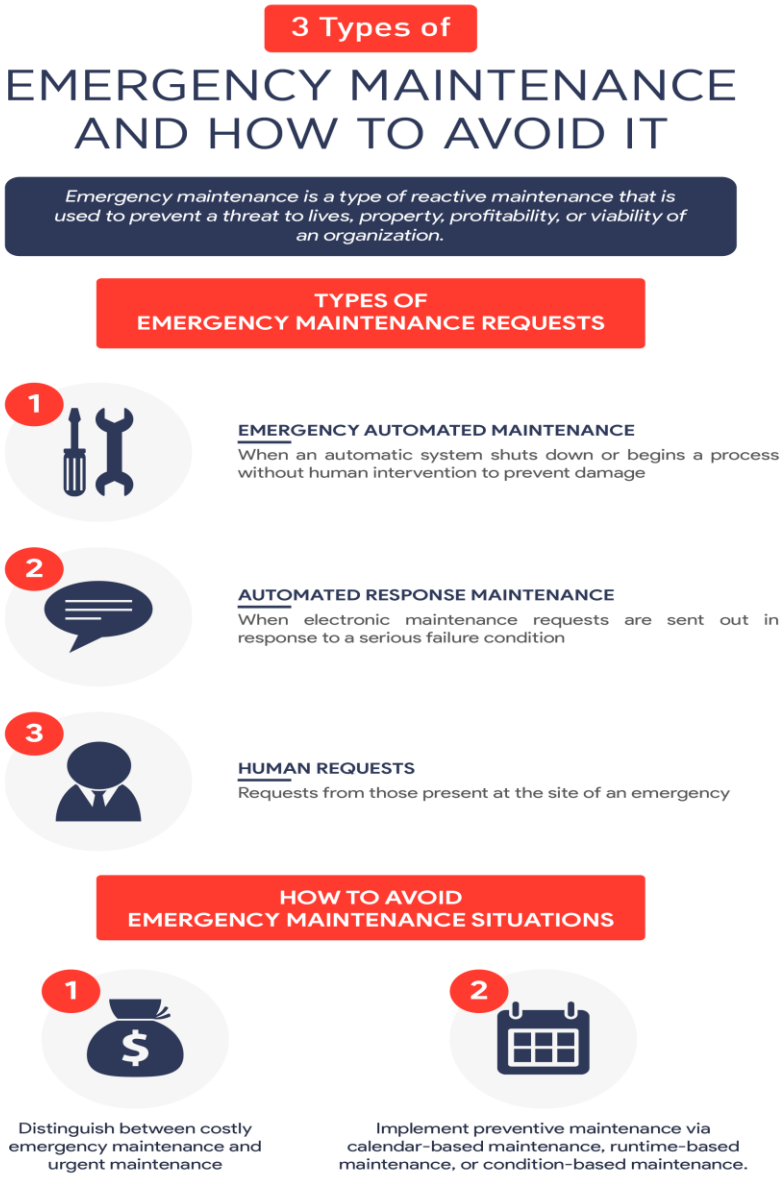


Figure 2.4.0 : Emergency Maintenance Approach to Avoid it

https://www.upkeep.com/learning/emergency-maintenance

Advantages and Disadvantages of Reactive Maintenance

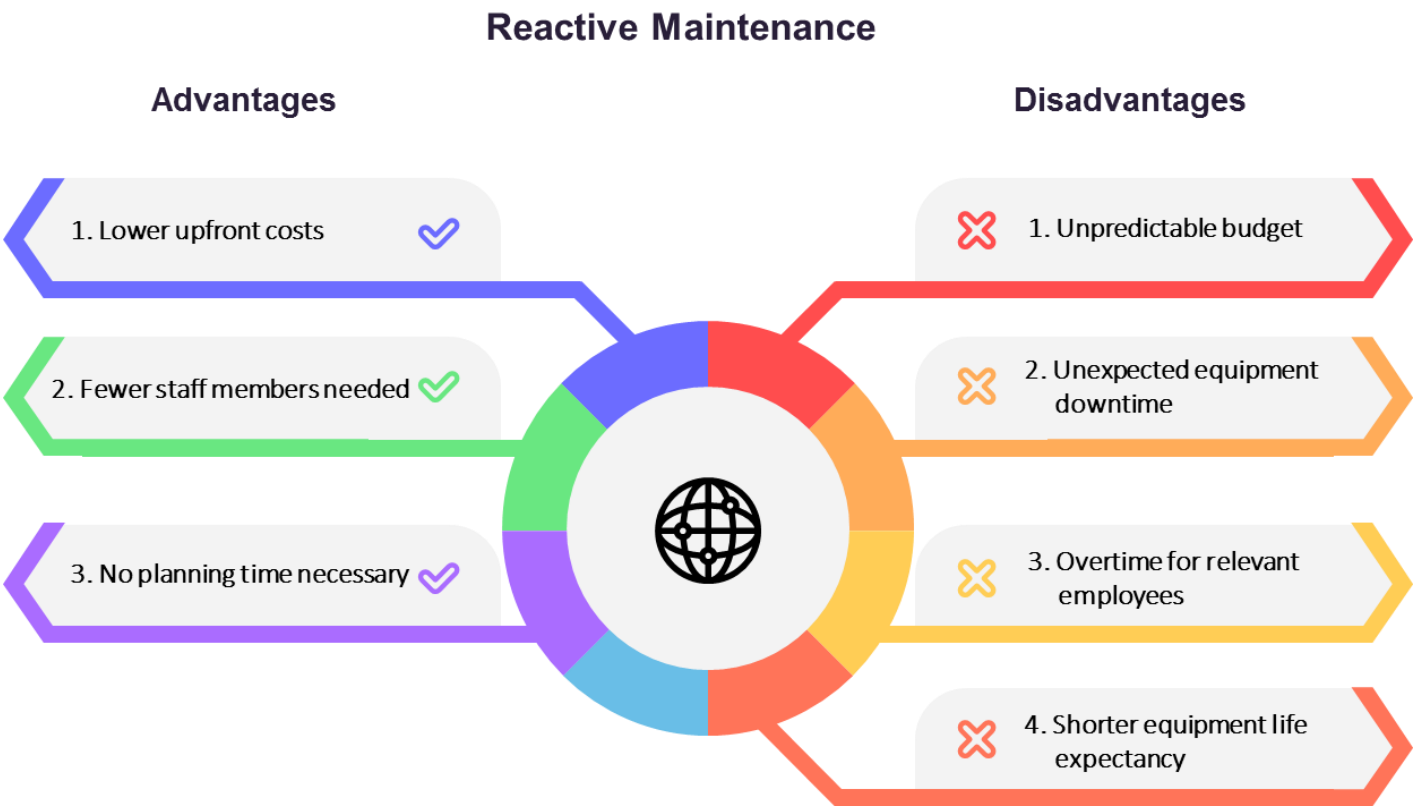


Figure 2.4.1 : Advantages And Disadvantages of Reactive Maintenance

Structured Question

1. List 5 (FIVE) types of maintenance
2. Define Breakdown Maintenance
3. Brief Run-to-failure Maintenance
4. Give advantage and disadvantage of corrective maintenance
5. Explain 3 advantages and 3 disadvantages of Reactive Maintenance

Proactive Maintenance

What Does Proactive Maintenance Mean?

- Proactive maintenance refers to a collection of activities, inspections, tests and procedures that are used to prevent the failure of equipment, a machine or a material in the future.
- It focuses on determining potential root causes of machine or material failure and dealing with those issues before problems occur.

Proactive Maintenance include:

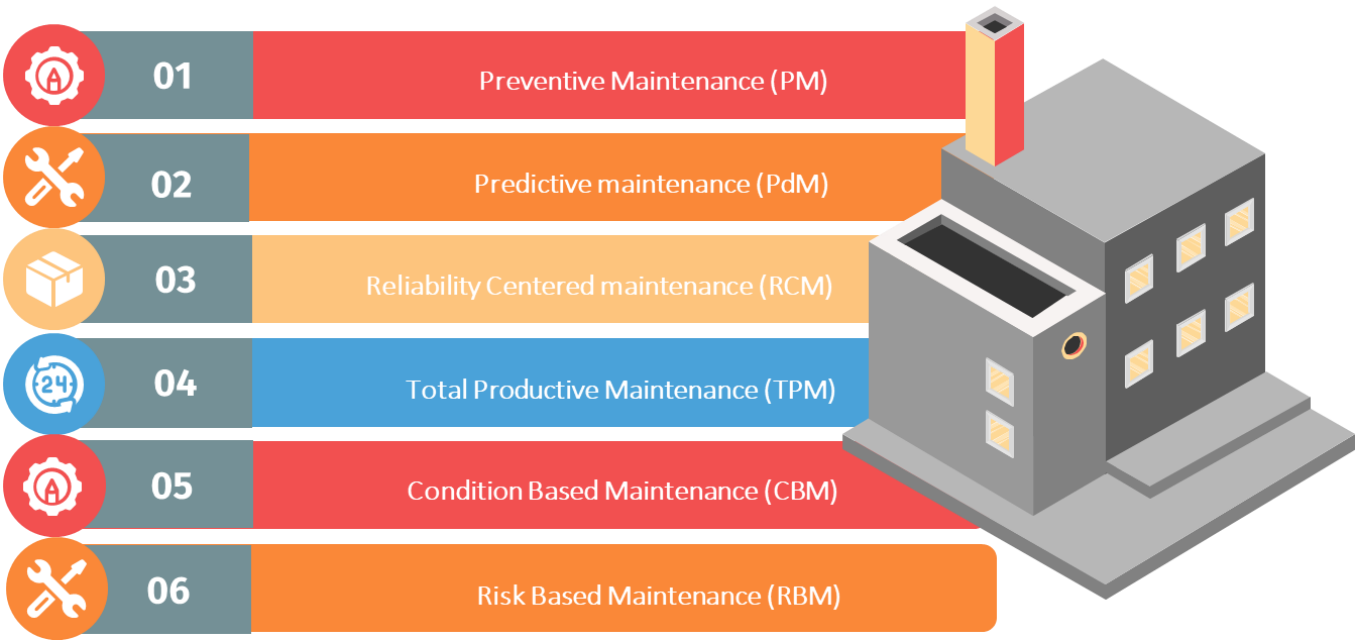


Figure 2.4.2 : Type of Proactive Maintenance

i. Preventative Maintenance

- Preventative maintenance consists of formal procedures and tasks that help prevent unplanned breakdowns and ensure equipment is operating in good manner.
- Prevent failure through the periodic inspection or equipment condition diagnosis, industry standards, guidebooks, environmental conditions, equipment criticality, location, impacts on safety and mission, past experience, work order histories, and predictive maintenance tasks.
- Preventive Maintenance jobs consider as lubrications, consumable parts replacements, cleaning, adjustments, Inspections and testing.

Preventive Maintenance

Advantages

01 Cost effective in many capital intensive processes and equipment

02 Provides flexibility for adjusting maintenance frequencies

03 Increases component life cycle

04 Generates energy savings. Results in 12% to 18% cost savings over Reactive methods

05 Reduces equipment and/or process failures

Disadvantages

01 Does not eliminate catastrophic failures

02 More labor intensive

03 Includes some invasive activities that have the potential to cause incidental damage to components

04 Performance of unneeded maintenance

Figure 2.4.3 : Advantages and Disadvantages of Preventive Maintenance

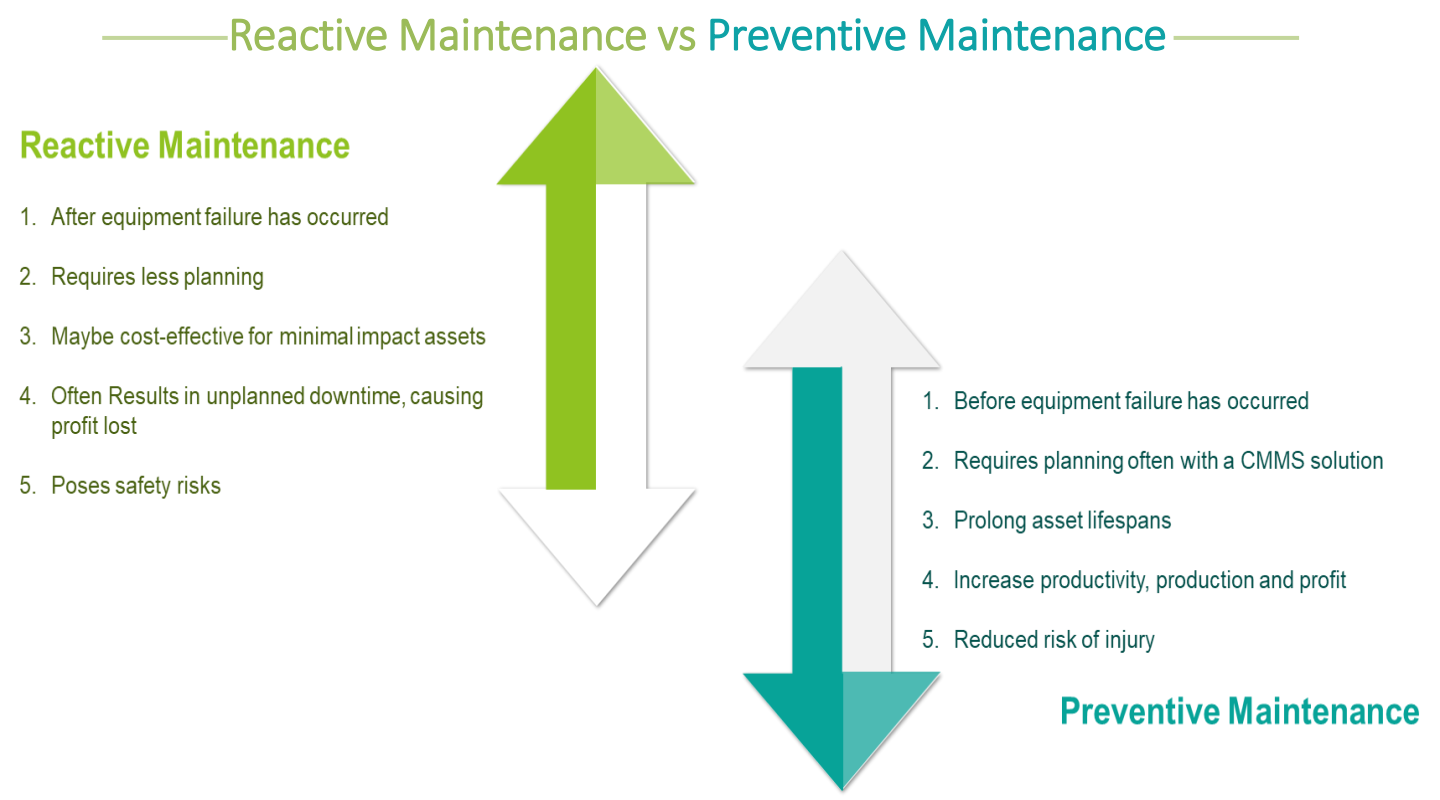


Figure 2.4.4 : Reactive Maintenance vs Preventive Maintenance

panoramic

PC-1000 Preventive Maintenance Checklist
(to be performed by Panoramic Certified Technician only)

FM 7431, Rev. C

Technician Info:
Company Name _____
Name _____
Preventive Maintenance Completion Date: _____
Counter Reading (*Lease Customers Only*) In _____ Out _____

Doctor Info:
Company / Doctor Name _____
Address _____
City _____
State _____ Zip _____ Phone _____

Machine Info: Machine Serial # _____ Tubehead Serial # _____ *Machine Type:* ☐ PC-1000 ☐ PC-1000/Laser 1000 ☐ PC-1000-DR

1. Visual Inspection
   - Tubehead Serial Match ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Data cable properly routed (*PC-1000-DR*) ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Exposure Cord ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Main power button ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Reset button ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Radiation button ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Mirror ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Forehead Support / Knob ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Handlebars (*Free of Movement*) ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Safety placard in place (FM 20205) ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Preventive maintenance placard in place (FM 20206) ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
2. Darkroom and Processing Analysis (*Film and Plate Systems Only*)
   - Light in the Darkroom ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Timer ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Thermometer ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Intensifying Screens ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Black Cassette ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Screen Type ☐ Ektavision ☐ Lanex ☐ X-Omat ☐ N/A
   - Film Type i. Manufacturer: _____ ii. Model: _____ iii. Speed: _____
3. Stability Of Unit
   - Unit is level/free of wobble ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
4. Inspect Screw Drive
   - Up/Down & Limit Switches ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Visually Confirm Safety Nut properly seated ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Inspect Motor Assembly Wear ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
5. Arm and Film Drum Rotation
   - Arm Rotation ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Film Drum ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
6. Tubehead Inspection
   - kVp Deflection @ 80kVp: _____
   - Tubehead Knobs (Ceph Only) ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Tubehead Leaking? ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
7. Calibrate/Verify Calibration
   - No load voltage reading: _____ If Serviced, new reading is: _____
   - Line Voltage _____
   - mA Pan _____ Ceph _____ If Serviced: Pan _____ Ceph _____
   - Pulse Count _____ If Serviced, new pulse count: _____
8. Panoramic Beam Alignment ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
9. Software Calibrations (*PC-1000-DR Only*)
   - Mechanical Alignment ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
   - Software Calibrations ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
10. Verify Cephalometric Alignment (*PC-1000/Laser 1000 Only*)
    - Soft Tissue on Front and Back ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
    - Ear Rod Rings/Posts ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
    - Laser / Laser Switch ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
    - Cephalometric Arm (*Level*) ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
11. Pin Test Measurement Right _____ Measurement Left _____
    ☐ Pass ☐ Fail ☐ N/A ☐ Action Taken _____
12. Update Preventive Maintenance Placard Year Box ☐ Completed

Additional Comments and Recommendations: _____

Panoramic Certified Technician Signature: _____ Date _____

Page 1 of 1

Figure 2.4.5 : Preventive Maintenance Checklist

https://www.academia.edu/34801793/PC_1000_Preventive_Maintenance_Checklist_to_be_performed_by_Panoramic_Certified_Technician_only

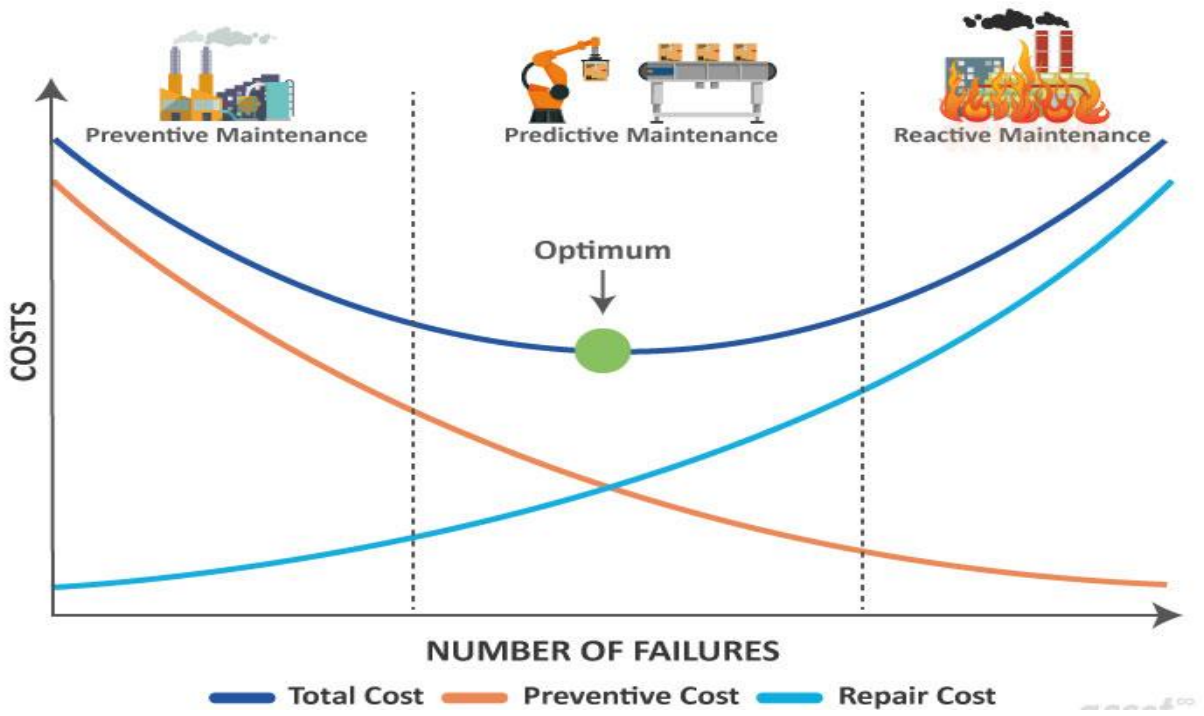


Figure 2.4.6 : Reactive Maintenance Vs Preventive Maintenance Vs Predictive Maintenance graph
https://www.assetinfinity.com/blog/reactive-vs-preventive-vs-predictive

Figure 2.4.7 : Preventive Maintenance Plan

ii. Predictive maintenance (PdM)

Definition of Predictive Maintenance

- Predictive maintenance compares the trend of measured physical parameters against known engineering limits for the purpose of detecting, analyzing, and correcting problems before failure occurs.
- **Detection of Failures**. It is aimed at early discovery of failures and their early repair.
- **Prediction of Failures and Defects.** This is predictive maintenance itself. The focus is on quality maintenance that leads to prediction of quality defects of the functional deterioration type.
- **Prediction of Remaining Service Life.** This is where natural deterioration is ending the life cycle of the equipment and plans should be made to replace the equipment.

Figure 2.4.8 : Most Common PdM Methods

https://www.servicepower.com/blog/preventive-vs-predictive-maintenance

- Users define it as:-

i. To prevent catastrophic failure of critical rotating machinery

ii. Maintenance scheduling tool that uses vibration and infra red or lubricating oil analysis data to determine the need for corrective maintenance action.

- This approach offers cost savings over routine or time-based preventive maintenance, because tasks are performed only when warranted.
- The main value of (PdM) is to allow convenient scheduling of corrective maintenance, and to prevent unexpected equipment failures.
- The key is " the right information is the right time".
- By knowing which equipment needs maintenance, maintenance work can be better planned, and what would have been 'unplanned stop' are transfer to shorter and fewer 'planned stops' thus increasing plant availability.
- It also can increase equipment lifetime, increase plant safety, fewer accidents with negative impact on environment, and optimized spare parts handling.
- The ultimate goal is to perform maintenance at a scheduled point in time when the maintenance activity is most cost-effective and before the equipment loses performance within a threshold.
- Most PdM inspections are performed while equipment is in service, thereby minimizing disruption of normal system operations.
- Adoption PdM can result in substantial cost saving and higher system reliability

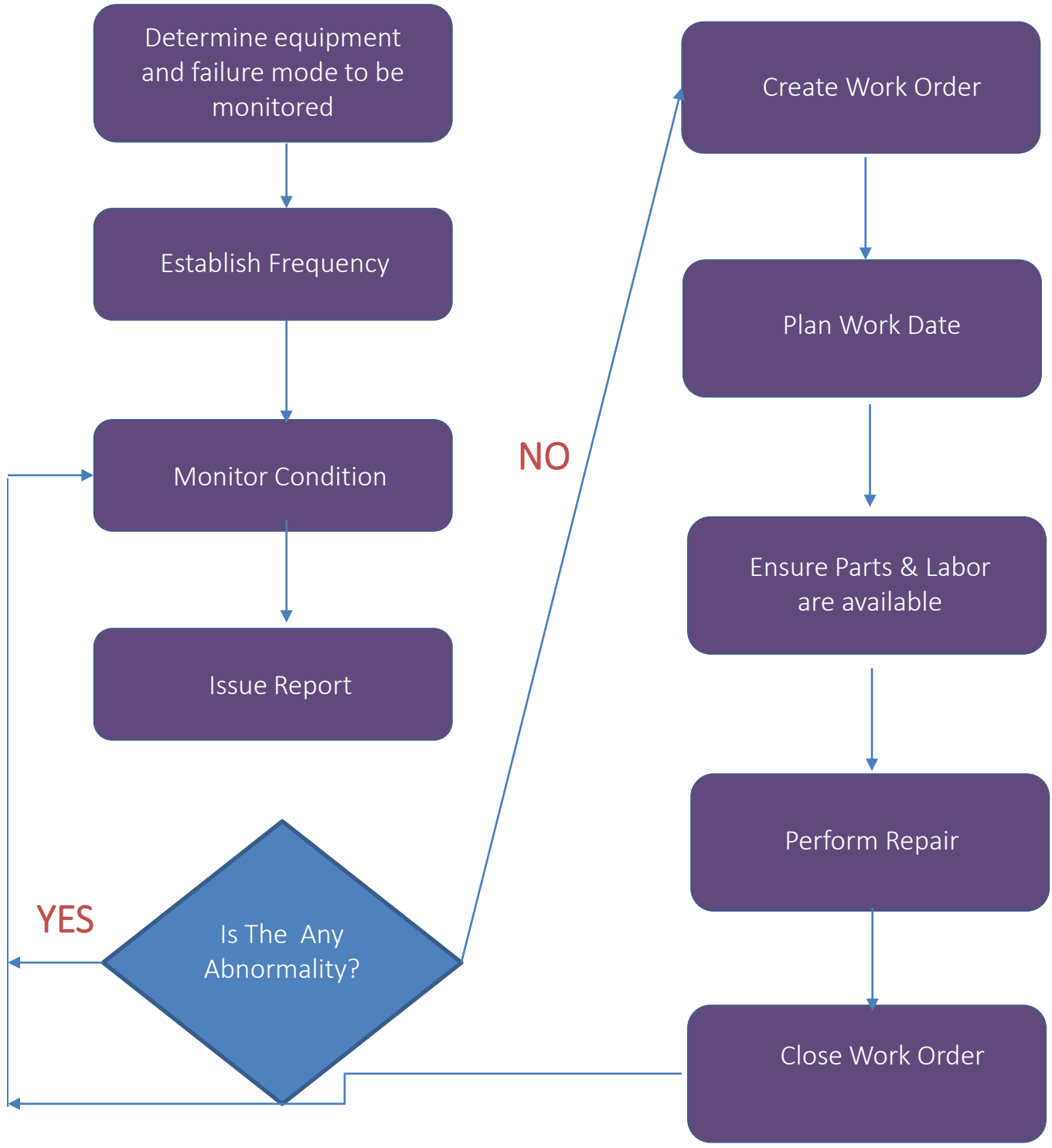


Figure 2.4.9 : Predictive Maintenance Flowchart

https://leanmanufacturing.online/predictive-maintenance-priority-criteria-and-flow/

iii. Reliability Centered maintenance (RCM)

- Reliability Centered Maintenance RCM is a process used to determine the maintenanc e requirements of any physical asset in its operating context."
- RCM. A maintenance approach that prioritizes some machines over others to increase reliability and optimize financial resources Required analysis
- Using RCM develops maintenance standards for ensuring that a system or device meets its designed reliability or availability.

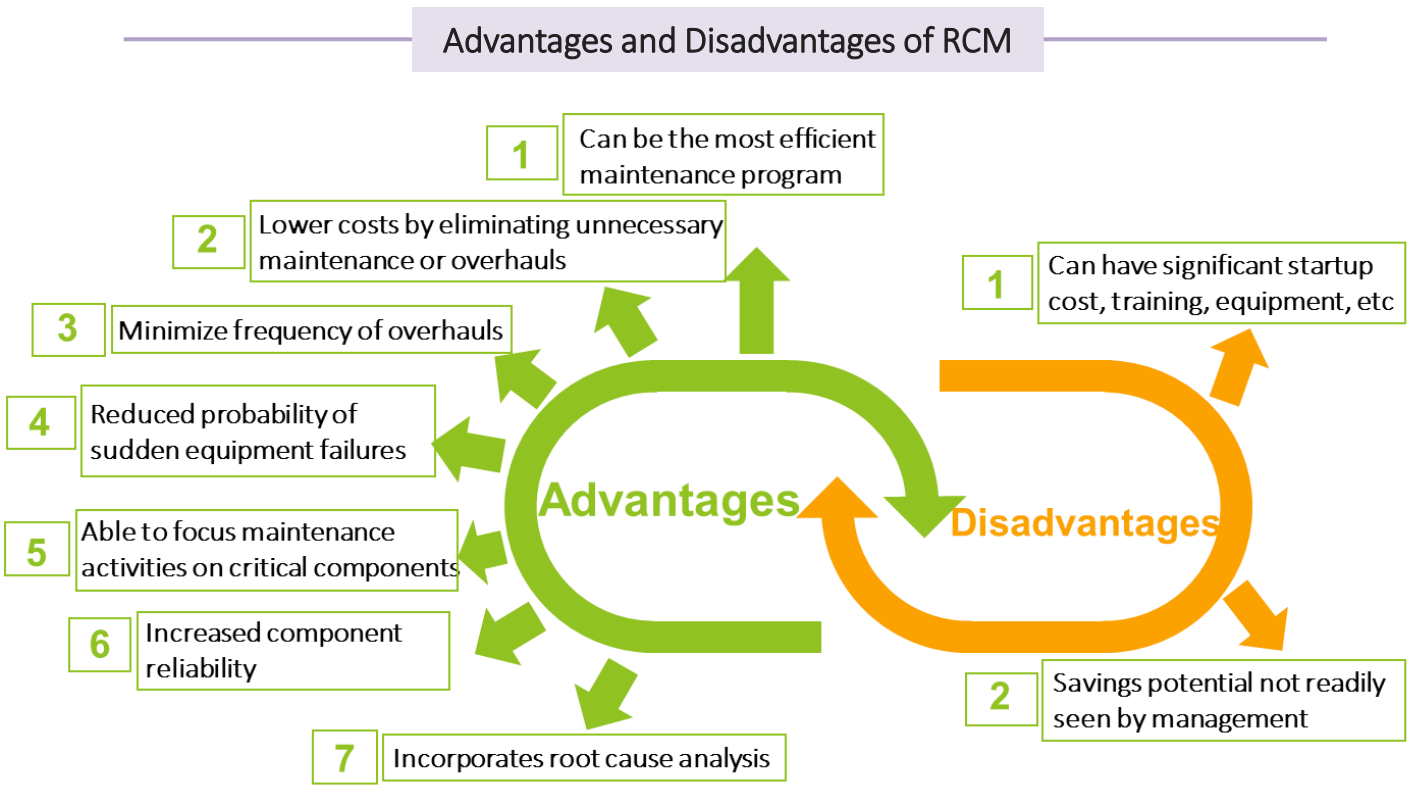


Figure 2.5.0 : Advantages and Disadvantages of RCM

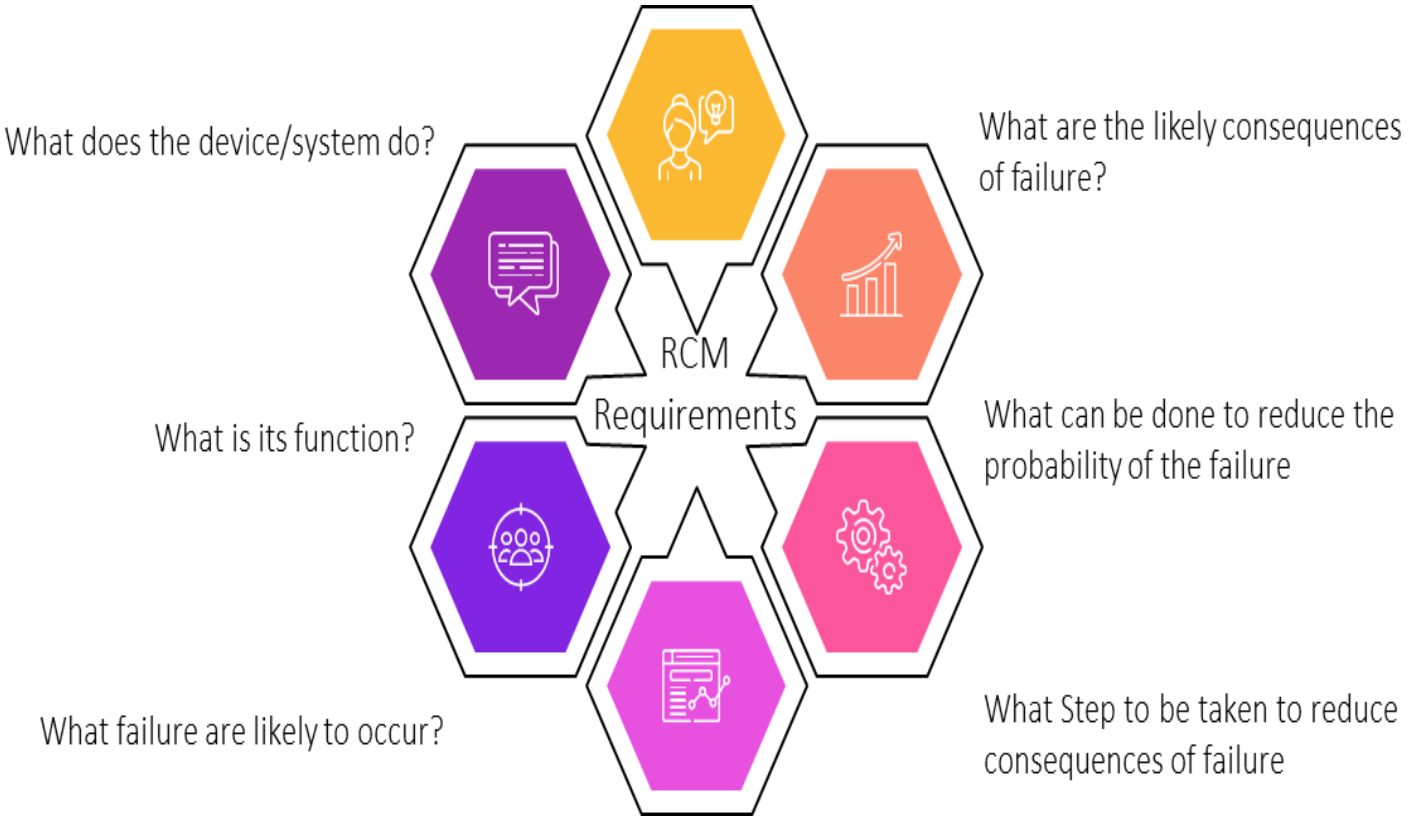


Figure 2.5.1 : RCM Requirements

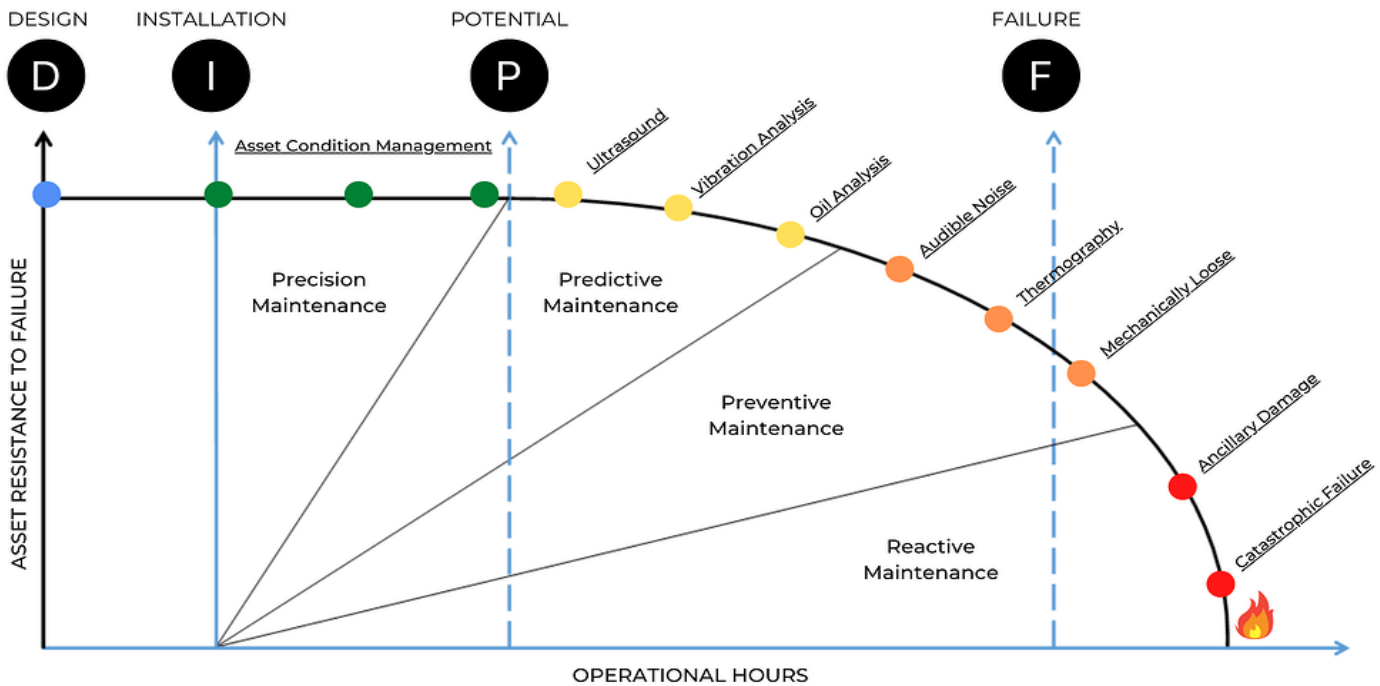


Figure 2.5.2 : Asset Lifecycle Curve

https://www.industrypartners.com.au/blog/reliability-centred-maintenance

Comparison of maintenance types

Maintenance type	Preventive Maintenance					Corrective Maintenance	
	Time based	Failure finding	Risk based	Condition based	Predictive	Deferred	Emergency
Task type	Scheduled Overhaul / Replacement	Functional Test	Measurement of condition	Calculation and extrapolation of parameters	Inspection or Test	Repair/ Replace	Repair/ Replace
Objective	Restore or replace regardless of condition	Determine if hidden failure has occurred	Restore or replace based on a measured condition compared to a defined standard	Determine if failure is imminent and intervention is required	Determine condition and conduct risk assessment to determine when next inspection, test or intervention is required.	Restore or replace following failure. Result of a Run to Failure Strategy or an unplanned failure.	Restore or replace following unplanned failure.
Interval	Fixed time or usage interval e.g. 1 month, 1,000hrs or 10,000 km	Fixed time interval (can be set based on risk assessment e.g. SIL)	Fixed time interval for condition measurements/ inspections	Continuous online monitoring of parameters, intervention as required	Time based interval between tasks and scope of task is based on risk assessment	Not applicable, but intervention is deferred to allow for proper planning & scheduling.	Immediate intervention required.

Figure 2.5.3 : Comparison of Maintenance Type

iv. Total Productive Maintenance

Total Productive Maintenance (TPM) is both

- a philosophy to permeate throughout an operating company touching people of all levels.
- a collection of techniques and practices aimed at maximizing the effectiveness (best possible return) of business facilities and processes.

Why is TPM so popular and important ?

Three main reasons:

1. It guarantees dramatic results (Significant tangible results)
    i. Reduce equipment breakdowns
    ii. Less idle time and minor emergency stops
    iii. Reduce quality defects and claims
    iv. Increase productivity
    v. Reduce manpower and cost
    vi. Lower inventory
    vii. Increase safety and reduce accidents
2. Visibly transform the workplace (plant environment)
    - Through TPM, a filthy, rusty plant covered in oil and grease, leaking fluids and spilt powders can be reborn as a pleasant and safe working environment.
    - Customers and other visitors are impressed by the change. Confidence on plant's product increases.
3. Raises the level of workers knowledge and skills as TPM activities begin to yield above concrete results, it helps:
    i. The workers to become motivated.
    ii. Involvement increases.
    iii. Improvement suggestions proliferate.
    iv. People begin to think of TPM as part of the job

Benefits of Total Productive Maintenance	
Direct Benefits	Indirect Benefits
Less unplanned downtime resulting in and increase in OEE	Increase in employee confidence levels
Reduction in customer complaints	Produces a clean orderly workplace
Reduction in workplace accidents	Increase in positive attitudes among employees through a sense of ownership
Reduction in manufacturing cost	Pollution control measures are followed
Increase in product quality	Cross departmental shared knowledge and experience

Figure 2.5.4 : Benefits of Total Productive Maintenance (TPM)

TPM Policy and Objectives

- To maximize overall equipment effectiveness (Zero breakdowns and failures, Zero accident, and Zero defects) through total employee involvement.
- To improve equipment reliability and maintainability as contributors to quality and to raise productivity.
- To aim for maximum economy in equipment for its entire life.
- To cultivate equipment-related expertise and skills among operators.
- To create a vigorous and enthusiastic work environment.

TPM benefits

- Improved equipment eliminates the root cause of defects.
- Defects are prevented through planned maintenance
- Preventive maintenance costs are reduced as equipment operators conduct autonomous maintenance.
- Improved equipment designs ensure that new equipment produces fewer defects.
- Simplified products designs and a redesigned process produce with few defects.
- Engineers, technicians and managers are trained in maintenance and quality.

The 8 Pillars of Total Productive Maintenance (TPM)

- Traditional total productive maintenance was developed by Seiichi Nakajima of Japan. The results of his work on the subject led to the TPM process in the late 1960s and early 1970s. Nippon Denso (now Denso), a company that created parts for Toyota, was one of the first organizations to implement a TPM program.
- This resulted in an internationally accepted benchmark for how to implement TPM. In corporating lean manufacturing techniques, TPM is built on eight pillars based on the 5-S system. The 5-S system is an organizational method based around five Japanese words.

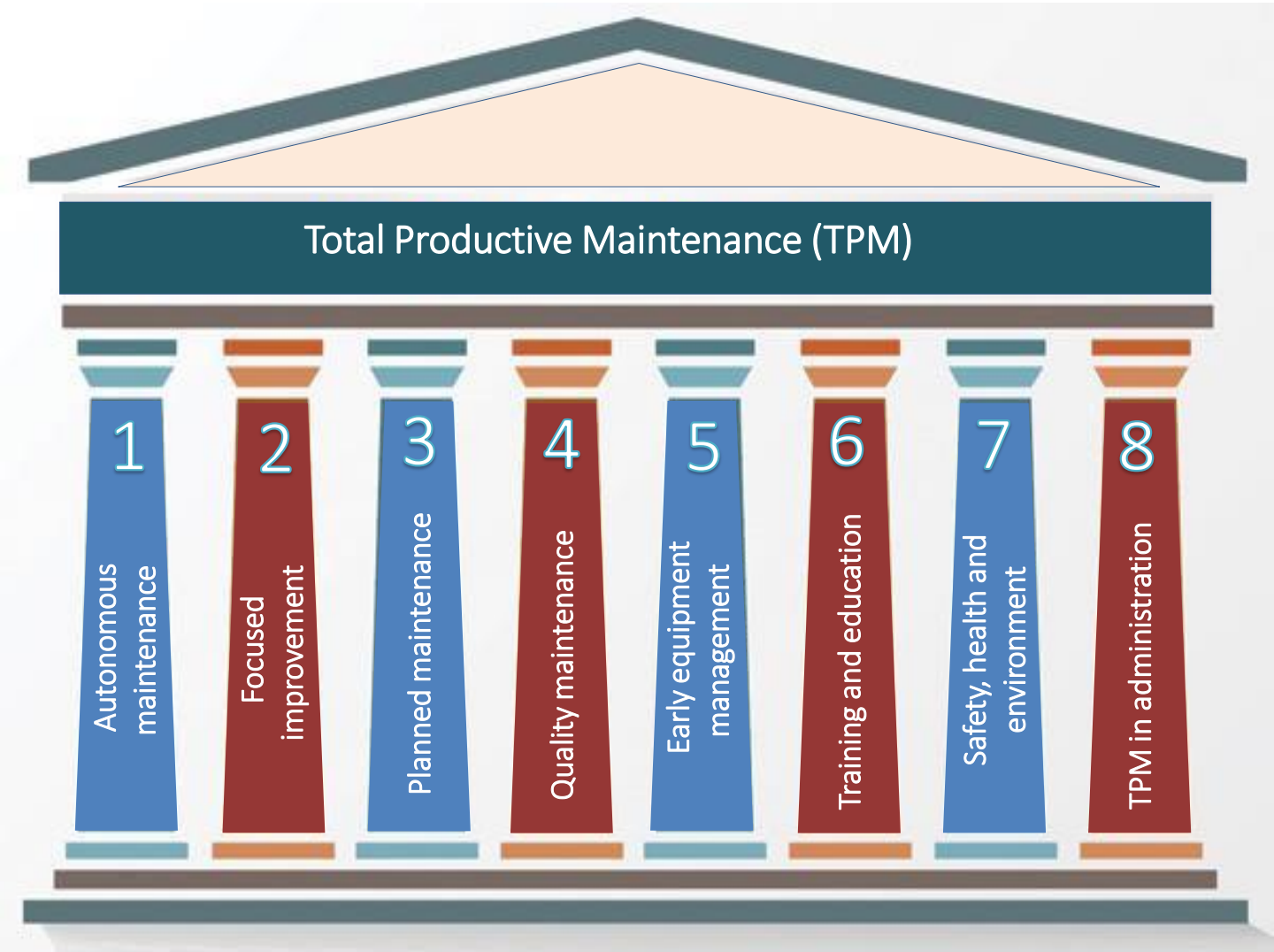


Figure 2.5.5 : 8 pillars of TPM

https://www.reliableplant.com/Read/26210/tpm-lean-implement

Figure 2.5.6 : 5'S

https://tulip.co/ebooks/the-ultimate-guide-to-5s/

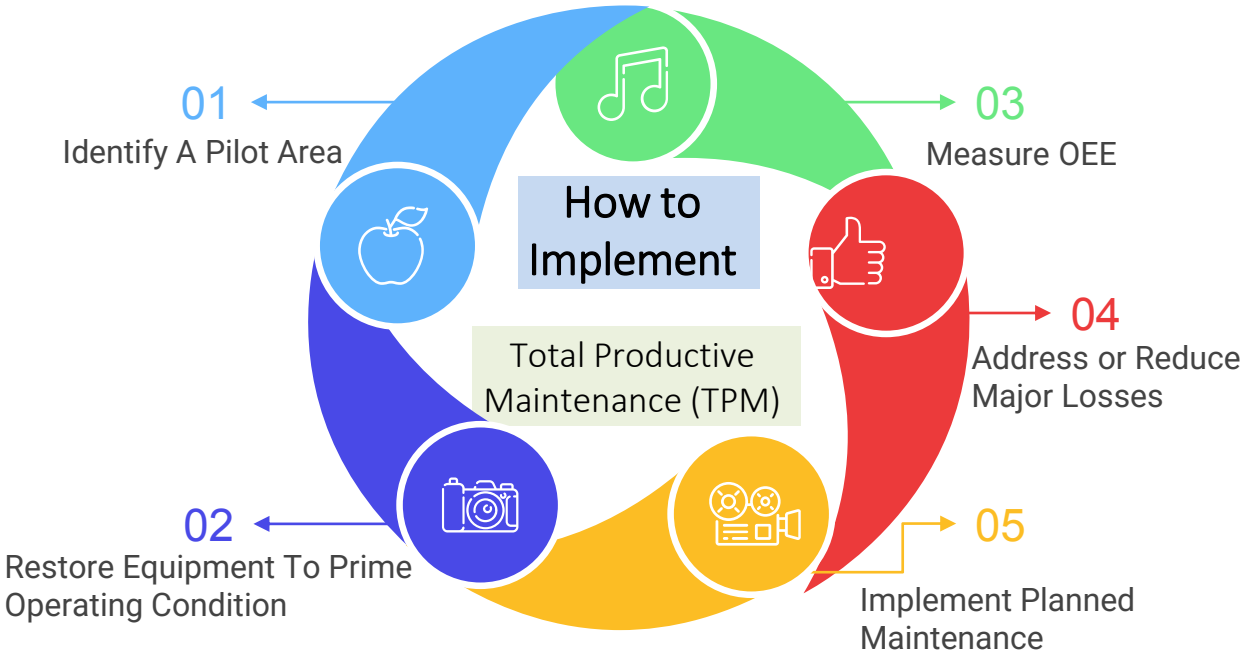


Figure 2.5.7 : How To Implement TPM

	Reactive Maintenance	Preventive Maintenance	Predictive Maintenance	Maintenance Prevention
System Description	1. Maintenance department responds to equipment malfunctions and breakdowns	1. Periodic adjustments and checks 2. Periodic replacement of wear parts 3. Periodic overhaul	1. Periodic measurement and trending of equipment and process parameters	1. Equipment design is based upon minimal maintenance requirements
Characteristics	1. Inefficient maintenance department 2. Unpredictable equipment operation 3. All maintenance work is unplanned	1. More predictable operation 2. More efficient maintenance department	1. Predictable maintenance requirements 2. Planned and scheduled equipment repairs	1. Close relationship with equipment suppliers
Examples	1. Light bulb replacement	1. Changing oil and filters	1. Vibration analysis	1. Sealed bearings in small electric motors
Results	1. Steady degradation of equipment performance	1. Maintain level of equipment performance	1. Maintain equipment performance with minimal disruption to production	1. Continually improving equipment designs
Maintenance Department Responsibility	1. Respond to emergencies 2. Get production back on line	1. Keep machines running by checking, replacing, and overhauling 2. Perform checks during down times	1. Log equipment parameters 2. Trend data 3. Predict equipment repair cycle	1. Input to equipment design 2. Minimize and eliminate maintenance requirements

Figure 2.5.8 : Maintenance System Comparison

Maintenance Strategy	Advantages	Disadvantages	Resources/ Technology Required	Application Example
Breakdown	No prior work required	Disruption of production, injury or death	May need labor/parts at odd hours	Office copier
Preventive	Work can be scheduled	Labor cost, may replace healthy components	Need to obtain labor/parts for repairs	Plant relamping, Machine lubrication
Predictive	Impending failures can be detected & work scheduled	Labor costs, costs for detection equipment and services	Vibration, IR analysis equipment or purchased services	Vibration and oil analysis of a large gearbox

Figure 2.5.9 : Maintenance Strategy comparison

Figure 2.6.0 : Goal of TPM

TPM Philosophy

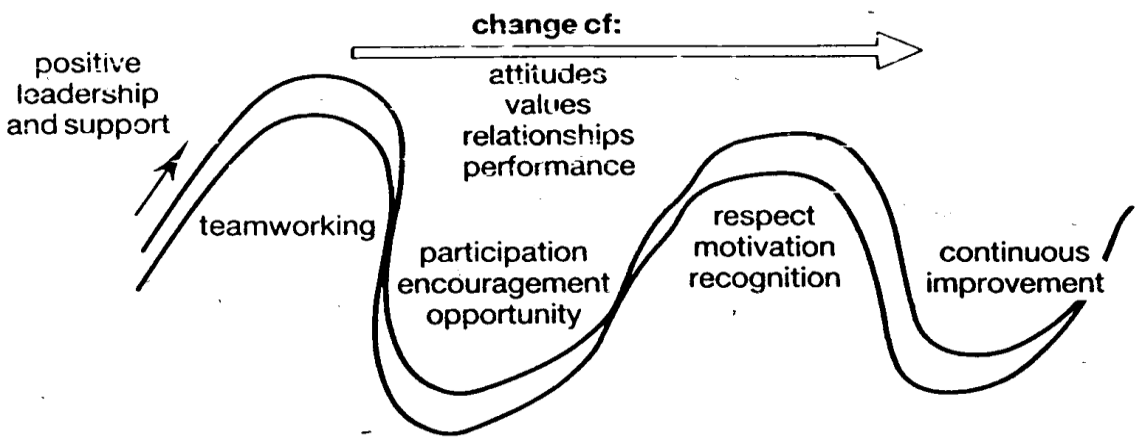


Figure 2.6.1 : TPM Philosophy

Evolution Toward Total Productive Maintenance

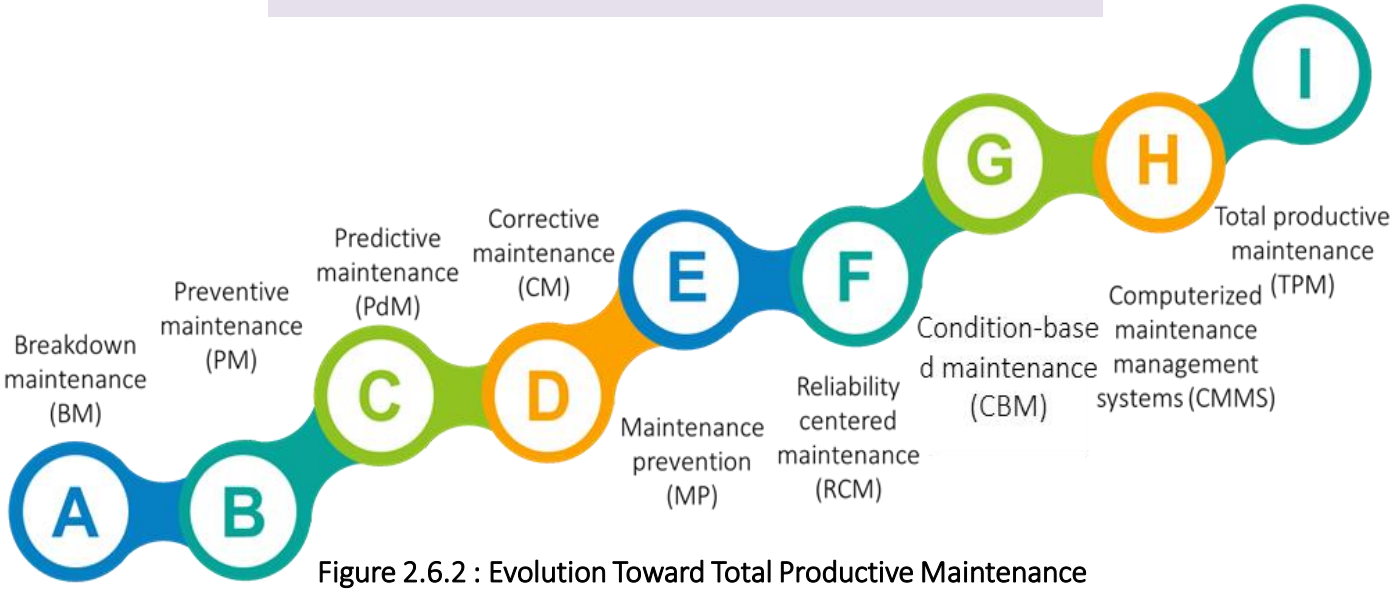


Figure 2.6.2 : Evolution Toward Total Productive Maintenance

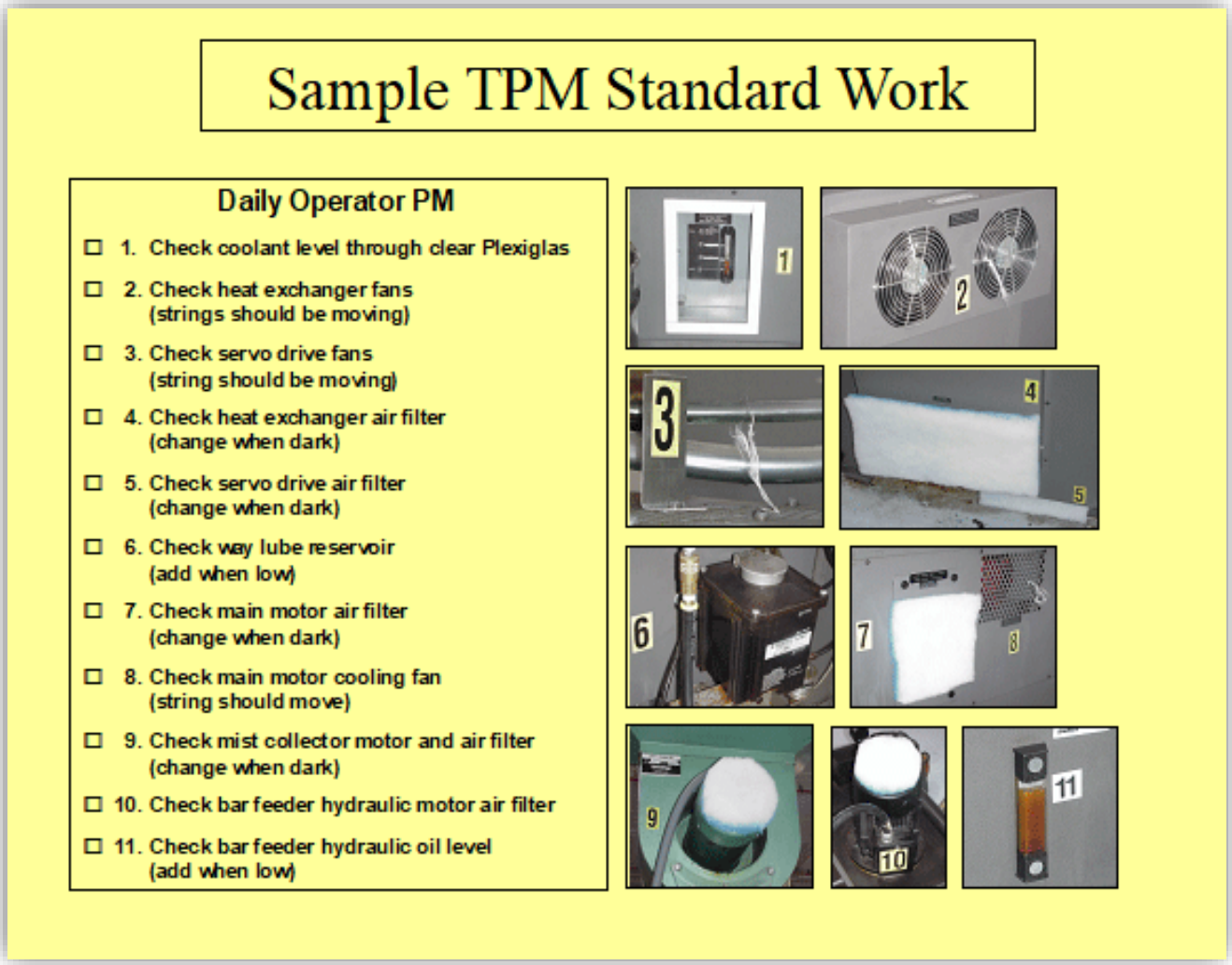


Figure 2.6.3 : Sample TPM Standard Work

https://www.prositconsult.com/total-productive-maintenance/

TOPIC 2.3

DISCOVER CONDITION BASED MAINTENANCE SYSTEM (CBM) CONCEPTS.

2.3.1 Methodology of Condition-based maintenance (CBM)

Point 1

Condition-based maintenance (CBM) is maintenance when need arises. This maintenance is performed after one or more indicators show that equipment is going to fail or that equipment performance is deteriorating. This concept is applicable to mission critical systems that incorporate active redundancy and fault reporting.

It is also applicable to non-mission critical systems that lack redundancy and fault reporting.

CBM is a set of maintenance actions based on real-time or near-real time assessment of equipment condition which is obtained from embedded sensors and/or external tests & measure ments taken by portable equipment.

Point 2

The purpose of CBM strategy is to perform maintenance only when there is objective evidence of need, while ensuring safety, equipment reliability and reduction of total ownership cost. (OPNAV INST 4790.16, Condition-Based Maintenance (CBM) Policy, 6 May 1998).

Ideally condition-based maintenance will allow the maintenance personnel to do only the right things, minimizing spare parts cost, system downtime and time spent on maintenance.

The goal of condition-based maintenance is to continuously monitor assets to spot impending failure, so maintenance can be proactively scheduled before the failure occurs.

The idea is that this real-time monitoring will give maintenance teams enough lead time before a failure occurs or performance drops below an optimal level.

Figure 2.6.4 : Methodology of Condition-based maintenance (CBM)

Condition Based Maintenance (CBM) System

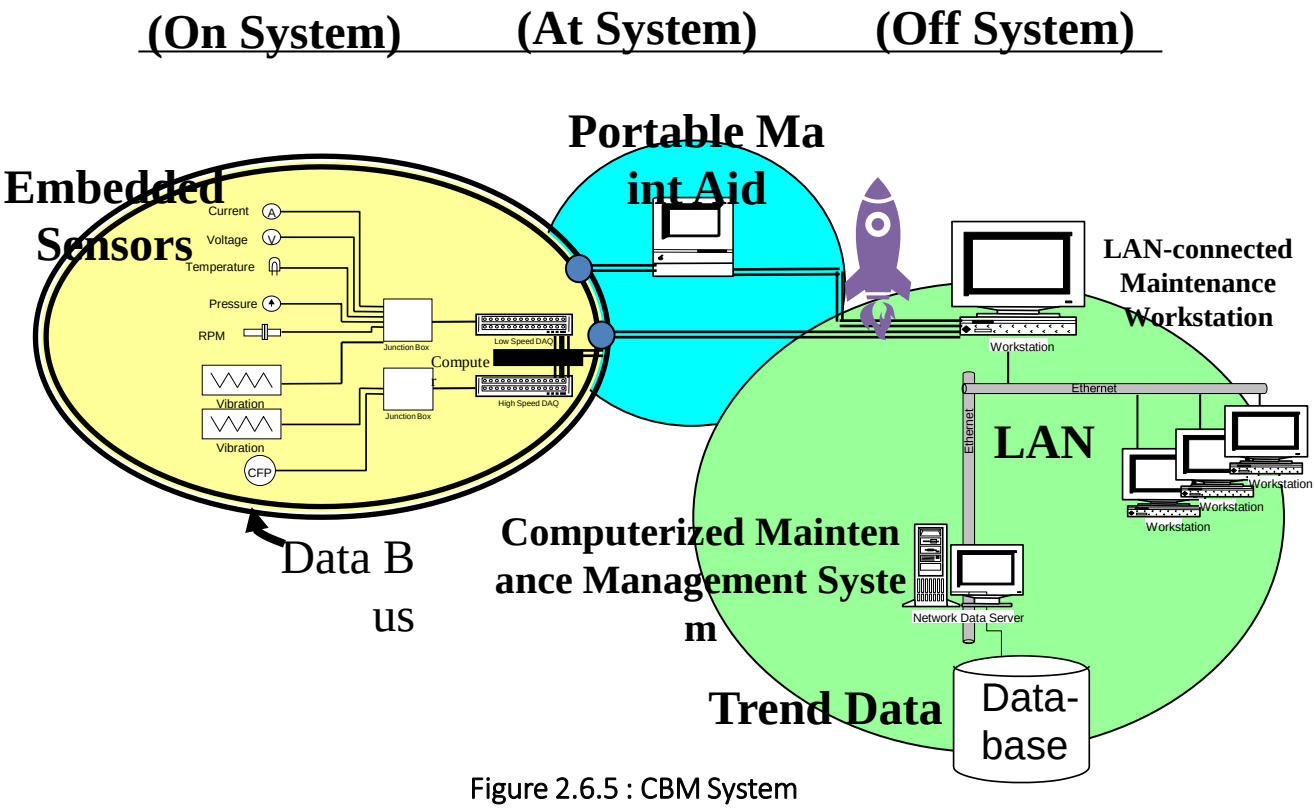


Figure 2.6.5 : CBM System

Condition Based Maintenance (CBM) Workflow

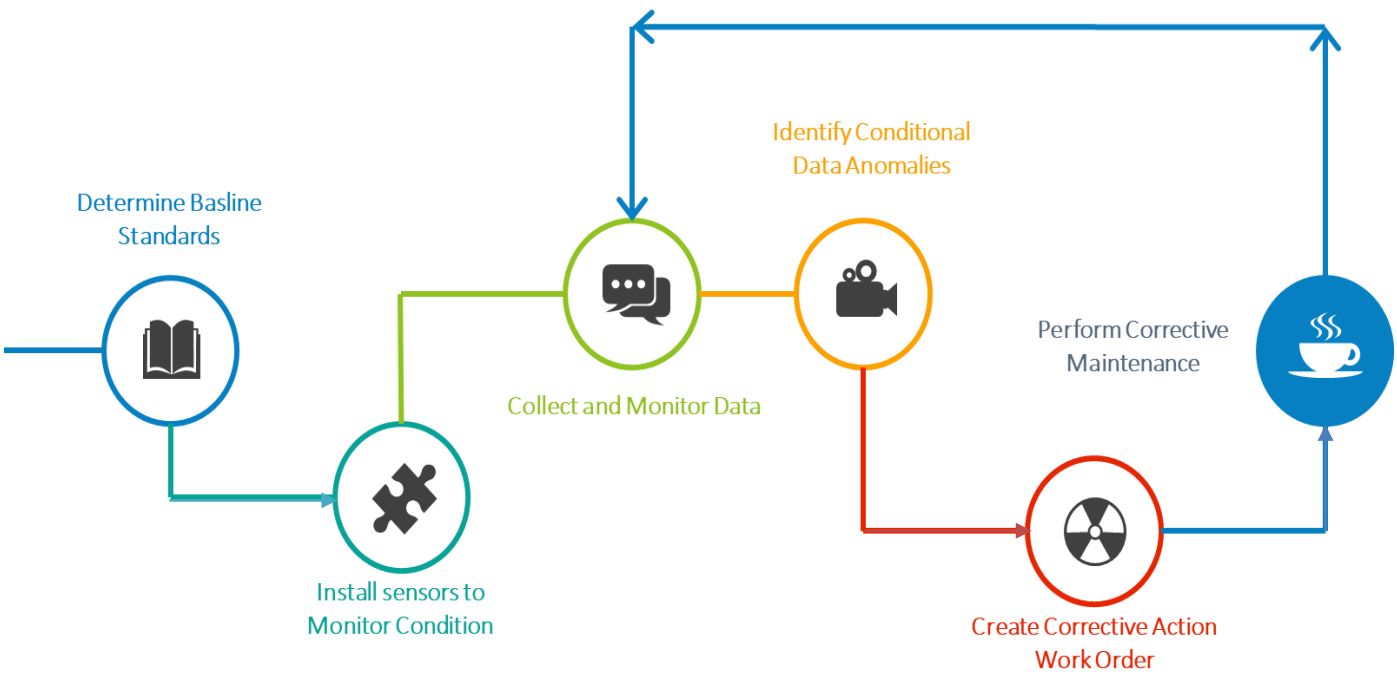


Figure 2.6.6 : CBM Workflow

How Condition Based Maintenance (CBM) Work

Point 1

Using sensors and spot readings are the most common ways real-time data is collected for analysis. For example, sensors can be installed on a piece of rotating equipment to monitor its vibration. Over time, as the moving components degrade and begin to fall out of alignment, vibration increases, which is picked up by the sensors. Sensors can be preset to alert the maintenance team when vibrations reach a determined limit

Point 2

While condition-based maintenance can be used on most equipment, that equipment must meet certain criteria for CBM to be effective. First, there needs to be a monitor able condition and need to be able to see changes in performance far enough in advance, so maintenance can be performed before the asset fails or lessens in production.

Figure 2.6.7 : How CBM Works

How Condition Based Maintenance (CBM) Work

Point 3

Asset criticality is another criterion you should consider before utilizing condition-based maintenance. You'll get the best return on investment (ROI) using CBM on your most critical assets. Doing a criticality analysis to rank which pieces of equipment are most likely to fail and the impact that failure will have on your operation is a vital step before performing condition-based maintenance.

Point 4

It's important to scale from the most critical assets down. Finally, condition-based maintenance is only as effective as the processes and systems used to analyze the data. Maintenance teams must be able to collect performance data and analyze it properly to make smart and timely decisions based on the results.

Figure 2.6.8 : How CBM Works

Advantages And Disadvantages of CBM

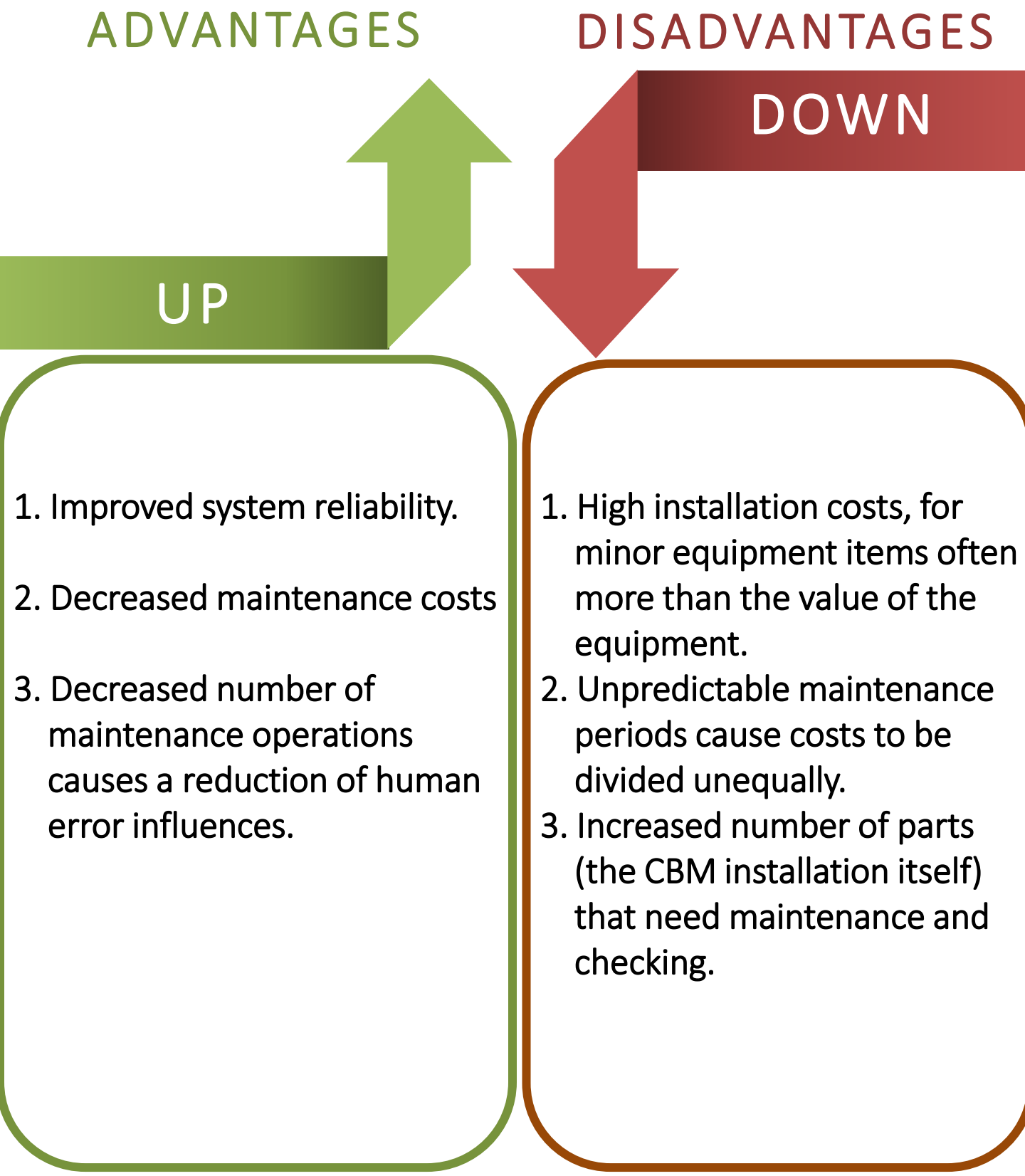
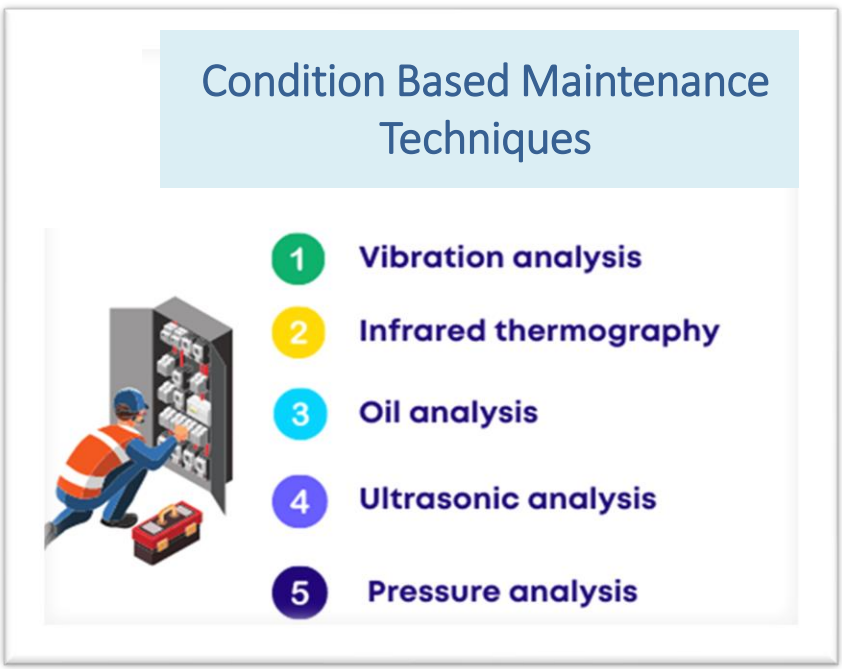


Figure 2.6.9 : Advantages and Disadvantages of CBM

	Preventive Maintenance	Condition Based Maintenance
Definition	Maintenance work is scheduled or performed at regular intervals	Maintenance work is done at the exact time when real-time analysis dictates irregularities
Trigger	Predicted date	Real-time measurement
Cost	Medium/high	Medium/high initial startup cost
Pros	• Maintenance need is predicted in advance • Reduces maximum amount of downtime • Improved automation of maintenance tasks	• Maintenance done only as needed while asset is running • Fewer unplanned downtime events • Better prioritization of maintenance time
Cons	• Expensive to implement and maintain • Time intensive • More resources required • Over maintenance	• High initial cost (install, training, etc.) • Hard to choose the correct sensor equipment • May require asset modifications

Figure 2.7.0 : CBM vs Preventive Maintenance Comparison



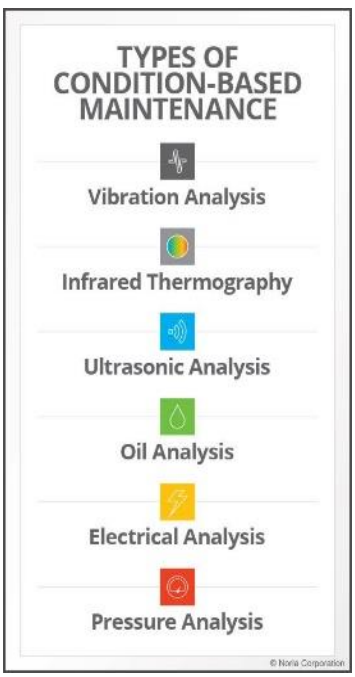


Figure 2.7.1 : CBM Techniques

https://safetyculture.com/topics/condition-based-maintenance/

2.3.2 Risk-Based Management (RBM)

1	2	3
Risk-Based Asset Management in Other Regulated Industries • Commercial Airline Industry • Nuclear Power Generation • Military • Space Programs Sub sea Oil & Gas Drilling (emerging)	Many foundational asset management, reliability and maintenance standards written in 1970s-1980s	The necessary components to sustain manufacturing operations: • Safety • Quality • Productivity

Figure 2.7.2 : RBM Introduction

Risk Based Maintenance Definition

01 Risk Based Maintenance (RBM) is a maintenance improvement program whereby the maintenance processes and procedures are planned based on (failure) risks and effects.

02 The concept of risk-based maintenance was developed to inspect the high-risk components usually with greater frequency and thoroughness and to maintain in a greater manner, to achieve tolerable risk criteria.

03 Risk-based maintenance methodology provides a tool for maintenance planning and decision making to reduce the probability of failure of equipment and the consequences of failure.

04 Ensure realization of inherent Safety and Reliability and Integrity of the equipment.

05 Restore equipment to required levels when deterioration occurs.

06 Obtain the information necessary for design improvements where inherent reliability is insufficient and accomplish these goals at a minimum total life cycle cost.

Figure 2.7.3 : RBM Definition

Risk-Based Management (RBM) Model

Figure 2.7.4 : RBM Model

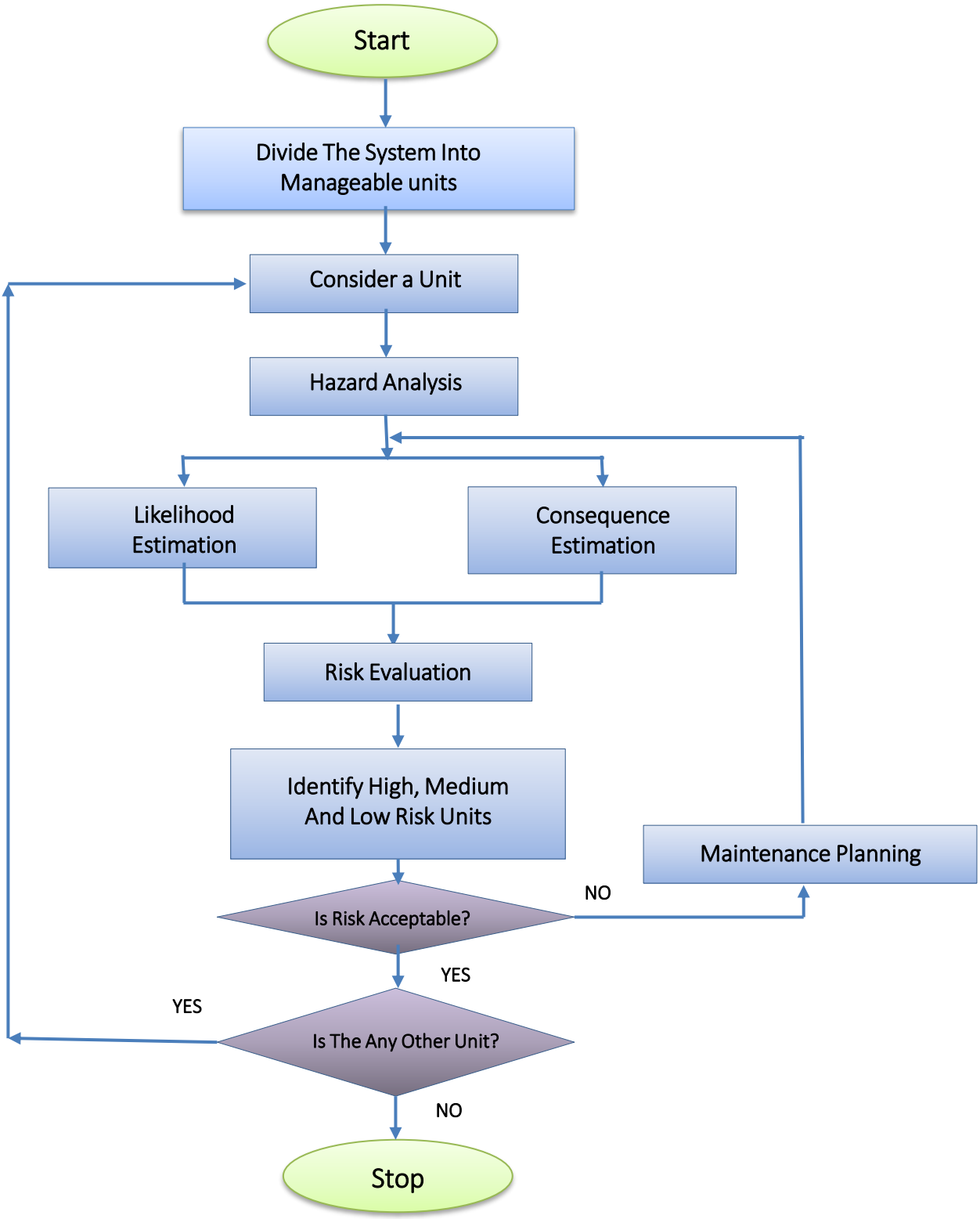


Figure 2.7.5 : RBM Flowchart

Structured Question

1. Define Proactive Maintenance
2. List 6 (SIX) Proactive Maintenance
3. Maintenance Strategies comparison among Breakdown, Preventive and Predictive
4. Brief Preventive Maintenance
5. Give advantage and disadvantage of corrective maintenance
6. Explain 3 advantages and 3 disadvantages of CBM
7. Explain Condition base Maintenance (CBM)
8. Name The 8 Pillars of Total Productive Maintenance (TPM)
9. Give 5 (FIVE) step how to implement Total Productive Maintenance (TPM)
10. State Comparison between Preventive Maintenance and Condition base Maintenance (CBM)

    in term of :

    a) Definition

    b) Cost

    c) Advantage

    d) Disadvantage

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