وما توفيقي إلا بالله

بسم الله الرحمن الرحيم

Global Maintenance Management – Level 1
(Maintenance Planning & Control)

High Level
Maintenance Strategy

Maintenance
Planner / Leader / Manager

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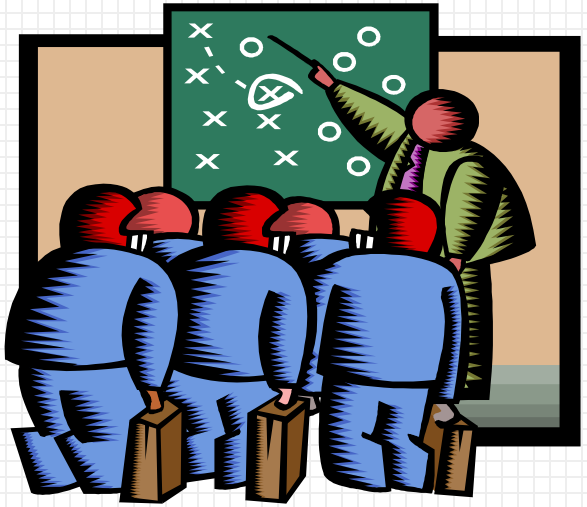
Global Maintenance Management – Level 1
(Maintenance Planning & Control)

Contents:

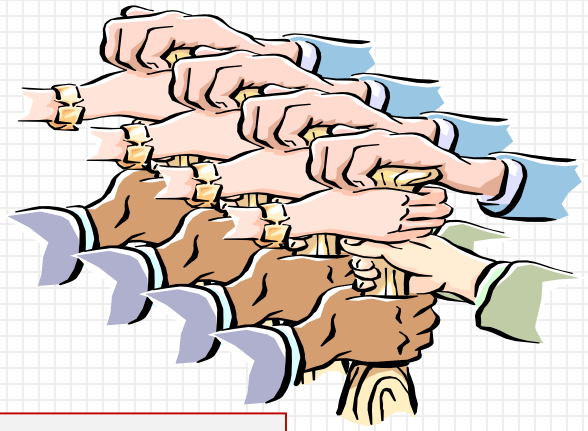
Rules of the Course



This is an Open Discussion Course:

- Share *Knowledge* – تبادل المعرفة
- Share *Experiences* – تبادل الخبرات
- Share *Best Practices* – تبادل التجارب الجيدة
- Share *Questions* – تبادل الأسئلة

Team Approach



Remember … You can't do it alone!

Let us be a teamwork.

Maintenance & Reliability Culture

Maintenance & Reliability Culture:

Core Objective:

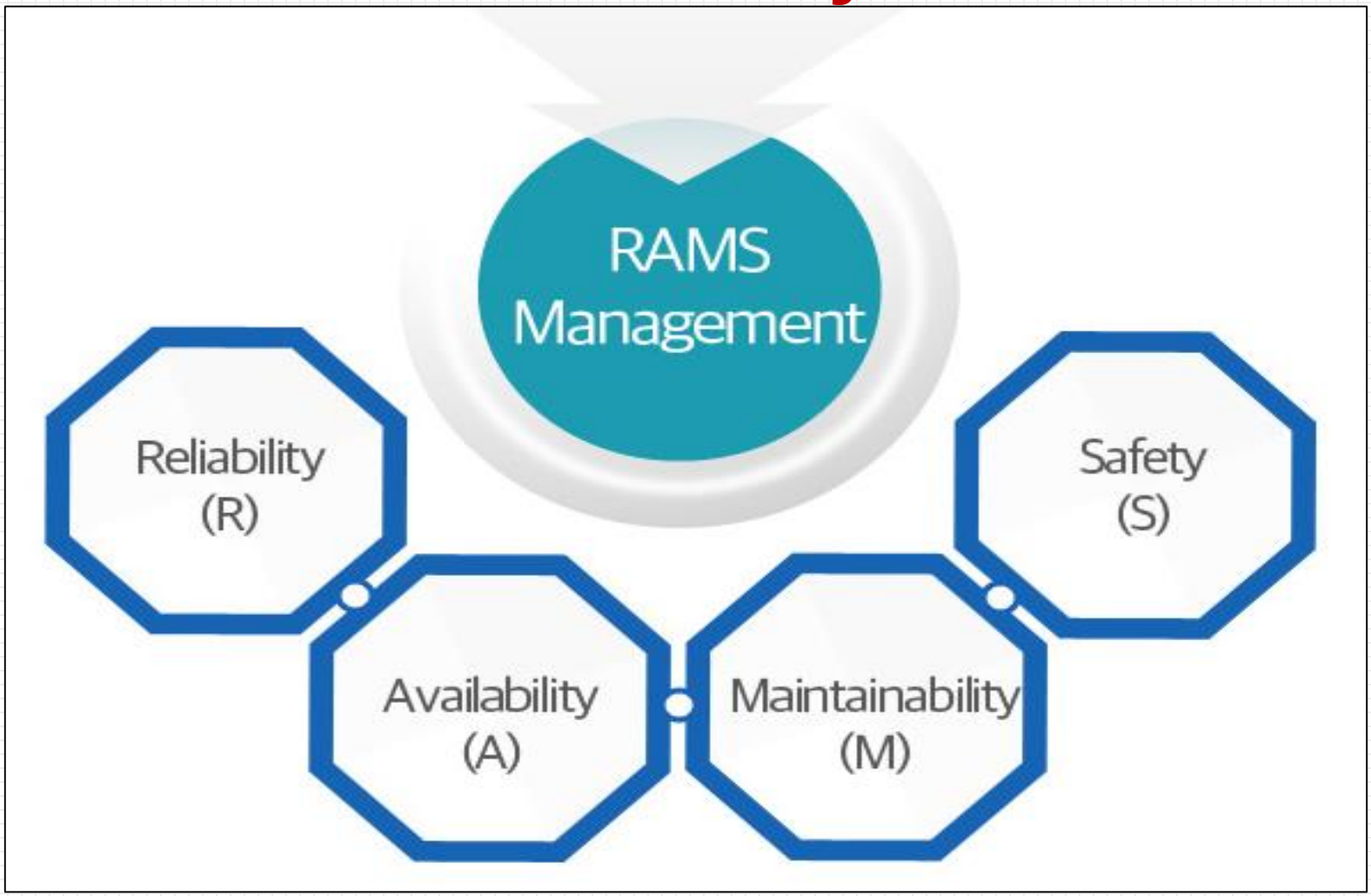
Improve System Reliability

(RAMS)

Improve Resource Productivity

(Spare Parts, Tools, Labors, ….)

RAMS Analysis



Maintenance & Reliability Culture: RAMS

Reliability is the probability of **zero failures** during standard time according to standard working conditions.

Reliability is Performance Over Time

Reliability is measured by **Mean Time Between Failure MTBF**

Availability is the probability of **zero downtime** during standard time according to standard working conditions.

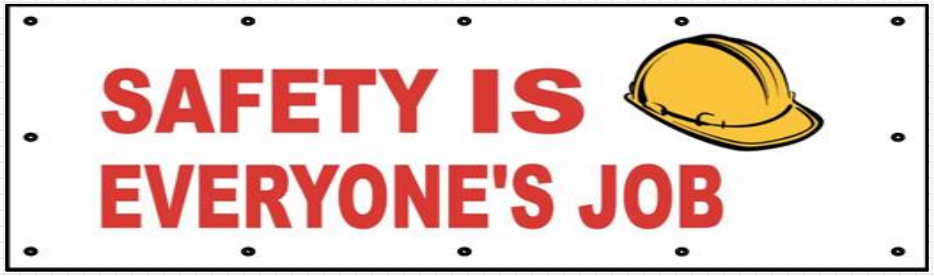
Availability = (Total Time – Total Downtime) / Total Time

Maintainability is the probability of **performing a maintenance** action during certain time.

Maintainability is measured by **Mean Time To Repair MTTR**

Safety:

Safety is No Accidents



Warning

> 30% of Accidents due to Maintenance for SCE

Maintenance & Reliability Culture:

Achieving a 99% level of Reliability means

accepting a 1% Failure

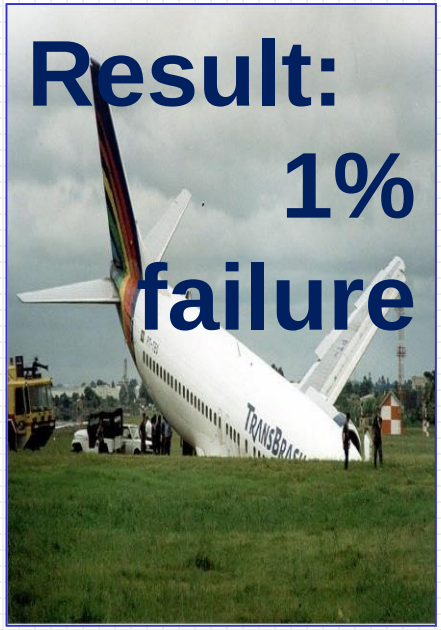
1% failure rate would mean **everyday**

- 14.4 minutes without water or electricity

  (0.01 * 24 hours/day * 60 minutes)

- Two bad landings at Cairo airport

  (0.01 * 200)



Maintenance & Reliability Culture:

To Improve Process Stability
Minimize Variance

Bearing Repair Time #1	8 Hours
Bearing Repair Time #2	4 Hour
Bearing Repair Time #3	16 Hours
Bearing Repair Time #4	Forecasting MTTR?

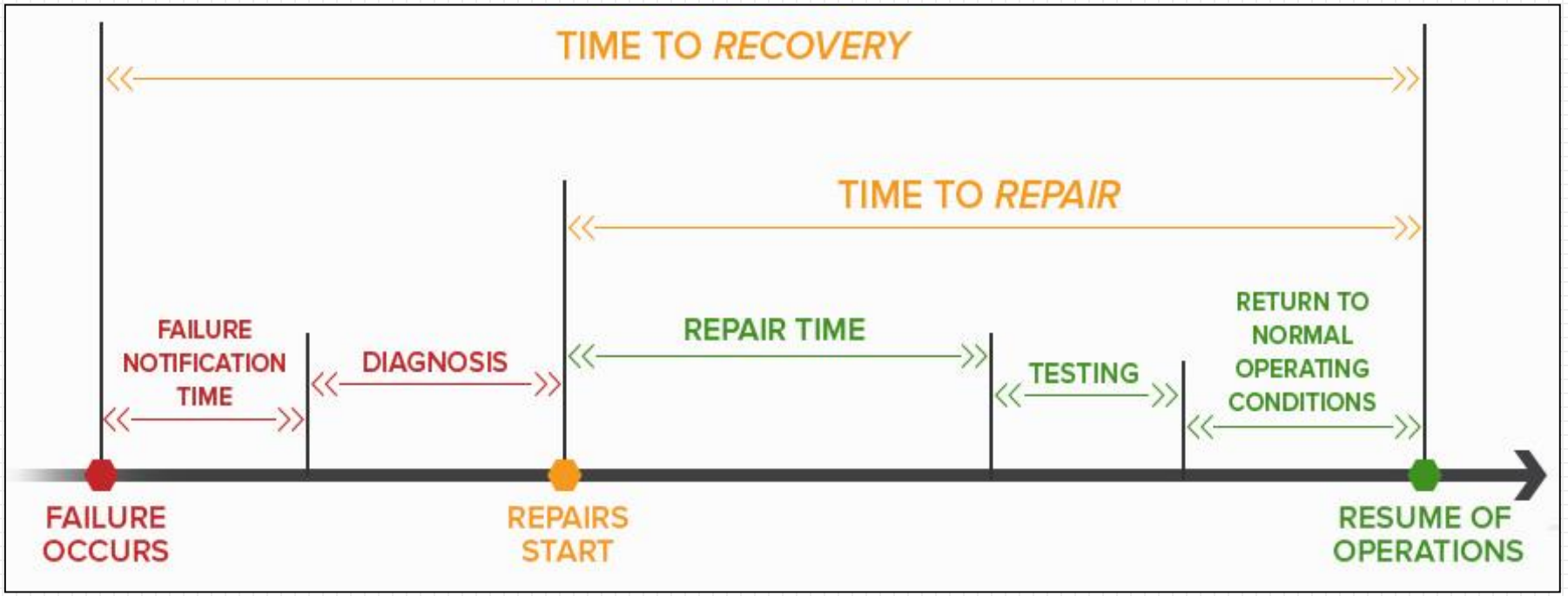
High Variance %

"Process Not Stable"

Maintenance & Reliability Culture:

What is the difference between:

1. **Maintenance Time**
2. **Repair Time**
3. **Logistic Time**
4. **Downtime**



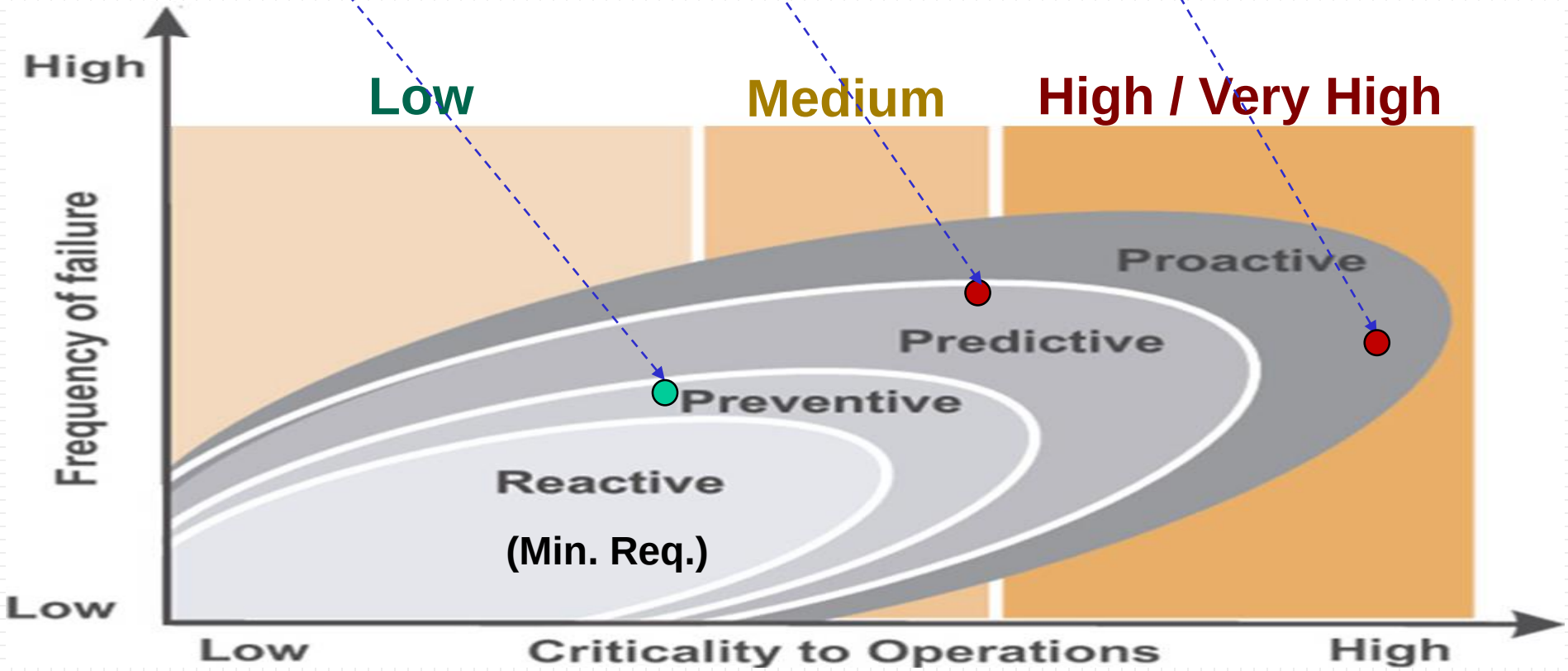
System Criticality Analysis

Element	High	Medium	Low
	Safety Critical Elements (SCE)	Process Critical Elements (PSE)	Non Critical Elements (NCE)
Car	Tires System	Cooling System	Lighting System
Pump Station	Fuel Pump	Water Pump Without Standby	Water Pump With Standby
HVAC System	Control Room	Process	Offices
Server	Banking System	Process	Training
UPS	Control Room	Process	Lighting System

System Criticality Analysis

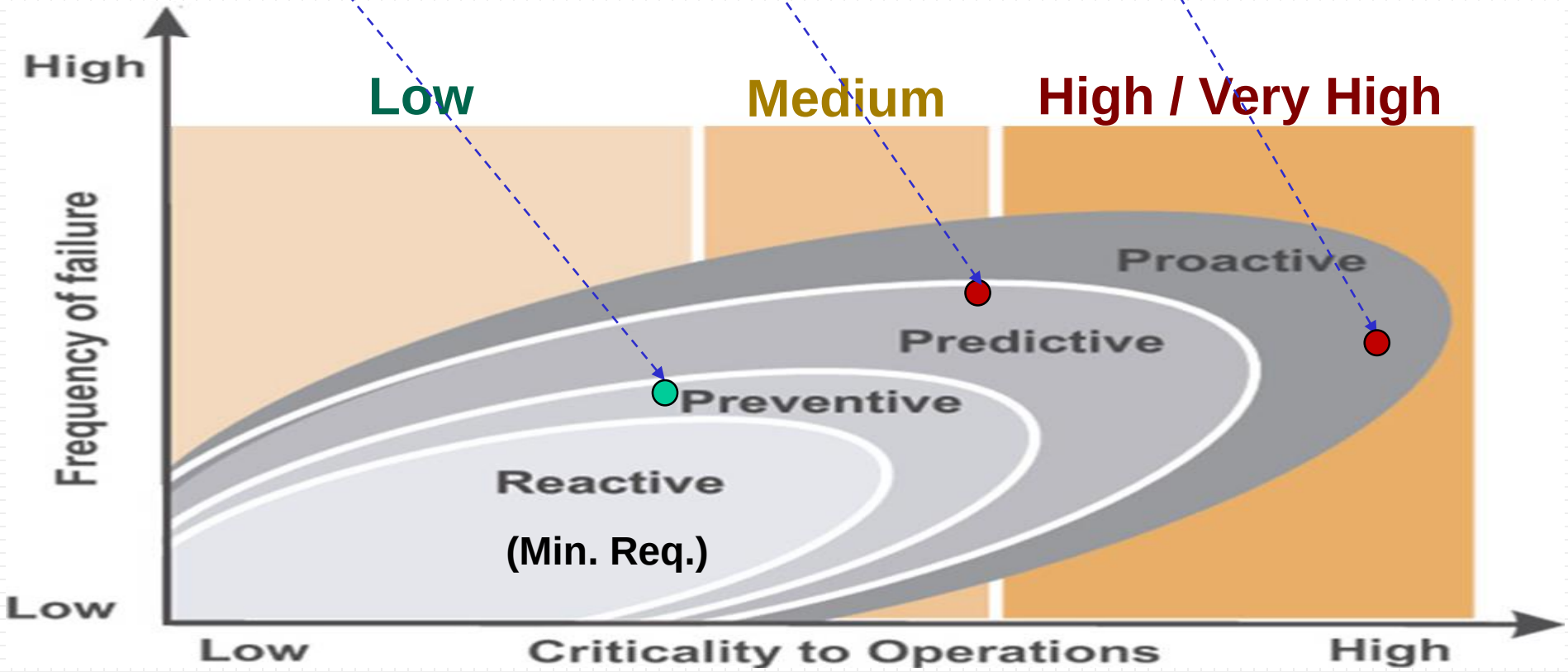
Low	Medium	High
Non Critical Elements (NCE)	Process Critical Elements (PSE)	Safety Critical Elements (SCE)

Refer to ISO 14224 / API 580 / API 581 / ….



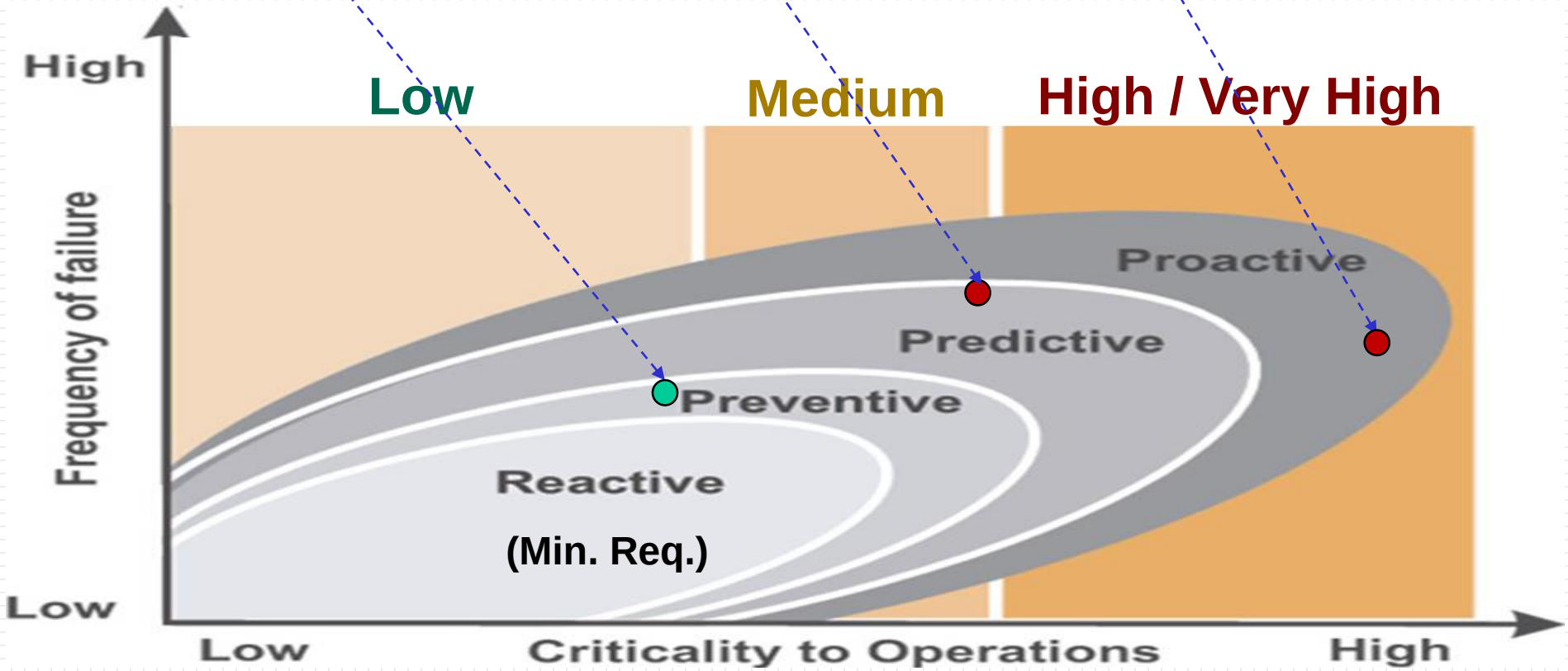
System Criticality Analysis

Low	Medium	High
Water Pump With Standby	Water Pump Without Standby	Fire Fighting Pump



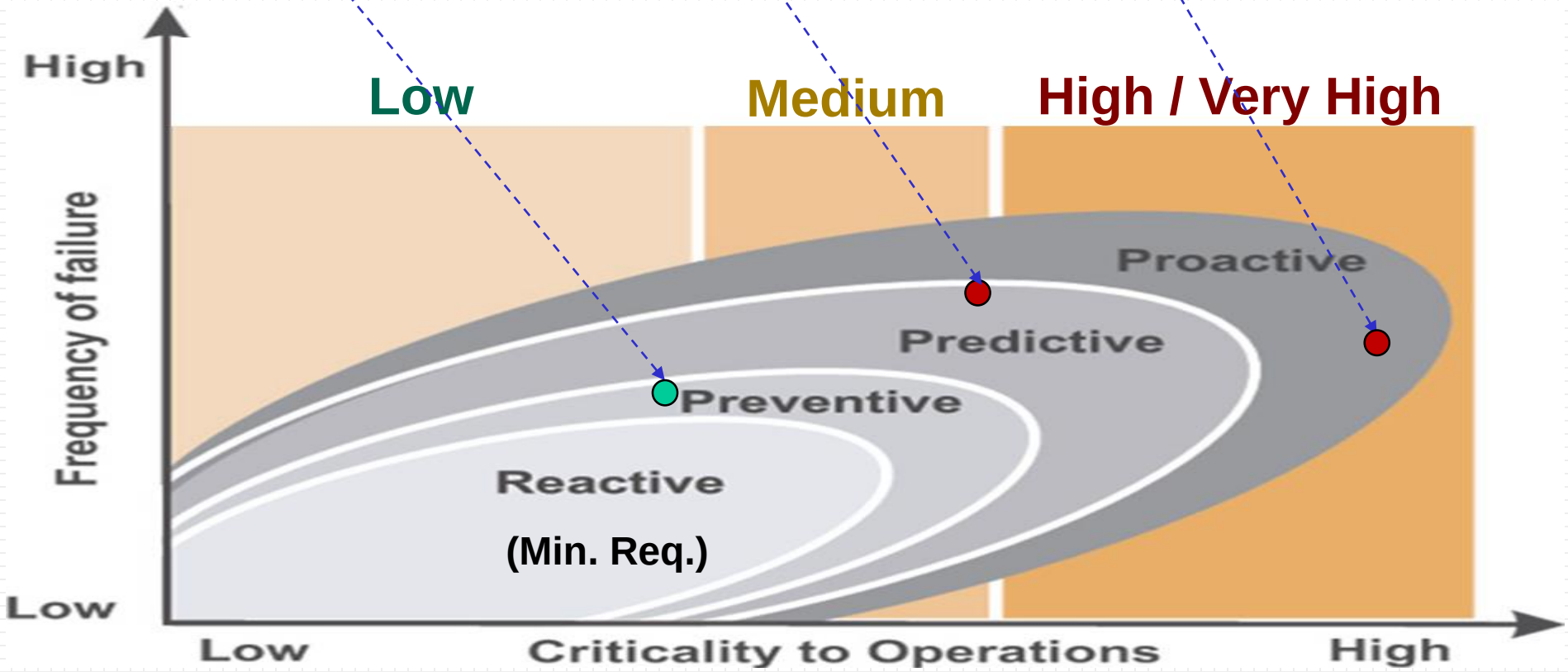
System Criticality Analysis

Low	Medium	High
HVAC in Office	HVAC in Process	HVAC in Control Room



System Criticality Analysis

Low	Medium	High
?	?	?



Root Causes of Pump Failures

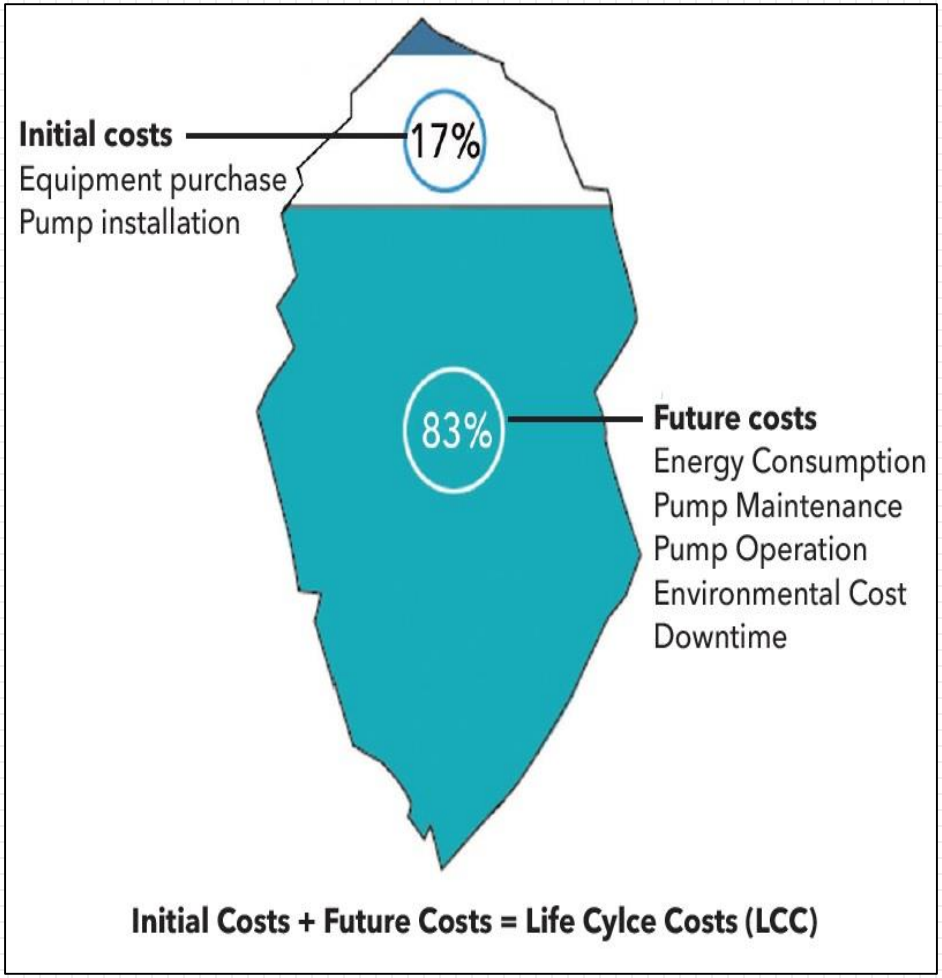
- Lack of maintenance (clean, check, Replace, ... etc.) > 30%
- Operating Conditions (flow rate, head, speed, … etc.) > 20%
- Human errors (not qualified, under stress, … etc.) > 10%
- Unsafe conditions (Near-miss) > 5%
- No Information (references, manuals, history, … etc.) > 5%

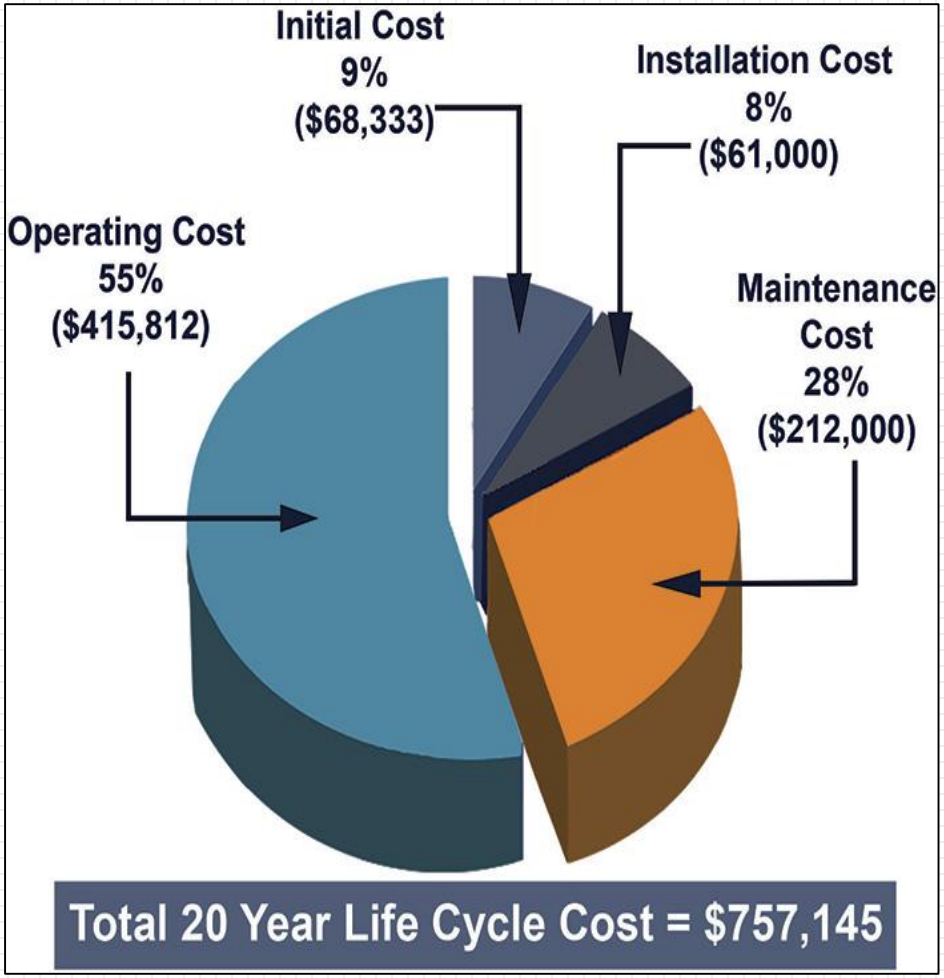
70% Maintenance Management

- Poor quality of spare parts (low cost, … etc.) >20%
- Poor design (selection, location, … etc.) >10%
- Others <10%

Maintenance & Reliability Culture:

Pump Life Cycle Cost Analysis; for example:





Maintenance Cost = (20% to 30%) from Life Cycle Cost

Maintenance & Reliability Culture:

Facility Level

Plant Level

System Level

Equipment Level

Component Level

Reliability Concept

KPIs for top management

Process: Petrochemical Industry

Improving Reliability through Culture Change

KPIs

Annual Information (2017):

Annual Standard Time	= 8760 hours/year
Performance Rate	= 15 ton/hour
Annual Production	= 100,000 ton

"Data Source"

(Process)
(Process)
(Process)

Operation Efficiency = ? %

KPIs for top management

Process: Petrochemical Industry

Improving Reliability through Culture Change

KPIs

Annual Information (2017):		"Data Source"
Annual Standard Time	= 8760 hours/year	(Process)
Performance Rate	= 15 ton/hour	(Process)
Annual Production	= 100,000 ton	(Process)
Unit Price Per ton	= 800 $/ton	(Market)
Planned Downtime	= 3 days/year	(Maintenance)
Unplanned Downtime	= 4 days/year	(Maintenance)
Direct Maintenance Cost	= 200,000 $	(Financial)

KPIs for top management

Process: Petrochemical Industry

Improving Reliability through Culture Change

KPIs

Annual Information (2017):

Annual Standard Time	= 8760 hr/year
Performance Rate	= 15 ton/hour
Annual Production	= 100,000 ton
Unit Price Per ton	= 800 $/ton
Planned Downtime	= 3 days/year
Unplanned Downtime	= 4 days/year
Direct Maintenance Cost	= 200,000 $

1) Process Downtime Losses
   = 7 * 24 * 15 = 2520 ton/week
   = 2520 * 800/2 = 1,008,000 $
2) S/D Cost = 200,000 / 1,008,000
   = 20% Downtime losses
3) Planned Ratio = 43 %

4) Operation Efficiency = 76 %
5) Process Availability = 98.1 %
6) Process Reliability = 98.9 %

KPIs for top management

Operation Efficiency =

Actual Capacity / Standard Capacity

Given:

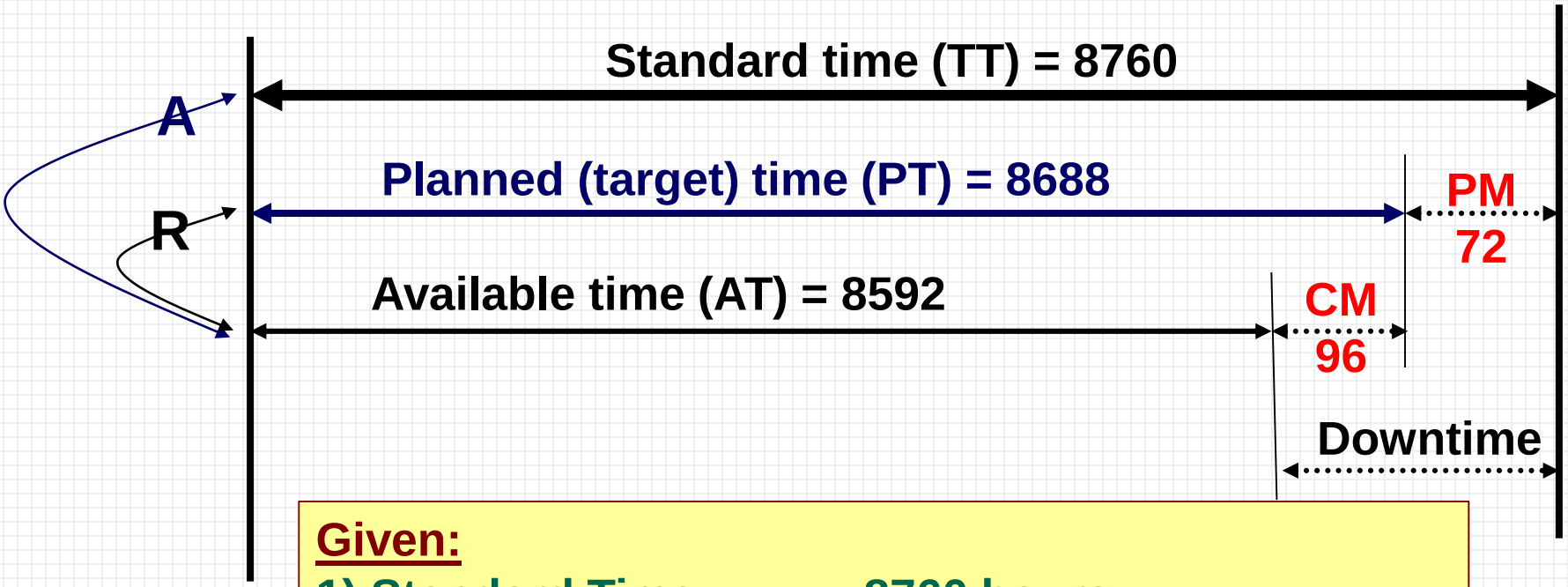
1) Standard Time = 8760 hours
2) Performance Rate = 15 ton/hour
3) Actual Capacity = 100,000 ton

Indicators:

Operation Efficiency = 76 %

Unused Capacity = 24%

Operational Availability & Reliability



Given:

1) Standard Time = 8760 hours
2) PM Downtime = 3 days = 72 hours
3) CM Downtime = 4 days = 96 hours

Indicators:

A = Availability = 98.1 % Downtime=1.9%
R = Reliability = 98.9 % Unplanned D.= 1.1%

KPIs for top management

Process: Cement Industry

Improving Reliability through Culture Change

KPIs

Annual Information (2017) :

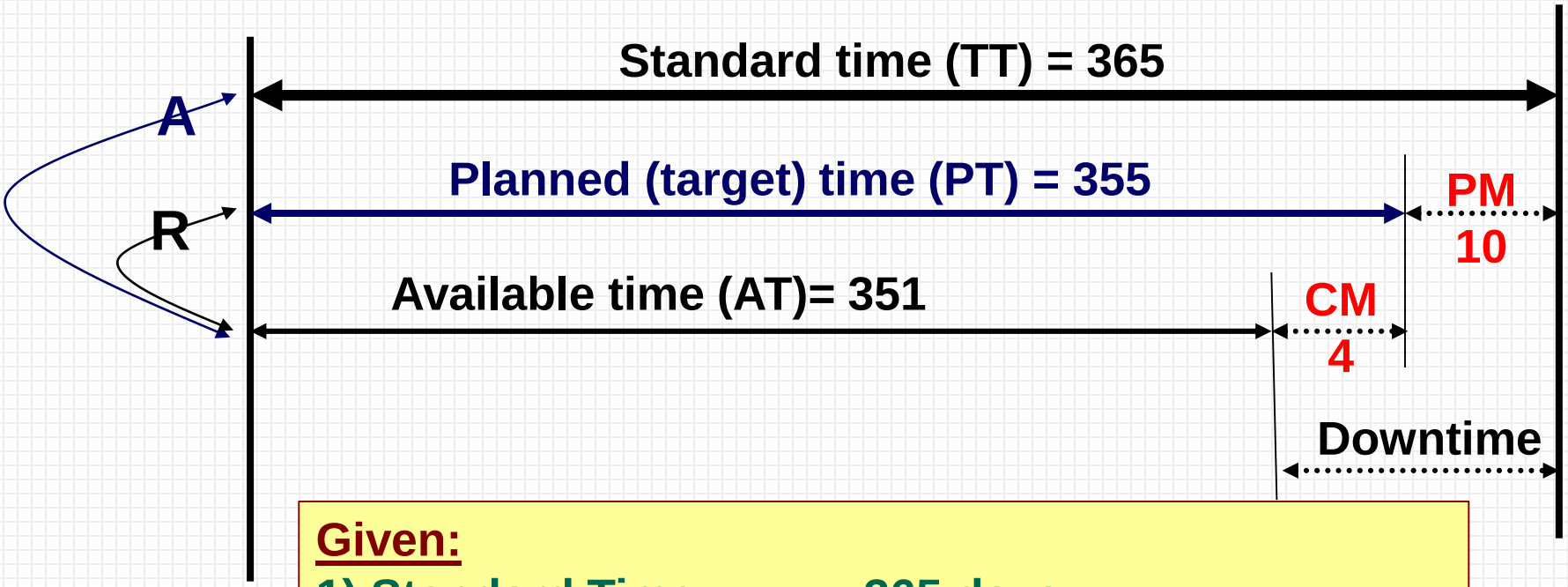
Annual Standard Time	= 8760 hr/year
Performance Rate	= 5,000 ton/day
Annual Production	= 1,500,000 ton
Unit Price Per ton	= 700 LE/ton
Planned Downtime	= 10 days/year
Unplanned Downtime	= 4 days/year
Direct Maintenance Cost	= 1,000,000 LE

1) Process Downtime Losses
= 14 * 5000 = 70,000 ton
=
2) S/D Cost =
=
3) Planned Ratio = 71.4%

4) Operation Efficiency = 82.2%
5) Process Availability = 96.2%
6) Process Reliability = 98.9%

KPIs for top management

Operational Availability & Reliability



Given:

1) Standard Time = 365 days
2) PM Downtime = 10 days
3) CM Downtime = 4 days

Indicators:

A = Availability = 96.2 %
R = Reliability = 98.9 %

Downtime=3.8%
Unplanned D.=1.1%

KPIs for top management

Process: Steel Furnace

Improving Reliability through Culture Change

KPIs

Annual Information (2017):

Annual Standard Time	= 8760 hr/year
Performance Rate	= 140 ton/hour
Annual Production	= 1,500,000 ton
Unit Price Per ton	= 10,000 LE/ton
Planned Downtime	= 12 day/year
Unplanned Downtime	= 2 day/year
Direct Maintenance Cost	= 12,000,000 LE

1) Process Downtime Losses
   =
   =
2) S/D Cost =
   = --- % Downtime losses
3) Planned Ratio = --- %

4) Operation Efficiency = --- %
5) Process Availability = --- %
6) Process Reliability = --- %

KPIs for top management

Process: مصنع تجميع ثلاجة

Improving Reliability through Culture Change

KPIs

Month Information (2017):

Annual Standard Time	= 624 hr/month
Performance Rate	= 90 units/hour
Annual Production	= 35,000 ton
Unit Price Per ton	= 10,000 LE/unit
Planned Downtime	= 78 hours/month
Unplanned Downtime	= 10 hours/month
Direct Maintenance Cost	= 200,000 LE

1) Process Downtime Losses
   =
   =
2) S/D Cost =
   = --- % Downtime losses
3) Planned Ratio = --- %

4) Operation Efficiency = --- %
5) Process Availability = --- %
6) Process Reliability = --- %

coffee break

Maintenance & Reliability Culture:

Vidoe

Common Maintenance Strategy (CMS)

Strategy is a systematic method to achieve a certain objective

Strategy is a high level plan to achieve one or more goals

Your success as a manager depends on making a common strategy to be aware with everything on the organization like a standard strategy for each department.

Five steps in the Common Maintenance Strategy (CMS):

1- Optimum Maintenance Strategy
2- Planning and Scheduling
3- Optimize Resource Levels (Critical Resources)
4- Key Performance Indicators (KPIs)
5- Benchmarking (Internal / External)

Six important elements to the CMS:

1- Leadership & Organization Structure
2- Facility Availability
3- Work Management
4- Materials Management
5- Change Management (Proactive)
6- Continuous Improvement

Terms To Understand

1. Quality & Reliability
2. Availability & Maintainability
3. Maintenance Insurance
4. Cost Effective
5. Maintenance Cost 25% Operation cost
6. Optimize (continuous improvement)
7. Planning & Schedule
8. Planning (What , When , How)
9. Critical Failure
10. Risk (Safety, Financial)
11. Facility Availability
12. Equipment Reliability
13. Mechanical Integrity
14. Sharing Information & Experience
15. Proactive & Reactive
16. Inventory Analysis
17. KPIs (Key Performance Indicators)
18. Benchmarking (Internal / External)
19. Operation efficiency%
20. Critical Equipment Reliability %
21. Planned v Unplanned 95%
22. Facility Availability%
23. Spare Parts Inventory Control
24. Insurance / consumable
25. Safety Stock (min. stock level)
26. Insurance Stock (Strategic for SCE)
27. OEE (Overall Equipment Effectiveness)
28. …. etc.

Maintenance Management - Key Objective:

Improve Maintenance Quality (RAMS) at Low Cost

Improve Reliability	Improve Availability	Improve Maintainability	Improve Safety	Improve Res. Productivity
Improve MTBF	Minimize Downtime	Minimize MTTR	Minimize Overdue SCE	Improve Labor Productivity

To Improve Mean Time Between Failure:

1) Criticality Analysis (SCE / PCE / NCE)
2) Critical Equipment / Parts / Failures
3) Root Cause Failure Analysis (RCFA)
4) Failure Mode Effect Analysis (FMEA)
5) Reliability Analysis & Improvement
6) Condition Based Maintenance

To Minimize Mean Time to Repair:

7) Troubleshooting (Failure List)
8) Maintenance Shutdown Planning
9) Spare Parts Analysis & Control
10) Common Maintenance Strategy
11) Total Productive Maintenance
12) Maintenance Motivation Programs

1) Critical Equipment

2) Maintenance Programs

3) Work Orders (PM & CM)

4) Feedback & RCFA

5) KPIs Report

6) Improve RAMS at Low Cost

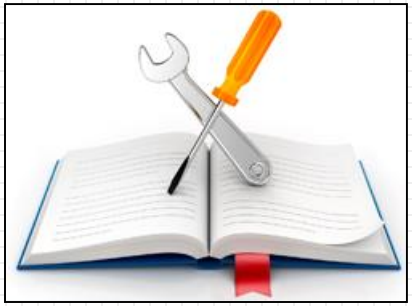
7) Gap Analysis

8) Improvement Recommendations

Maintenance Types & Policies

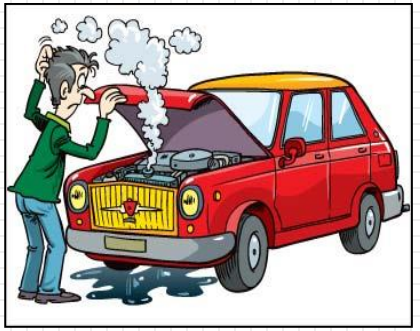
Maintenance

All activities involved in keeping a system in working order



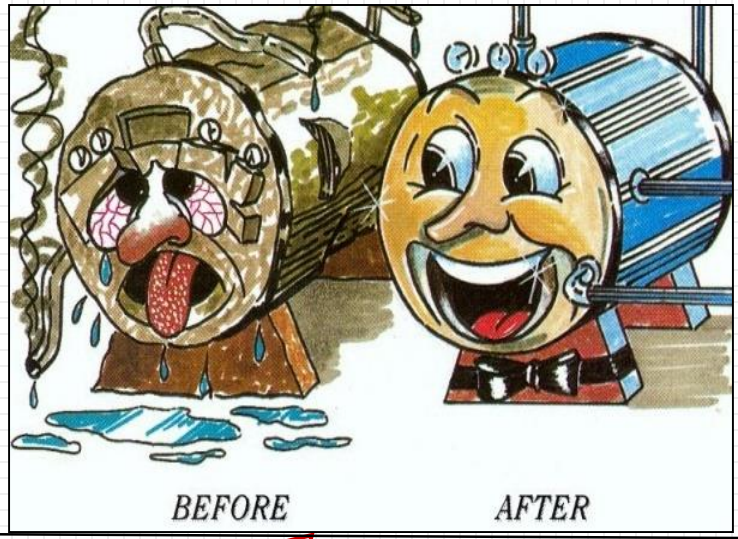
- **Preventive Maintenance (Planned Maintenance)**

  A plan that involves routine inspections, servicing, and keeping facilities in good repair to prevent failure



- **Breakdown Maintenance (Unplanned Maintenance)**

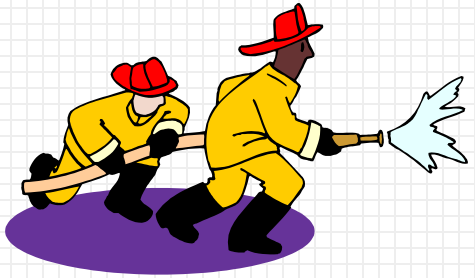
  Remedial maintenance that occurs when equipment fails and must be repaired on an emergency or priority basis



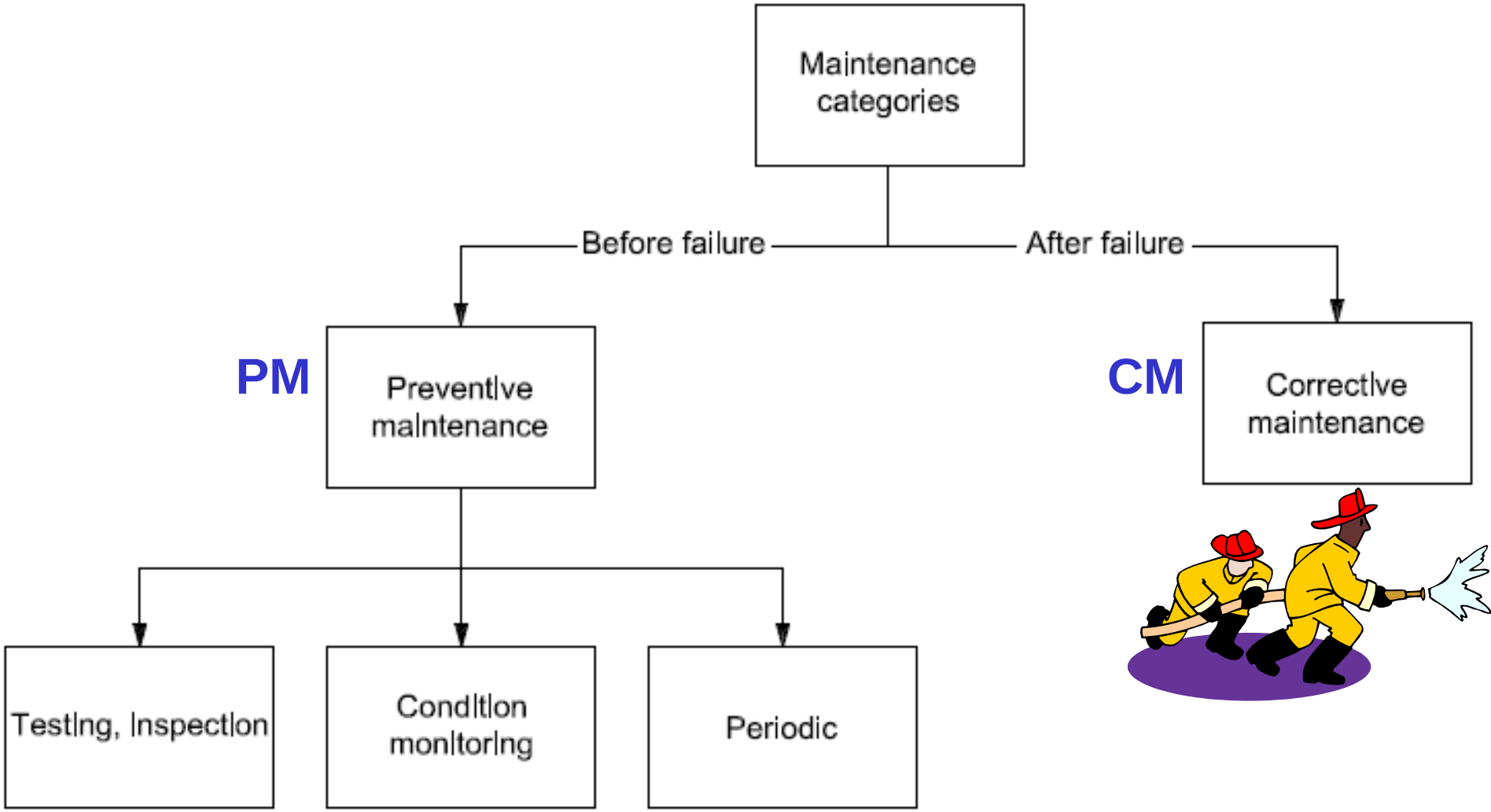
TYPES OF MAINTENANCE

British Standard (3811:1993) classified maintenance types as the followings:

- **MAINTENANCE**
  - **Planned Maintenance** (What? When? How?)
    - **Preventive Maintenance**
      - **Time-based Maintenance**
      - **Condition-based Maintenance**
    - **Planned Corrective (Planned CM)**
  - **Unplanned Maintenance**
    - **Unplanned Corrective (emergency Maintenance)**
      - **Breakdown**



Refer to (ISO 14224:2016):



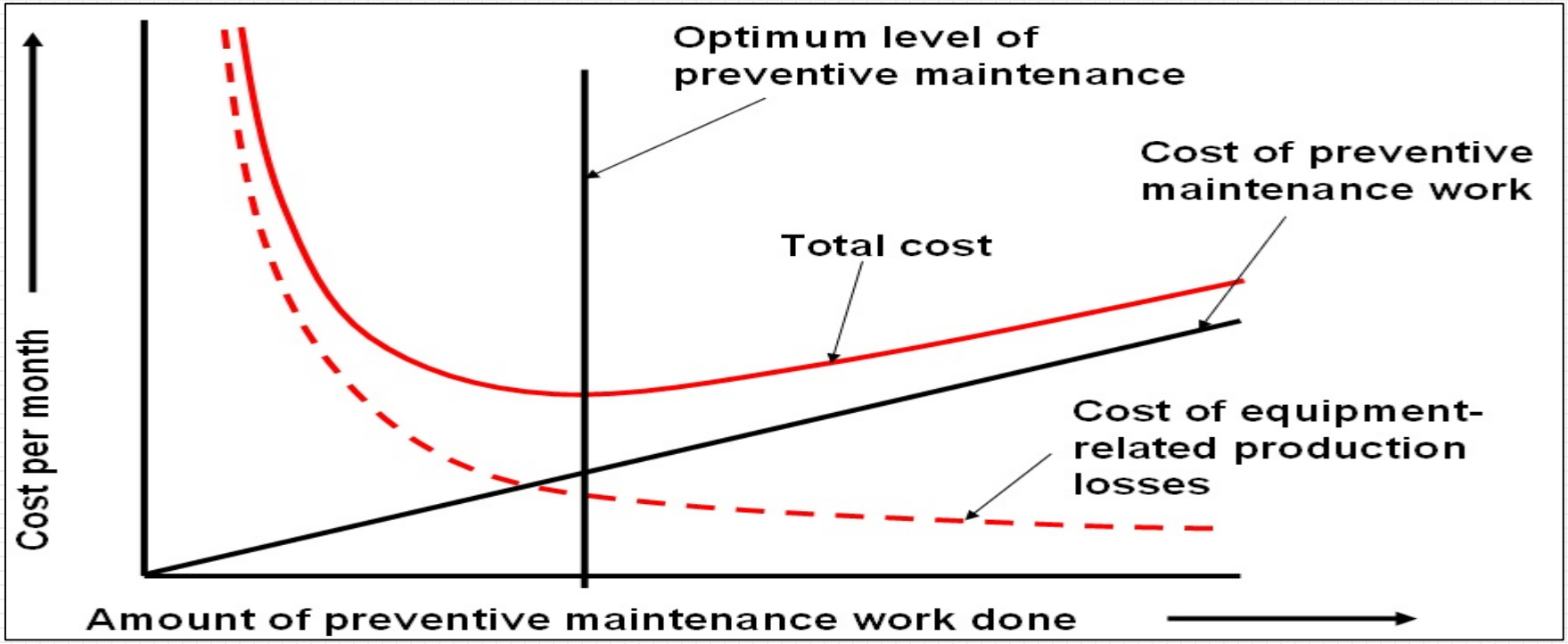
Maintenance Policy?

Maintenance / Failure Cost Analysis

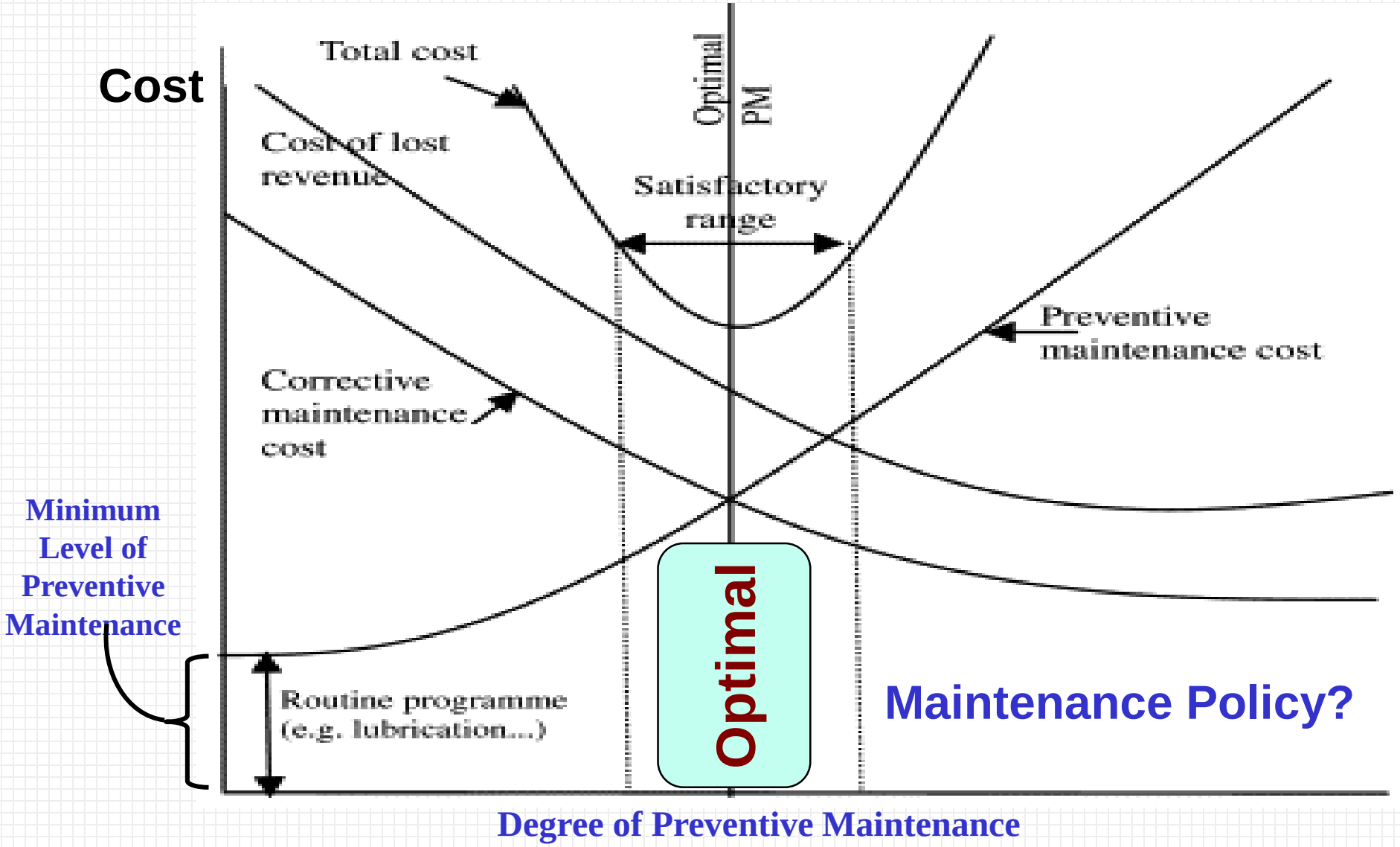
Direct costs
- Material
- Manpower
- Tools

Overhead costs
- Technical o/h
- Office o/h

Downtime losses
- Process Losses
- Quality Losses
- Safety Losses



Tradeoff Between Repairs and PM



Preventive Maintenance Tasks: *S, L, OC, HT, FF*

- **S (Servicing Task) - Replenishment of consumable materials depleted during normal operations**
- **L (Lubrication Task) - Replacement of a lubricant based on manufacturer's predicted or measured life of the lubricant**
- **OC (On Condition Task) - Periodic or continuous inspection designed to detect a potential failure condition prior to functional failure**
- **HT (Hard Time Task) - Scheduled removal of an item or a restorative action at some specified age limit to prevent its functional failure**
- **FF (Failure Finding Task) - A preventive maintenance task performed at a specified interval to determine whether a hidden functional failure has occurred.**

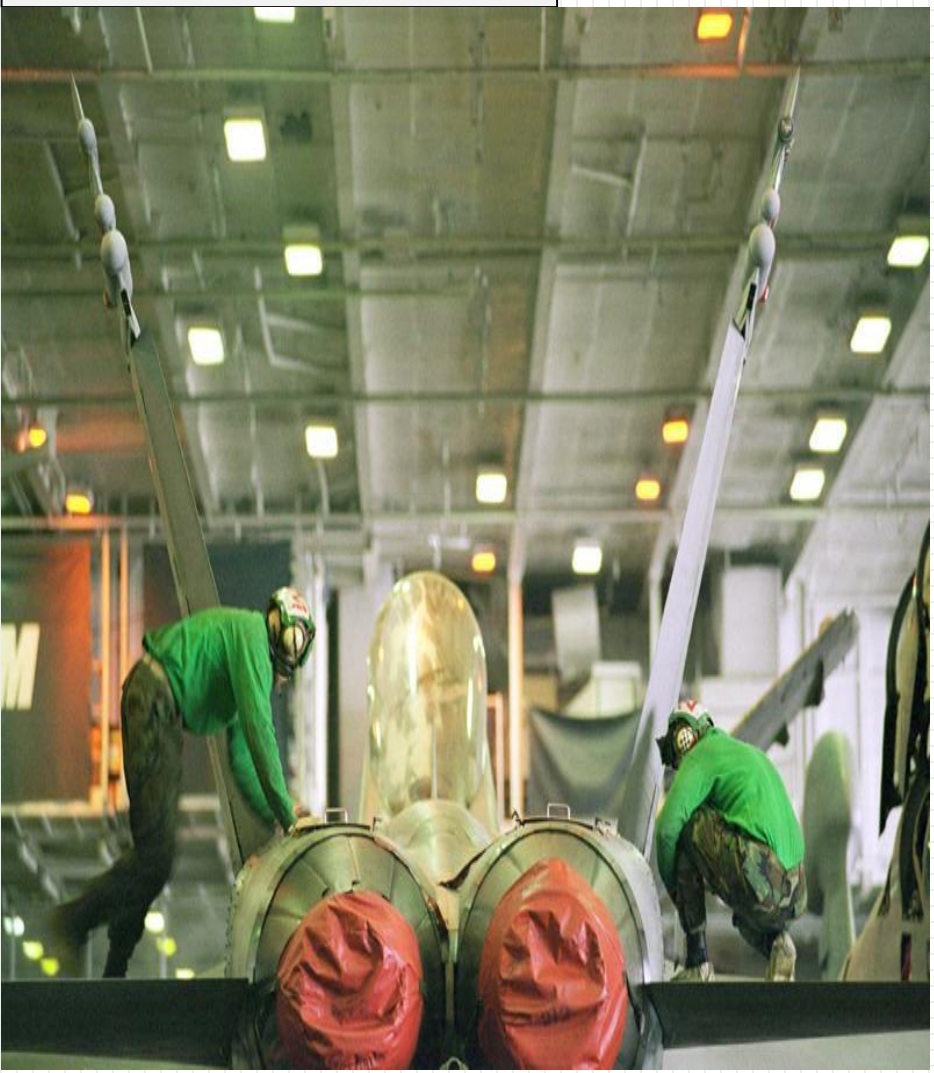
Servicing:

The replenishment of consumable materials that are depleted during normal operations

Lubrication:

The scheduled lubrication of a component (usually based on the manufacture's recommendations) where the item's design requires a non-permanent lubricant for proper operation

On-Condition



Periodic or continuous inspection designed to detect a potential failure condition prior to functional failure

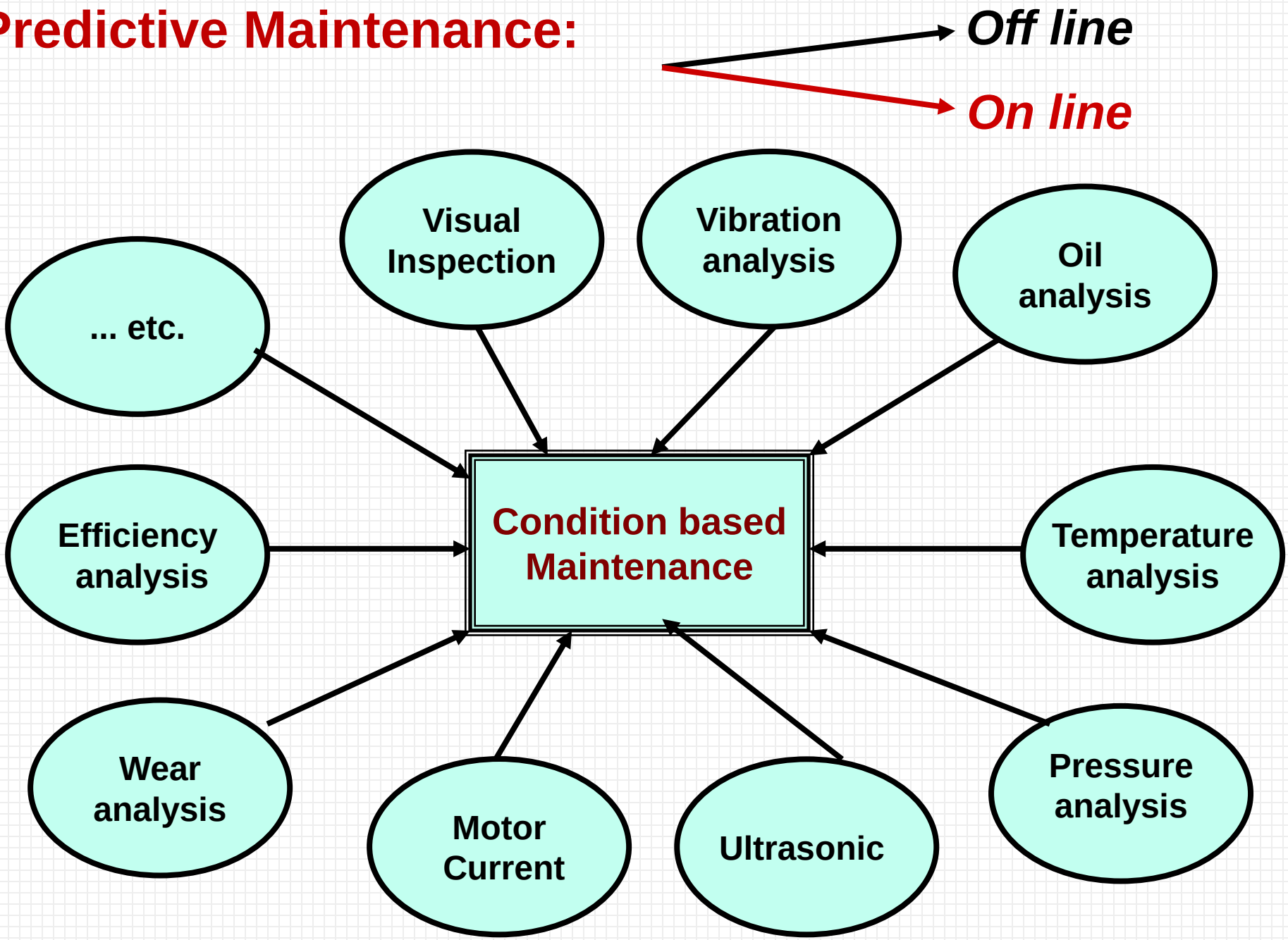
Hard Time Task:

Scheduled removal of an item or a restorative action at some specified age limit to prevent its functional failure

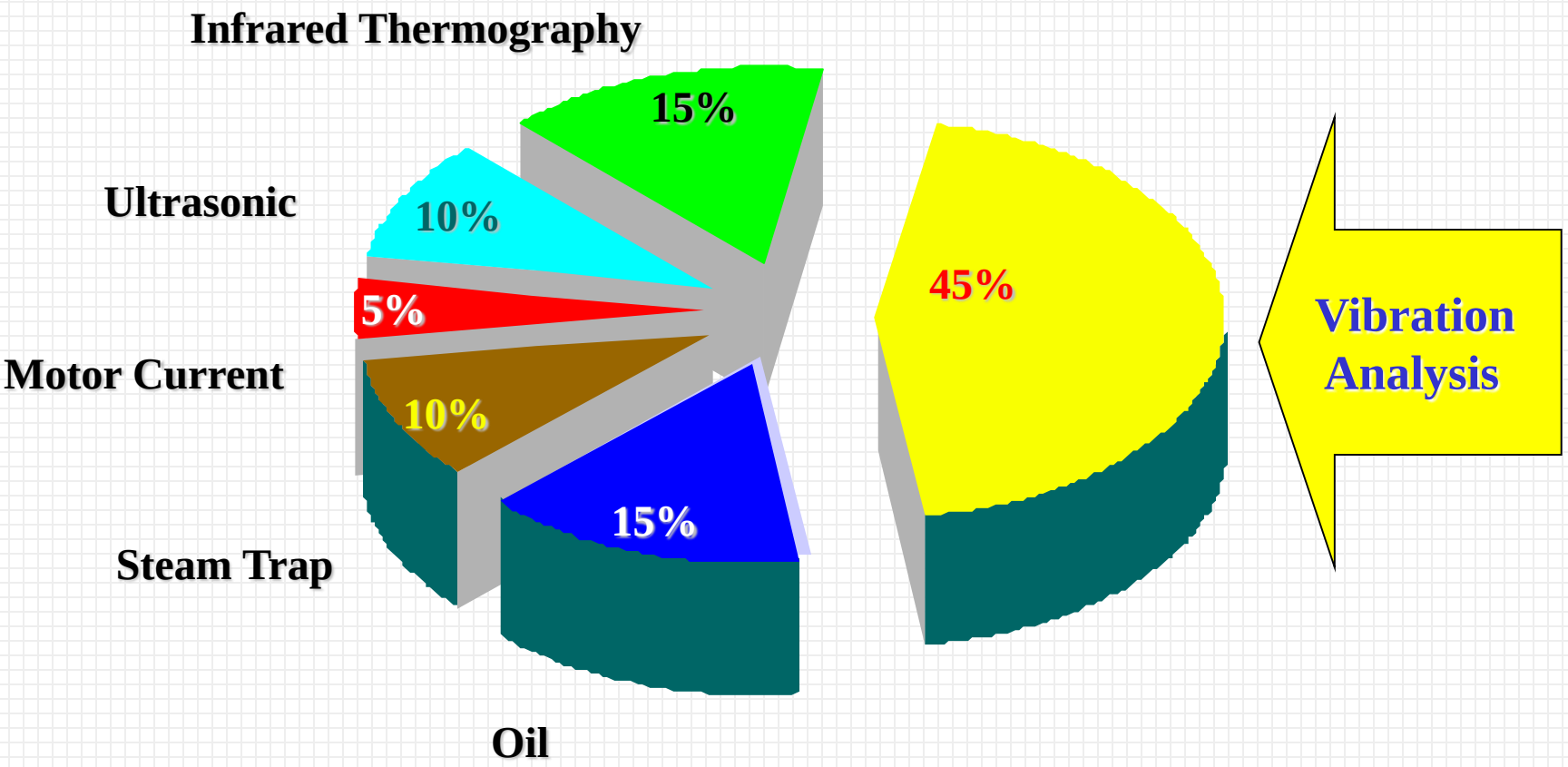
Failure Finding (special tools):

A preventive maintenance task performed at a specified interval to determine whether a hidden functional failure has occurred

Predictive Maintenance:



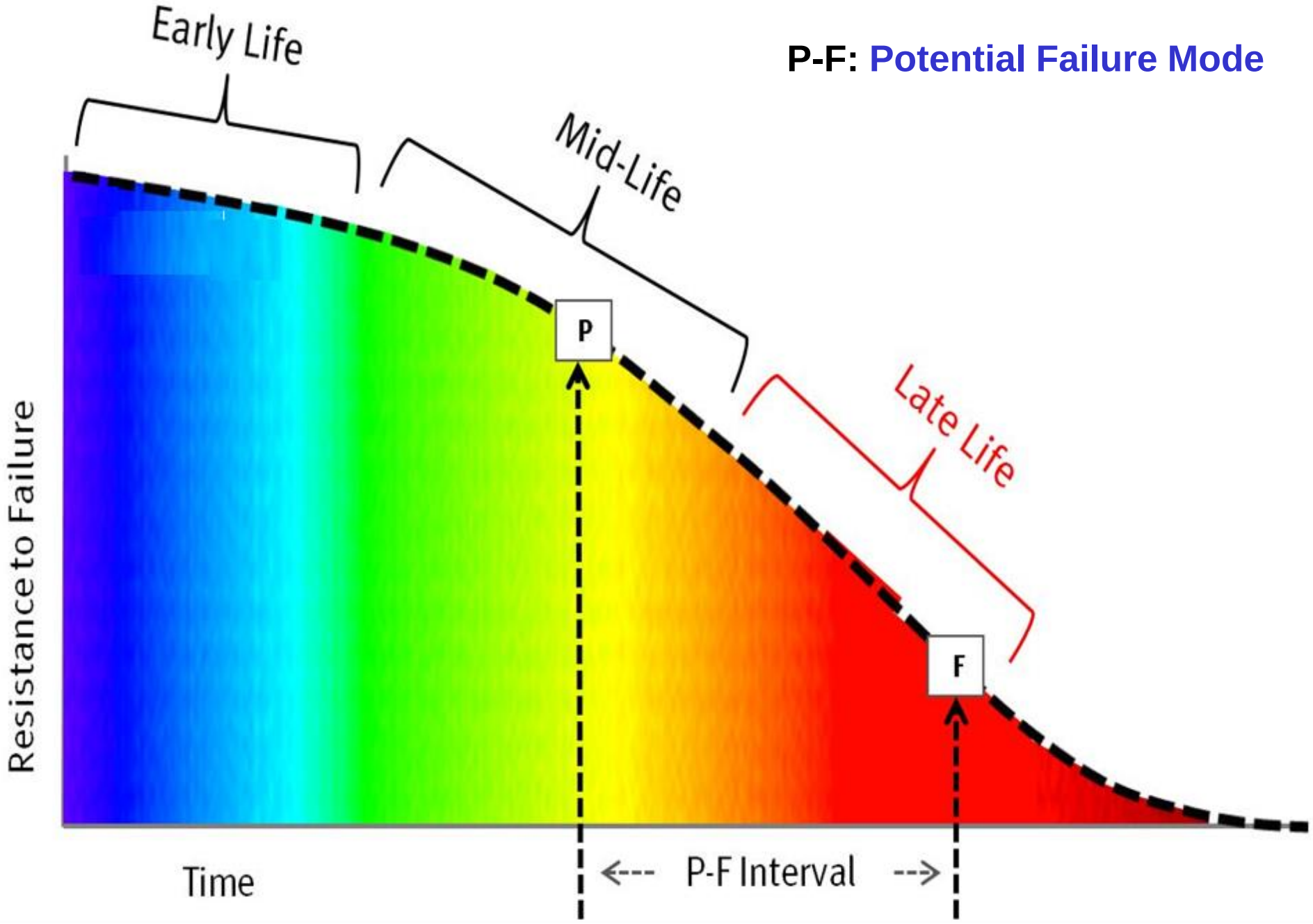
Which Technology offers the best return?



Of all the various maintenance technologies, Vibration Analysis provides the greatest percentage of payback when adopting a predictive maintenance program

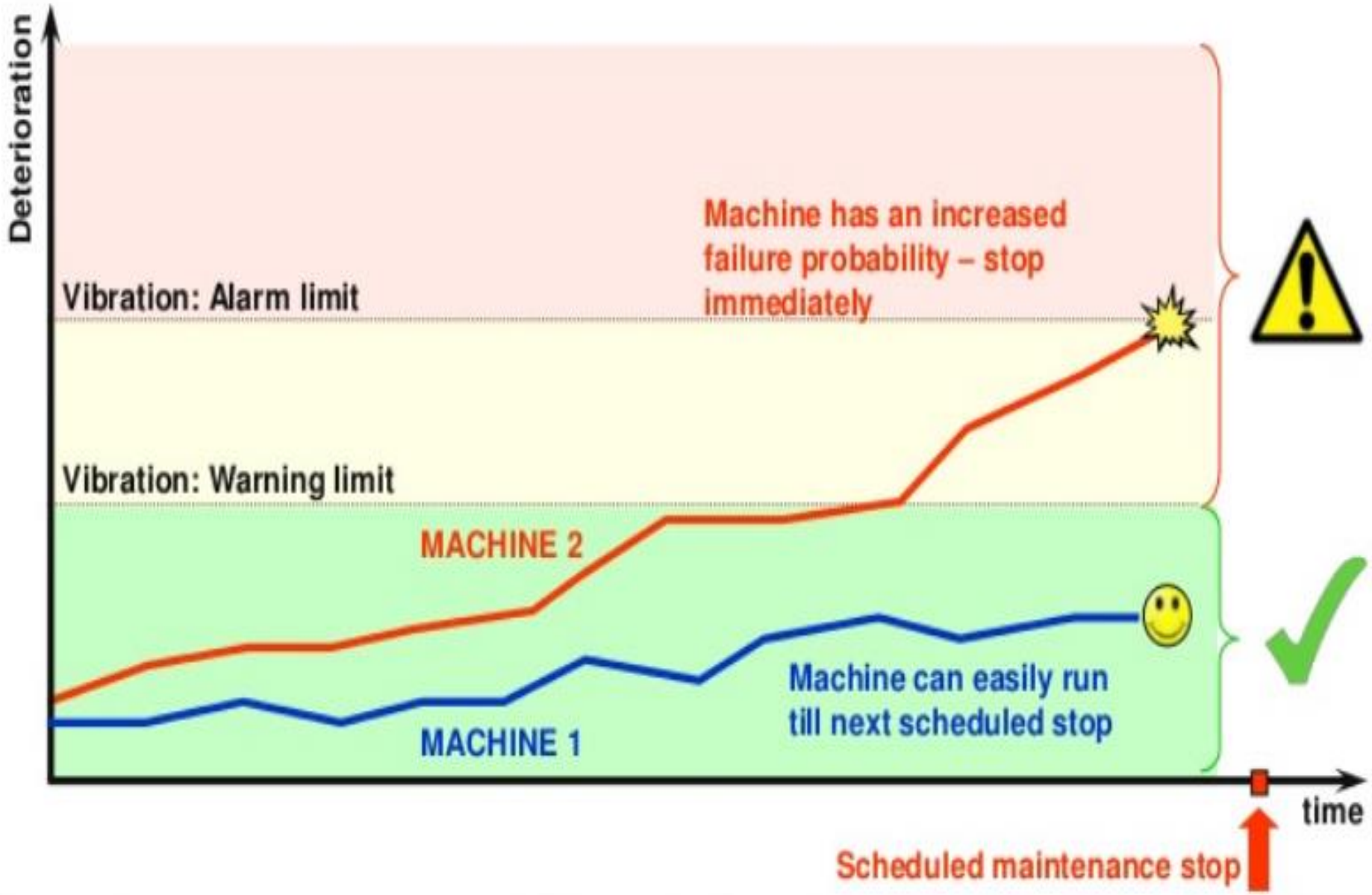
Predictive Maintenance

P-F: Potential Failure Mode




Collected data is stored on a software platform (database), analyzed and printed into reports
Machine (pump)
VIBXpert® II instrument
Manual data collection with portable instrument on a large number of machines
Measurement sensors attached to machines via magnetic bases

Failure Analysis Concept: (Failure & Failure Mode)



Failure Analysis Concept: (Failure & Failure Mode)

Failure Mode: High Temperature > 80 ° C

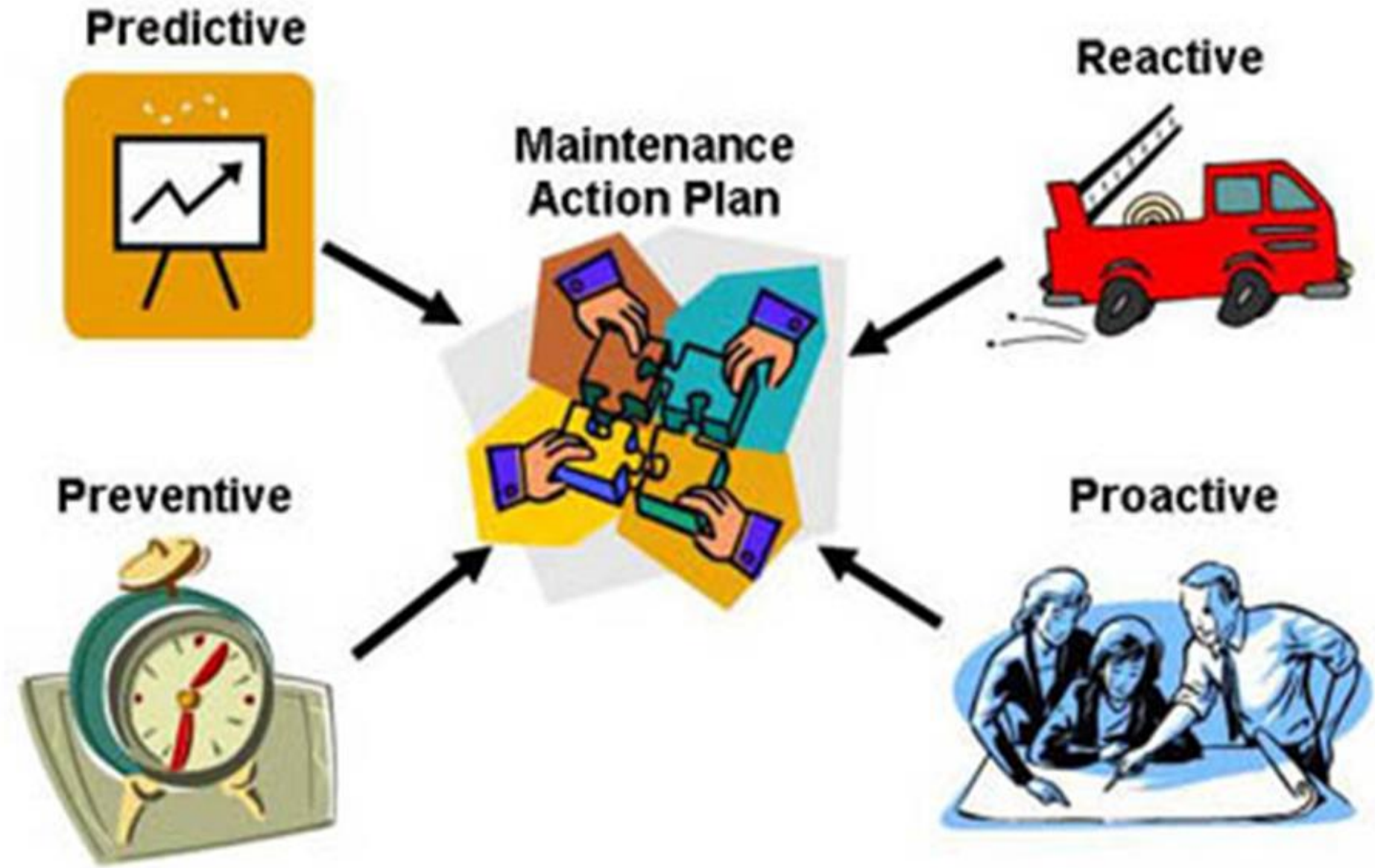
70 80 90 100

P-F: Potential Failure Mode

P-F: Potential Failure

Good Conditions	Early Failure	Hidden Failure	Risk Failure
Normal	Failure Mode	Failure Mode	Engine Failure
PM W/O	Call for Service	Call for Repair	B/d Emergency
Planned Maintenance	Planned CM	Planned CM	Unplanned CM
Evaluation: A	B	C	D

Maintenance Policy?



Road Map for Maintenance Policies

What? When? How?

Unplanned Maintenance

Planned Maintenance

Current Maintenance Program

Continuous Improvement

(1) Failure-Based
Reactive (ReM):
- RTF
- CM
- BD
::

(2) Time-Based
Preventive (PM):
- Calendar:
  - Weekly
  - Monthly
  ::
- Running:
  - 1000 Hours
  - 10000 Km
  ::

Uniform ± 10%

(3) Condition-Based
Predictive (PdM):
- Oil analysis
- Vibration analysis
- Temperature analysis
- Pressure analysis
- Wear analysis
- Color analysis
- Efficiency analysis
::

Most Effective Parameters

(4) Risk-Based

Proactive (PaM):

(Continuous Improvement)

1- Criticality Analysis

2- Failure Analysis:

-Trouble Shooting

- RCFA (Why-Why?)

- FMEA (What If Analysis?)

- Reliability Analysis

3- Update Maintenance Program

International Standards:
- RBM / RCM
- RBI / RBT

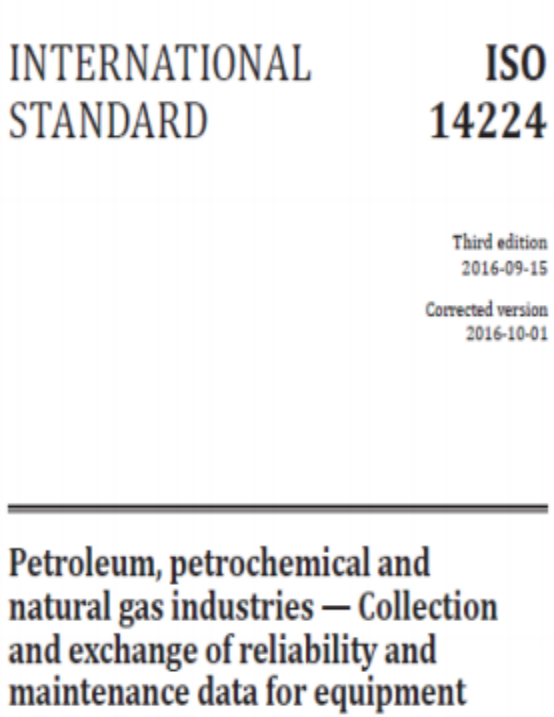
Common Strategy

Long Term Continuous Improvement (Improve RAMS at Low Cost ➔ KPIs)

ISO 14224:2016

"Collection and exchange of reliability and maintenance data for equipment"

- *Scope*
  - Standardized data format to facilitate exchange reliability and maintenance (RM) data between operator and owner, etc.
  - Provide key definitions
  - Basis for communicating equipment experience **«reliability esperanto»**
  - Normative terminology e.g.
    - **Failure modes (per equipment class)**
    - **Failure mechanism and failure cause (generic across all equipment classes)**
  - **Key Performance Indicators (KPI)**
  - Applicable for all type of oil & gas facilities and operation, and all phases.
  - Guidance for analysis of reliability and maintenance data



Important standard also with respect to digitalization and LCI.

CEN version approved July 2016: EN ISO 14224
(Per April 2018: Adopted by 37 CEN-member countries)
e.g. adopted in Norway as Norwegian standard 1 Jan 2017: NS-EN ISO 14224:2016
Edition 2 was adopted in USA as ANSI/API Std 689 in July 2007. Ed. 3 pending?

Maintenance Leaders / Managers

Leadership

is the ability to move teamwork towards certain objectives

القيادة هي القدرة نحو تحريك وتحفيز فريق العمل باتجاه أهداف محددة

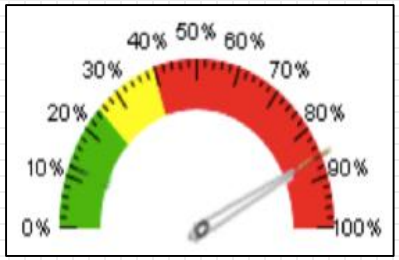
Leadership
عناصر القيادة

1) Objectives
تحديد واضح للأهداف

2) Teamwork
بناء وتطوير فريق العمل

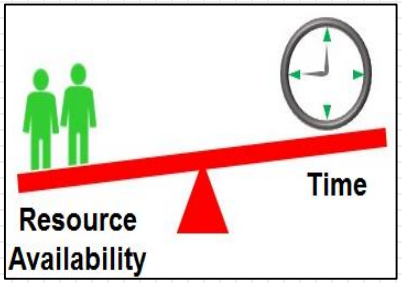
3) Motivation
أسلوب تحفيز مناسب

Maintenance Leader Skills



Management Skills

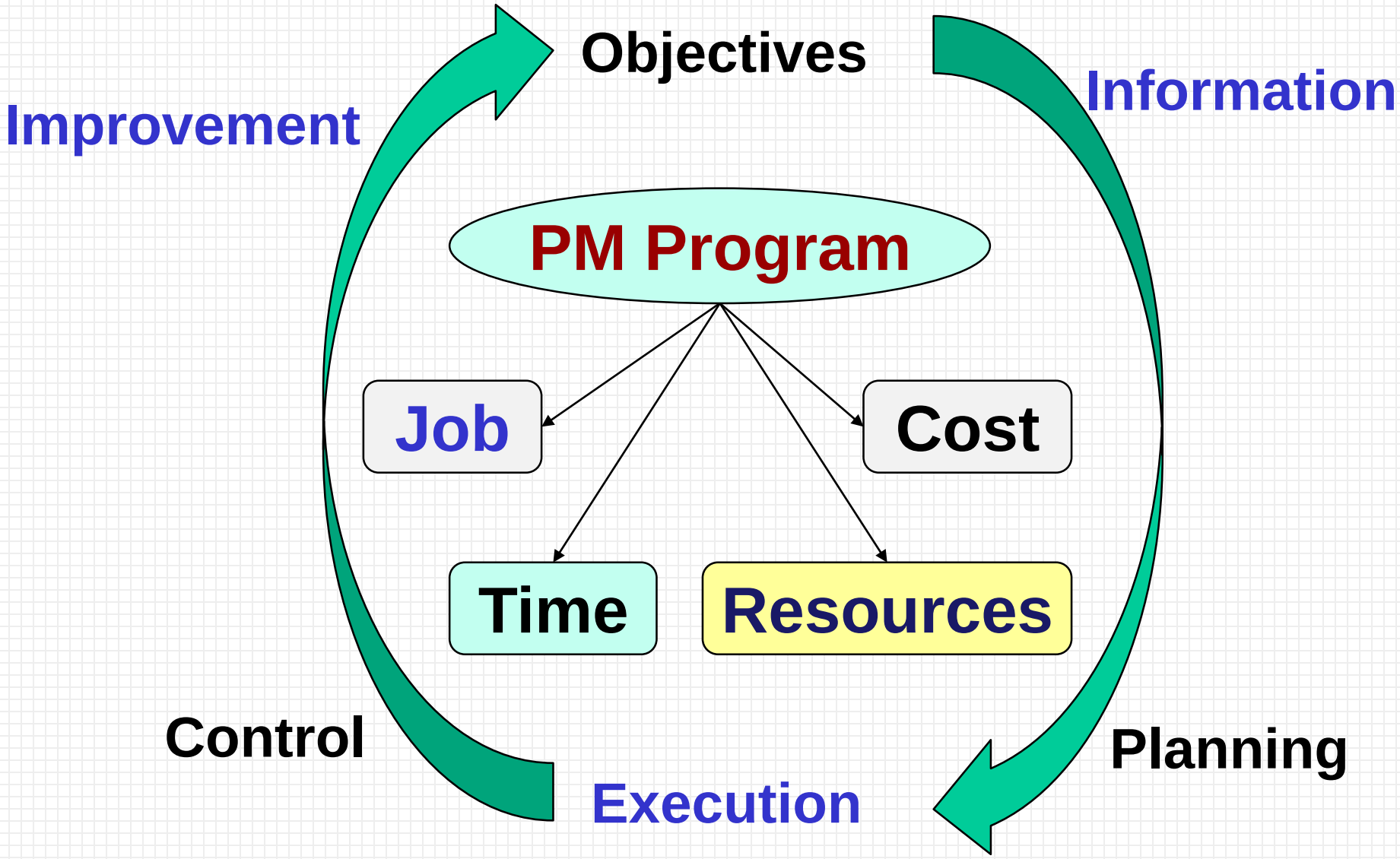
People Skills



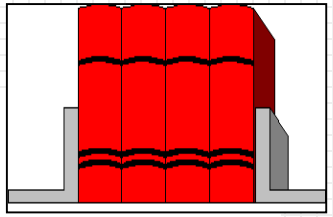
Technical Skills

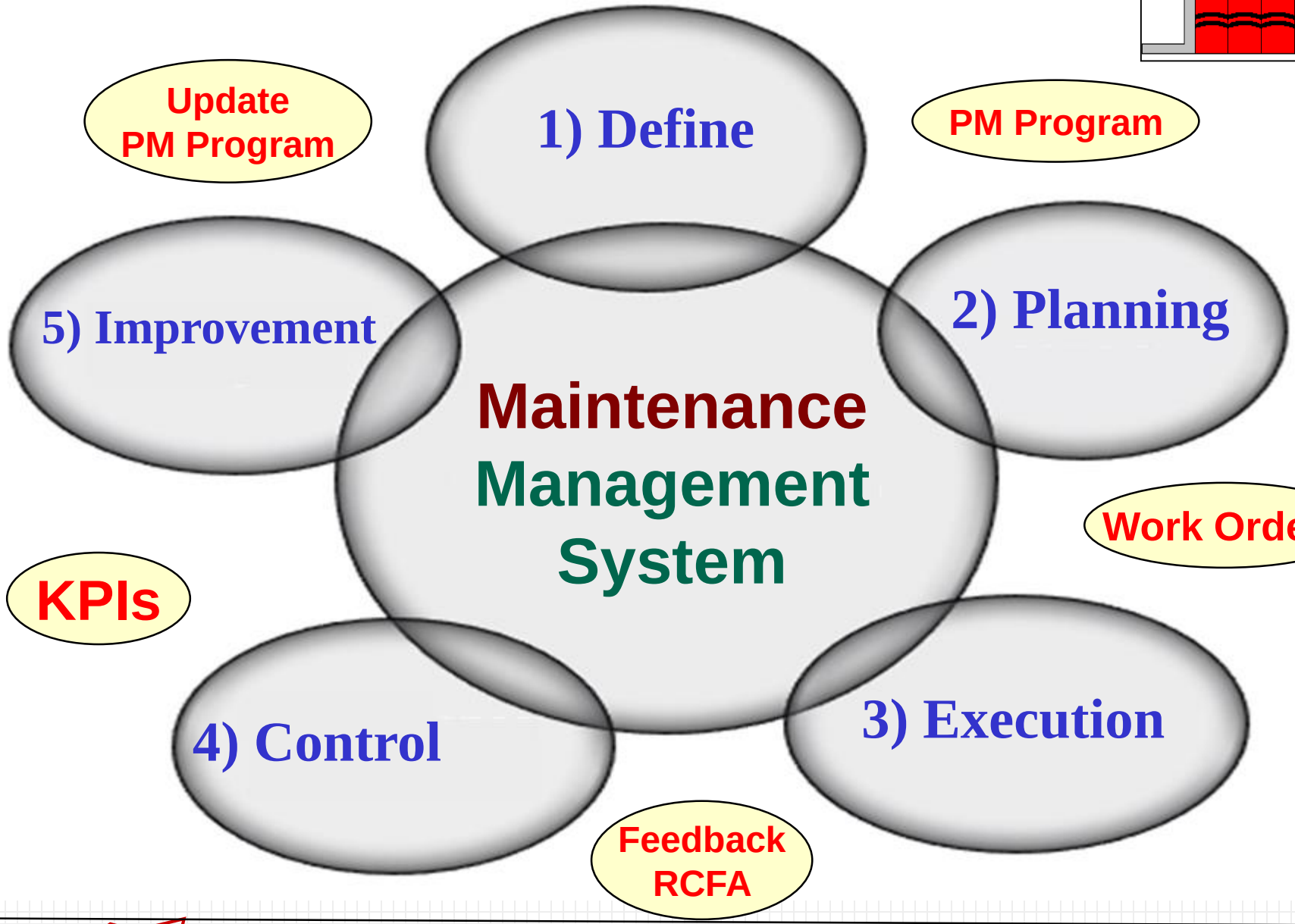
Maintenance Management

Maintenance Management Cycle



Maintenance Management System:





Maintenance Management System:

Define (Maintenance Information / Identify)
(System, Process, Equipment, Job, Resources, Cost, References… etc.)

Targets

Financial

Cost Plan
- Direct Costs
- Overhead Costs
- Downtime Losses

Cost Control
Cost Efficiency Analysis

KPIs

Job Plan
- Corrective Maintenance
- Preventive Maintenance
- Predictive Maintenance
- Design Changes

W/o

Execution
- Reduce Failures
- Reduce Downtime
- Reduce Hazards

Feedback

Feedback

Feedback

Process Satisfaction

Job Control
RAMS Analysis
- Improve Reliability
- Improve Availability
- Improve Maintainability
- Improve Safety

KPIs

Resources

Resource Plan
- Materials
- Manpower
- Service Equipment
- Special Tools
- Method

Critical Resources

Resource Control
Resource Productivity Analysis

KPIs

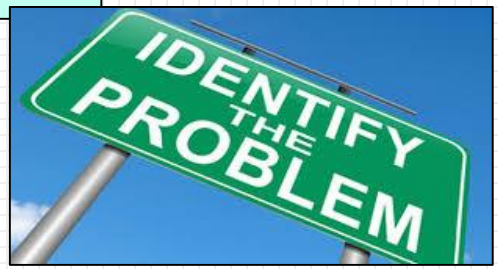
Continuous Improvement
(Failure Analysis, RAMS, Job, Resources productivity, Cost efficiency, Doc. , … etc.)

Maintenance Planning

1) Define (Identify)

(Maintenance Information)

1. System Structure (Tree)
2. Equipment List
3. Criticality Analysis
4. Equipment Data Sheet
5. PM Program (Job, Time, Resources, Cost)
6. Maintenance Manuals
7. References , … etc.

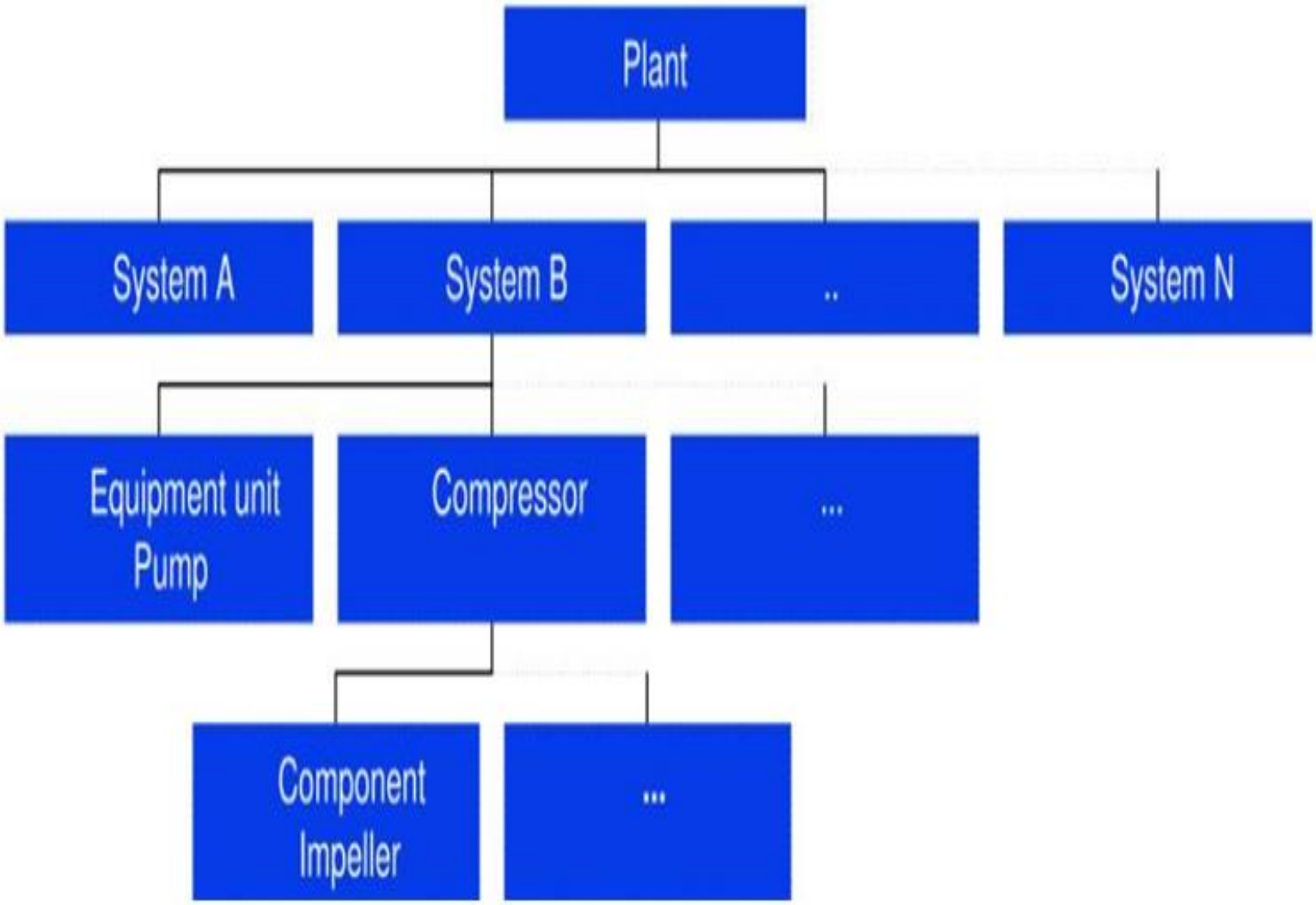


Good Data = Good Outputs

Bad Data = Bad Outputs

System hierarchy

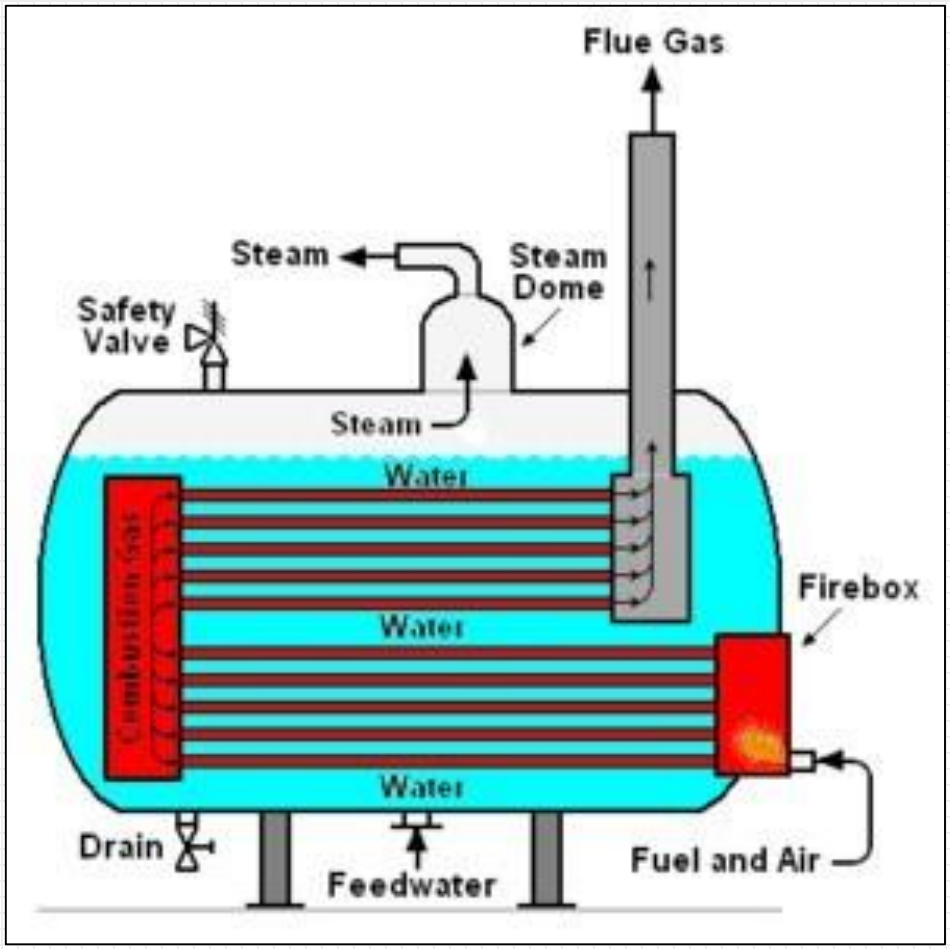
System



Component

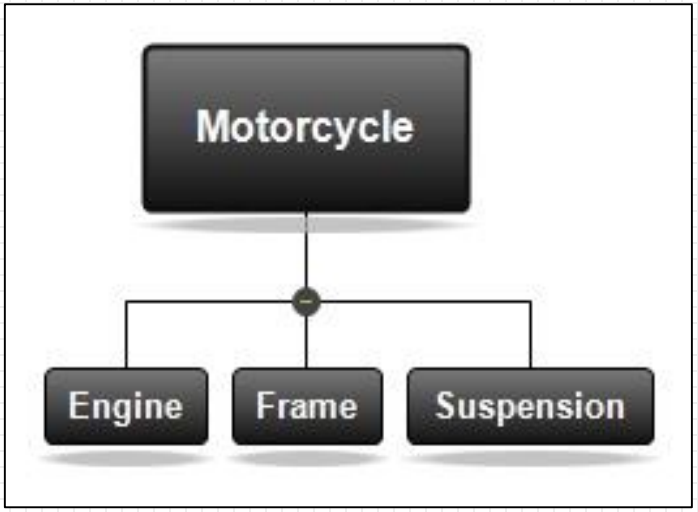
System Selection; for example (2014)

- **System:** Steam Boilers (3 units) **Criticality:** High
- **Equipment:** Feed Water Pumps (4 units 3 Running & 1 Standby)



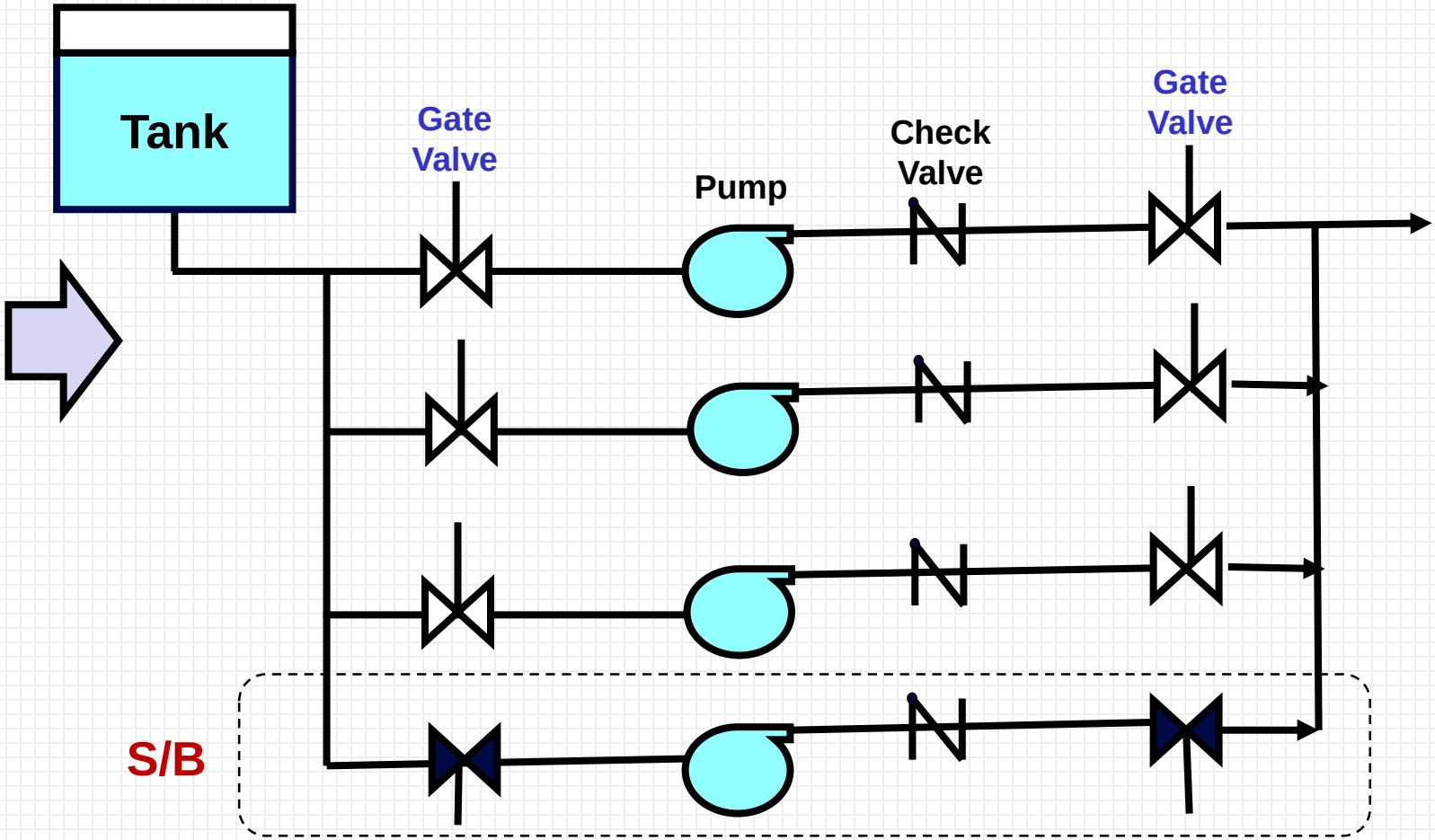
System Structure:

- Facility
  - Steam System
    - Boiler
      - ....
      - ....
    - Pump Station
      - Pump unit
      - Coupling
      - Motor
      - Valves
      - .....
  - System #2



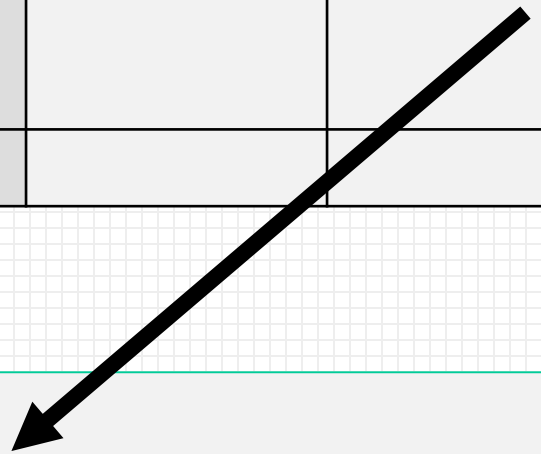
Process Flow Diagram (PFD) "Layout":

Main Items



Equipment List (Tree):

#	Equipment Type	Short Description	Main Function Parameters	Number of Equipments	TAG No.
1	Feed Water Pump	Centrifugal	Flow rate: 44 m3/hr Discharge Pressure: 10 kg/cm2	4	410-P-01 to 410-P-04
2	Gate Valves				
3	Check Valves				
	…				



TAG No. Structure; For Example:

Location/Area - Type/Model – Serial Number

XXX – XX - XXX

Equipment Criticality List (SCE, PCE, NCE)

Safety Critical Elements (SCE)		Process Critical Elements (PSE)		Non Critical Elements (NCE)	
Equipment	Tag No.	Equipment	Tag No.	Equipment	Tag No.
Feed Water Pumps	410-P-01/04				

Equipment Record (Data Sheet)

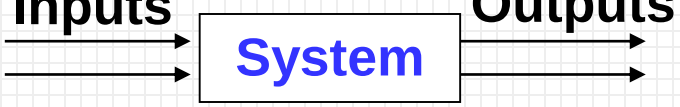
Reference Data:

- **Area / Location:** 410
- **System:** Steam Boilers
- **TAG No.:** 410-P-001
- **Criticality:** High
- **Equipment Type:** Pump
- **Number of Units:** 4 units
- **Working Conditions:** 24 hours/day
  (3 Running & 1 Standby) (A/B/C/D)
- **Maintenance Resp.:** Outsource (XX)

Details: (Main 10 parameters required to identify the equipment)

- **Pump Type:** Centrifugal
- **Geometric:** Horizontal
- **Fluid:** Water
- **Number of Stages:** Single Stage
- **Suction Pressure:** ATM
- **Flow Rate:** 44 m3/hour
- **Discharge Pressure:** 10 Kg/cm2
- **Design Speed:** 3000 RPM
- **Power:** 22 Kilowatt
- **Available NPSH:** 5.66 m

Functional Block Diagram:



Inputs:
Fluid: Water
Speed: 3000 RPM
Power: 22 Kilowatt
Available NPSH: 5.66 m

Control system:
-
-

xxx Pump Station

Environment:
-
-

Outputs:
Fluid: Water
Flow rate (44 m3/hour)
Pressure (10 Kg/cm2)

Failure Mode List (High / Low)

PM Program / Unit (Maintenance Manual & Experience); for example

PM Level		Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
Job	Check (Replace if required)					
	Replace					
	Maintenance Type					
Time	Downtime (hours/order)					
	Maintenance Time (hours/order)					
Resources	Manpower					
	Effort (Man-Hour)					
	Tools / Special					
	Service Eq.					
Cost	Cost (outsource) (LE/order/unit)					

PM Program / Unit (Maintenance Manual & Experience); for example

	PM Level	Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
Job	Check (Replace if required)	Cleaning Check operation Check seals Check noise	Cleaning Check operation Check seals Check noise Check valves	Cleaning Check operation Check seals Check noise Check valves Check bearing	Cleaning Check operation Check noise Check valves Check bearing Check coupling Check impeller Check casing Check strainers Check motor	Cleaning Check operation Check noise Check valves Check coupling Check impeller Check casing Check shaft Check strainers Check motor
	Replace	-	-	-	Replace seal	Replace seal Replace bearing
	Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Time	Downtime (hours/order)	-	-	-	8	12
	Maintenance Time (hours/order)	1	2	3	10	15
Resources	Manpower	Mech.+Elec.	Mech.+Elec.	Mech.+Elec.	2 Mech. + 1 Elec.	3 Mech. + 1 Elec.
	Effort (Man-Hour)	2	4	6	30	60
	Tools / Special					
	Service Eq.					
Cost	Cost (outsource) (LE/order/unit)	200	500	1,000	4,000	10,000

Annual PM Program (Shutdown Work Order)

Work Types		Elec. Works	Mech. Works	Instrumentations
Job	Check (Replace if required)			
	Replace			
Time	Maintenance			
	Repair			
	Downtime			
Resources	Spare Parts			
	Manpower			
	Tools			
	Service Eq.			
Cost	LE (outsource)			

Routine Maintenance (Check List):

Note:
60% of failures due to Bad Routine Maintenance

Equipment: XXX Centrifugal Pump

Weekly PM:

1- Visual inspection

- Detect any abnormal operations:
  - Check Bearing Oil, add oil (ISO VG-68) if required
  - Check Bearing Temperature (from 70 to 90 ºC)
  - Check Flow rate (44 m3/hour)
  - Check Pressure (10 kg/cm2)
  - Check Leakage from mechanical seal or pump
  - Check Noise
  -

2- House keeping

Specific √

Bearing Temperature	
Limit	Status
70-90 ºC	Good condition
90-100	Call for service
100-110	Call for repair
>110	Breakdown

Maintenance Program Matrix – Item Level

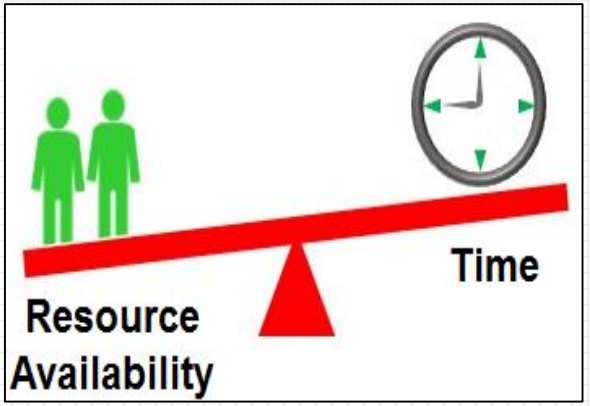
System: Steam System | **Equipment:** Feed Water Pumps | **Criticality:** High

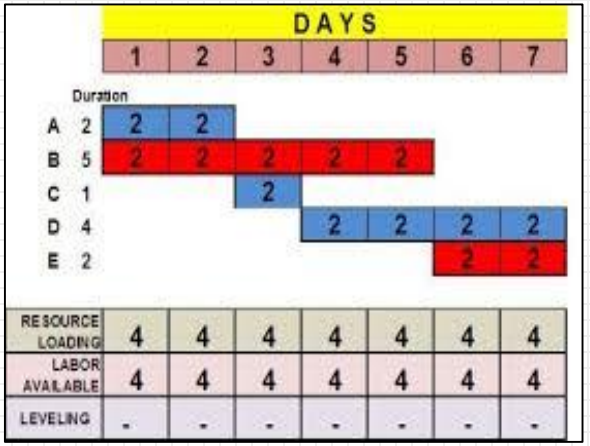
Policy	#	Maintainable Items	PM Levels					
			W	M	Q	6M	A	Disciplines
PM	1	Mechanical Seals	C	C	C	R	R	M
	2	Bearing			C	C	R	M
RTF	3	Shaft Sleeve					C	M
	4	Shaft					C	M
	5	Coupling				C	C	M
	6	Impeller				C	C	M
	7	Casing				C	C	M
	8	Strainers				C	C	M
	9	Electric Motor				C	C	E
	10	Valves		C	C	C	C	I
	11	Oil & Grease		C	C	C	R	M
	12	Instruments			C	C	C	I

C: Check R: Replace M: Mechanical E: Electrical I: Instrumentations

2) Planning

1. Estimation (Targets)
2. Work Orders
3. Job Plan
4. Resources Plan
5. Cost Plan
6. Shutdown Planning
7. Standard Templates, … etc.





Annual Maintenance Estimation

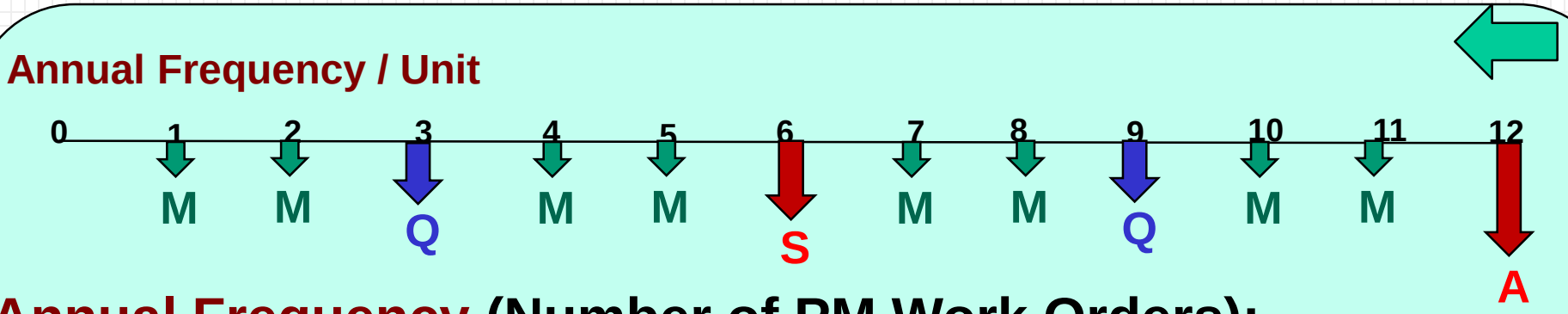
System: A Water Pumping Station **(4 units 3 Running & 1 Standby)**

PM Program / Unit:

PM Level	Weekly	Monthly	Quarter	Semi-Annual	Annual
Maintenance Cost LE/order/unit	200	500	1,000	4,000	10,000

Based on this information; discuss the annual cost estimation

PM Information Importance; for example:



Annual Frequency (Number of PM Work Orders):

PM Level	W	M	Q	S	A
	52	12	4	2	1
Annual Frequency / Unit	40	8	2	1	1

Annual Maintenance Cost

Cost / Order/unit	200	500	1000	4000	10000

Annual Cost Per Unit = 28,000 LE/unit

Annual Maintenance Cost = 28,000*4 = 112,000 LE

Annual Maintenance Estimation

System: A Water Pumping Station (4 units 3 Running & 1 Standby)

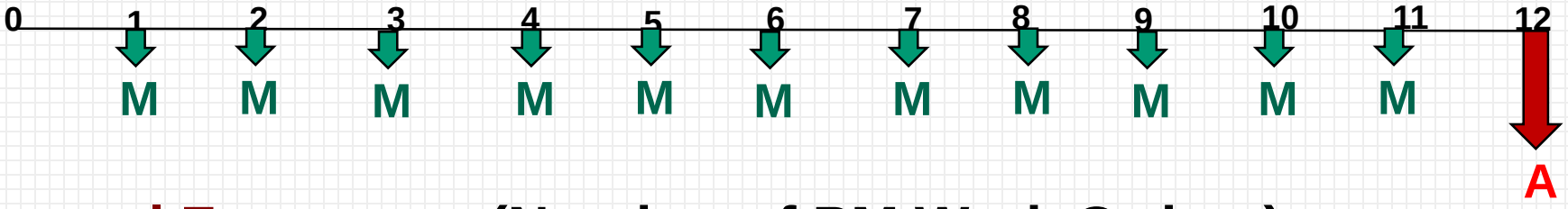
PM Program / Unit:

PM Level	Weekly	Monthly	Annual
Maintenance Cost (out source) LE/order/unit	200	500	10,000

Based on this information; discuss the annual cost estimation

PM Information Importance; for example:

Annual Frequency / Unit



Annual Frequency (Number of PM Work Orders):

PM Level	W	M	A
	52	12	1
Annual Frequency / Unit	40	11	1

Annual Maintenance Cost

Cost / Order/unit	200	500	10000

Annual Cost Per Unit = 23,500 LE/unit

Annual Maintenance Cost = 23,500*4 = 94,000 LE

Annual Maintenance Estimation

System: A Water Pumping Station (4 units 3 Running & 1 Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	Annual	2 Years	3 Years
Maintenance Cost LE/order/unit	200	500	10,000	20,000	50,000
Maintenance Type	R	R	S/D	S/D	S/D

Based on this information; discuss the annual cost estimation

Annual Maintenance Estimation

System: A Water Pumping Station (4 units 3 Running & 1 Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	Annual	2 Years	3 Years
Maintenance Cost LE/order/unit	200	500	10,000	20,000	50,000
Maintenance Type	R	R	S/D	S/D	S/D
Frequency over 3 years	40*3=120	11*3= 33	1	1	1
Cost over 3 years	24,000	16,500	10,000	20,000	50,000
	120,500 LE/unit * 4 units = 482,000 LE				
Annual Cost	482,000 / 3 years = 160,667 LE/year (Average ➔ Annual Schedule ??)				

Annual Maintenance Estimation

System: A Water Pumping Station (4 units 3 Running & 1 Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	Quarter	Semi-Annual	Annual
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Maintenance Time (hours/order)	1	2	3	10	15
Manpower	Mech.+Elec.	Mech.+Elec.	Mech.+Elec.	2 Mech. + 1 Elec.	3 Mech. + 1 Elec.

Annual Working Hours = 2000 hours/man

Based on this information; discuss the Labor effort.

Annual Maintenance Estimation

System: A Water Pumping Station (4 units 3 Running & 1 Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	Quarter	Semi-Annual	Annual
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Maintenance Time (hours/order)	1	2	3	10	15
Manpower	Mech.+Elec.	Mech.+Elec.	Mech.+Elec.	2 Mech. + 1 Elec.	3 Mech. + 1 Elec.

PM Level	Weekly	Monthly	Quarter	Semi-Annual	Annual
Annual Frequency	40	8	2	1	1
Total Effort	2*1*40= 80	2*2*8= 32	2*3*2= 12	3*10*1= 30	4*15*1= 60
	214 man-hours / unit * 4 units = 856 man-hours/2000 = 0.43 < 4 = 4 Workers ➔ Labor Productivity = 0.43/4= 10.7%				
Mech. Effort	1*1*40= 40	1*2*8= 16	1*3*2= 6	2*10*1= 20	3*15*1= 45
	127 man-hours / unit * 4 units = 508 man-hours/2000 = 0.25 < 3 = 3 Workers ➔ Labor Productivity = 0.25/3= 8.5%				
Elec. Effort	1*1*40= 40	1*2*8= 16	1*3*2= 6	1*10*1= 10	1*15*1= 15
	87 man-hours / unit * 4 units = 348 man-hours/2000 = 0.17 < 1 = 1 Worker ➔ Labor Productivity = 0.17/1= 17%				

Annual Maintenance Estimation

System: A Water Pumping Station (60 units 45 Running & 15 Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	Quarter	Semi-Annual	Annual
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Maintenance Time (hours/order)	1	2	3	10	15
Manpower	Mech.+Elec.	Mech.+Elec.	Mech.+Elec.	2 Mech. + 1 Elec.	3 Mech. + 1 Elec.

Annual Working Hours = 2000 hours/man

Based on this information; discuss the Labor effort.

System: A Water Pumping Station (60 units 45 Running & 15 Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	Quarter	Semi-Annual	Annual
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Maintenance Time (hours/order)	1	2	3	10	15
Manpower	Mech.+Elec.	Mech.+Elec.	Mech.+Elec.	2 Mech. + 1 Elec.	3 Mech. + 1 Elec.

Annual Working Hours = 2000 hours/man

PM Level	Weekly	Monthly	Quarter	Semi-Annual	Annual
Annual Frequency	40	8	2	1	1
Total Effort					
	8 Workers (Labor Productivity 76.2% ≤ 80%)				
Mech. Effort					
	5 Workers (Labor Productivity 76.6% ≤ 80%)				
Elec. Effort					
	3 Workers (Labor Productivity 87.0% ≤ 80%)				

Maintenance Labor Force: (PM + 20% CM)

System / Area	Craft	PM Weekly Load (man-hour)				
		Week #1	Week #2	Week #3	Week #4	…
Area #1	Mech.	80	70	60	55	
	Elec.	45	50	30	40	
	Inst.	15	20	10	30	
Area #2	Mech.	10	90	120	70	
	Elec.	55	35	70	40	
	Inst.	30	30	30	25	
Area #3	Mech.	70	85	70	100	
	Elec.	45	50	50	50	
	Inst.	25	20	20	15	
…	…	…	…	…	…	…

Standard Working Hours (Policy) = 200 man-hour/month

Based on this information , calculate the maintenance labor force.

Maintenance Labor Force: (PM + 20% CM)

System / Area	Craft	PM Weekly Load (man . hour)				
		#1	#2	#3	#4	…
Area #1	Mech.	80	70	60	55	
	Elec.	45	50	30	40	
	Inst.	15	20	10	30	
Area #2	Mech.	10	90	120	70	
	Elec.	55	35	70	40	
	Inst.	30	30	30	25	
Area #3	Mech.	70	85	70	100	
	Elec.	45	50	50	50	
	Inst.	25	20	20	15	
…	…	…	…	…	…	…
Weekly Totals	Mech.	160	245	250	225	
	Elec.	145	135	150	130	
	Inst.	70	70	60	70	
Monthly Totals	Mech.	880 man-hr / (200 hr/month) = 4.4 *1.2 = 6 workers (3)				
	Elec.	560 man-hr / (200 hr/month) = 2.8 *1.2 = 4 workers (2)				
	Inst.	270 man-hr / (200 hr/month) = 1.4 *1.2 = 2 workers (1)				

Annual Maintenance Estimation

System: A Water Pumping Station (4 units 3 Running & 1 Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	Quarter	Semi-Annual	Annual
Check	Check …	Check …	Check …	Check …	Check …
Replace	-	-	-	Change seal	Change seal Change bearing
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Downtime (hours/order)	-	-	-	8	12
Maintenance Time (hours/order)	1	2	3	10	15
Manpower	Mech.+Elec.	Mech.+Elec.	Mech.+Elec.	2 Mech. + 1 Elec.	3 Mech. + 1 Elec.
Effort (Man.Hour)	2	4	6	30	60
Cost (LE/order/unit)	200	500	1,000	4,000	10,000

Labor Availability: 4 workers (3 Mech. + 1 Elec.) & 2000 hours/y

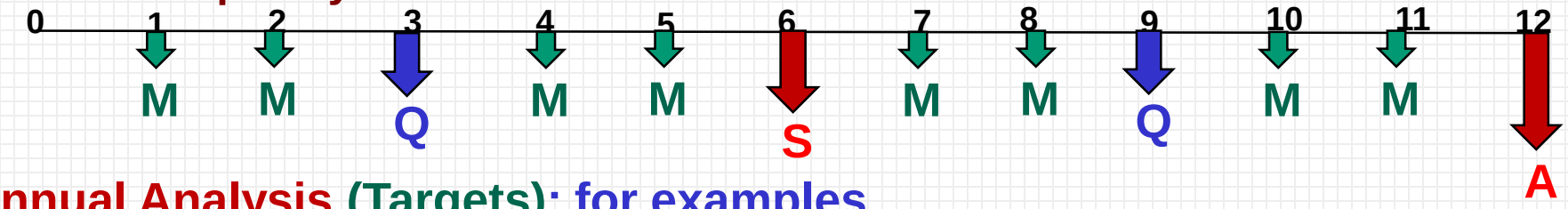
Based on this information; discuss the annual estimation for the following

(Cost , PM downtime, Maintenance time, Planned Availability, Labor, Labor Productivity).

PM Information Importance:

Annual Estimation

Annual Frequency / Unit



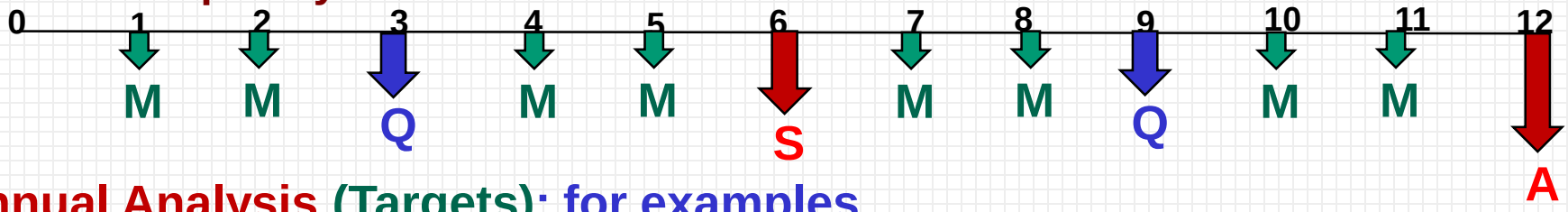
Annual Analysis (Targets); for examples

Level		Indicator	Base	Unit	Target
Top	Cost	Annual Cost	PM	LE/year	
		....	....	....	
Middle	Time	Equipment Down time	PM	Hours / Equip.	
		Average Operating Time	PM	Hours/year	
		Equipment Availability	PM	%	
		Maintenance time	PM	hours	
Operational	Resources	Workers	PM+20%CM	Man-hours	
		Labor Productivity	4 workers 2000 hours/y	%	
		Spare Parts	PM+20%CM	Bearing Kit Mechanical Seal	
		....	....	....	

PM Information Importance:

Annual Estimation

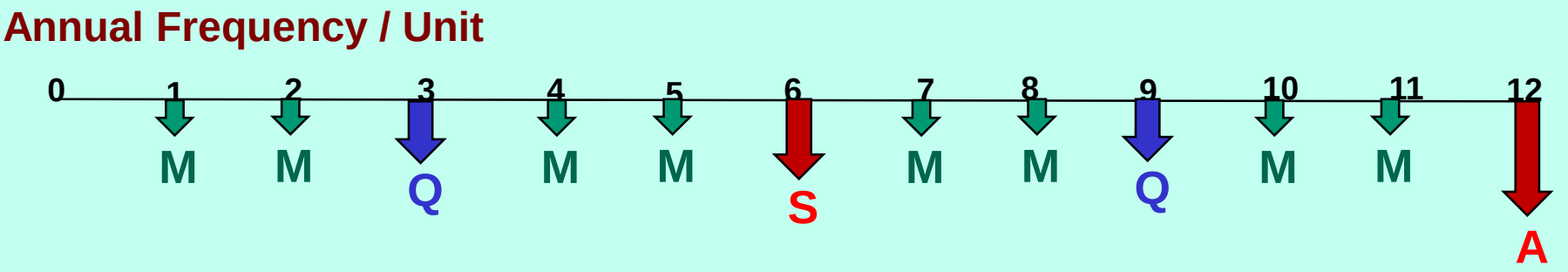
Annual Frequency / Unit



Annual Analysis (Targets); for examples

Level		Indicator	Base	Unit	Target
Top	Cost	Annual Cost	PM	LE/year	112,000
		....	....	....	....
Middle	Time	Equipment Down time	PM	Hours / Equip.	20
		Average Operating Time	PM	Hours/year	6570
		Equipment Availability	PM	%	99.7 %
		Maintenance time	PM	hours	348
Operational	Resources	Workers	PM+20%CM	Man-hours	1028
		Labor Productivity	4 workers 2000 hours/y	%	13 %
		Spare Parts	PM+20%CM	Bearing Kit Mechanical Seal	5 10
		....	....	....	....

PM Information Importance; for example:



Annual Frequency (Number of PM Work Orders):

PM Level	W	M	Q	S	A
Annual Frequency / Unit	40	8	2	1	1

Annual Maintenance Cost

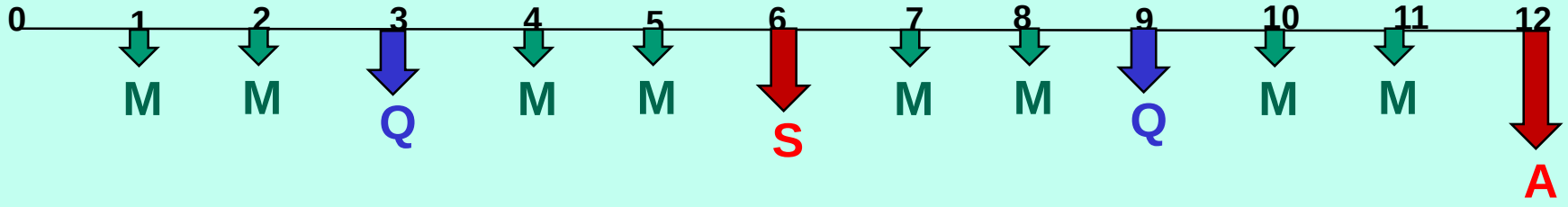
Cost / Order/unit	200	500	1000	4000	10000

Annual Cost Per Unit = 28,000 LE/unit

Annual Maintenance Cost = 28,000*4 = 112,000 LE

PM Information Importance; for example:

Annual Frequency / Unit



Annual Frequency (Number of PM Work Orders):

PM Level	W	M	Q	S	A
Annual Frequency / Unit	40	8	2	1	1

Equipment Availability = (Total Time –Downtime) / Total Time

Downtime / Order/unit	-	-	-	8	12

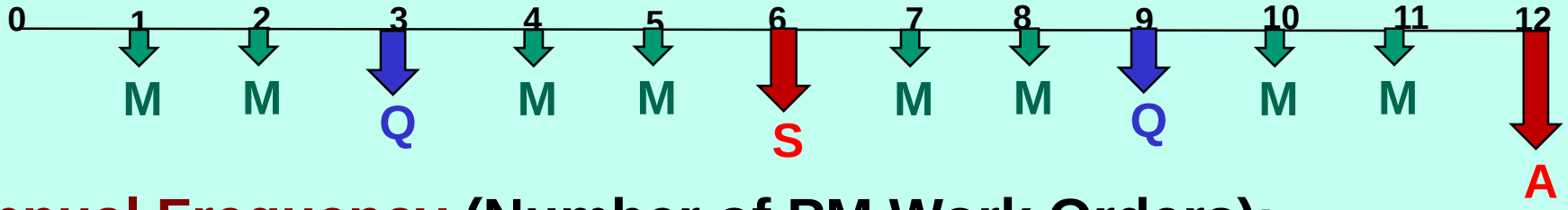
Average Running Time = 8760*3/4 = 6570

Equipment Availability = (6570 – (8+12)) / 6570

= 99.7 %

PM Information Importance; for example:

Annual Frequency / Unit



Annual Frequency (Number of PM Work Orders):

PM Level	W	M	Q	S	A
Annual Frequency / Unit	40	8	2	1	1

Maintenance Labor Effort = PM + 20% "CM"

Man . hours/Order/unit	2	4	6	30	60

Maintenance Labor Effort = 214 *1.2 = 256.8 man . hours / unit

Total Maintenance Labor Effort = 1028 man . hours

Labor Productivity = Labor Effort / Labor Availability

= 1028 / (4*2000) = 13 %

Annual Maintenance Estimation

System: A Water Pumping Station (3 units 2 Running & 1 Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	Annual
Check	Check …	Check …	Check …
Replace	-	-	Change pump seal Change pump bearing
Maintenance Type	Running	Running	Shutdown
Downtime (hours/order)	-	-	12
Maintenance Time (hours/order)	1	2	15
Manpower	Mech.+Elec.	Mech.+Elec.	3 Mech. + 1 Elec.
Effort (Man.Hour)	2	4	60
Cost (LE/order/unit)	200	500	10,000

Labor Availability: 4 workers & 2000 hours/year

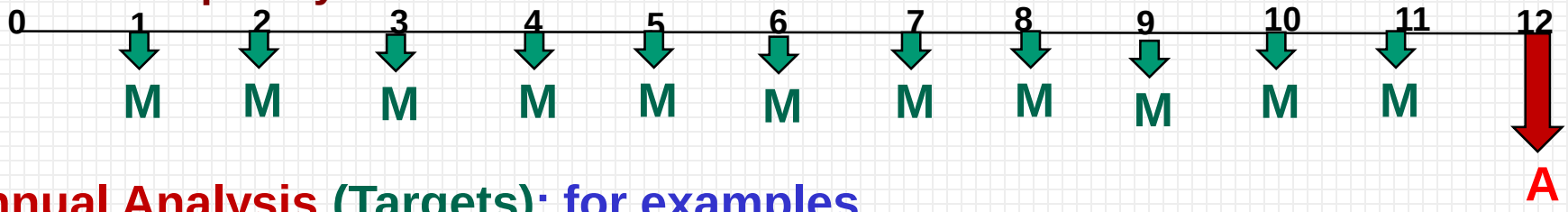
Based on this information; discuss the annual estimation for the following

(Cost , PM downtime, Maintenance time, Planned Availability, Labor, Labor Productivity).

PM Information Importance:

Annual Estimation

Annual Frequency / Unit



Annual Analysis (Targets); for examples

Level		Indicator	Base	Unit	Target
Top	Cost	Annual Cost	PM	LE/year	70,500
		....	....	....	
Middle	Time	Equipment Down time	PM	Hours / Equip.	12
		Average Operating Time	PM	Hours/year	5,840
		Equipment Availability	PM	%	99.86%
		Maintenance time	PM	hours	231
Operational	Resources	Workers Effort	PM+20%CM	Man-hours	662
		Labor Productivity	4 workers 2000 hours/y	%	8.2%
		Spare Parts	PM+20%CM	Bearing Kit Mechanical Seal	4 4
		....	....	....	

Annual Maintenance Estimation

System: A Water Pumping Station (8 units 6 Running & 2 Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	Annual
Check	Check …	Check …	Check …
Replace	-	-	Change seal Change bearing
Maintenance Type	Running	Running	Shutdown
Downtime (hours/order)	-	-	12
Maintenance Time (hours/order)	1	2	15
Manpower	Mech.+Elec.	Mech.+Elec.	3 Mech. + 1 Elec.
Effort (Man.Hour)	2	4	60
Cost (LE/order/unit)	200	500	10,000

Labor Availability: 4 workers & 2000 hours/y

Based on this information; discuss the annual estimation for the following

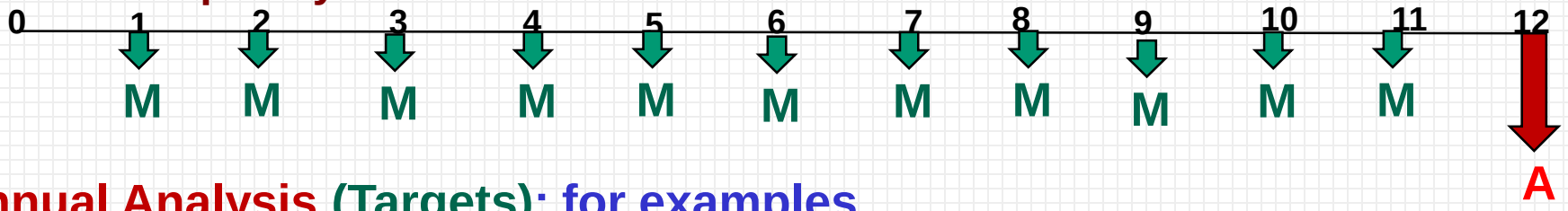
(Cost , PM downtime, Maintenance time, Planned Availability, Labor, Labor Productivity).

PM Information Importance:

DOCS

Annual Estimation

Annual Frequency / Unit



Annual Analysis (Targets); for examples

Level		Indicator	Base	Unit	Target
Top	Cost	Annual Cost	PM	LE/year	188,000
		....	....	....	
Middle	Time	Equipment Down time	PM	Hours / Equip.	12
		Average Operating Time	PM	Hours/year	6570
		Equipment Availability	PM	%	99.9
		Maintenance time	PM	hours	616
Operational	Resources	Labor Effort	PM+20%CM	Man-hours	1767
		Labor Productivity	4 workers 2000 hours/y	%	22%
		Spare Parts (items)	PM+20%CM	Bearing Kit Mechanical Seal	10 10
		....	....	....	

Annual Frequency (Number of PM Work Orders):

PM Level	W	M	A
Annual Frequency 1 Equip.	40	11	1
Annual Frequency 8 Equip.	320	88	8

Annual Maintenance Cost

Cost / Order/unit	200	500	10,000

Annual Maintenance Cost = 188,000 LE

Annual Cost Per Unit = 188,000/8 = 23,500 LE/unit

Annual Maintenance Estimation

System: A Water Pumping Station (8 units 6 Running & 2 Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	5000 RH
Check	Check …	Check …	Check …
Replace	-	-	Change seal Change bearing
Maintenance Type	Running	Running	Shutdown
Downtime (hours/order)	-	-	12
Maintenance Time (hours/order)	1	2	15
Manpower	Mech.+Elec.	Mech.+Elec.	3 Mech. + 1 Elec.
Effort (Man.Hour)	2	4	60
Cost (LE/order/unit)	200	500	10,000

Labor Availability: 4 workers & 2000 hours/y

Based on this information; discuss the annual estimation for the following

(Cost , PM downtime, Maintenance time, Planned Availability, Labor, Labor Productivity).

Annual Running Hours = 8760 hours/year * 6 Running =

52560 Equipment-hours

Annual Frequency for 5000 RH = 52560/5000 = 10.5 = 11 turns

Annual Frequency (Number of PM Work Orders):

PM Level	W	M	5000
Annual Frequency 8 Equip.	320	85	11

Annual Maintenance Cost

Cost / Order/unit	200	500	10,000

Annual Maintenance Cost = 216,500 LE

Annual Cost Per Unit = 216,500/8 = 27,062 LE/unit

Annual Maintenance Estimation

System: A Water Pumping Station (8 units 6 Running & 2 Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	Annual	2 Years
Check	Check …	Check …	Check …	Check …
Replace	-	-	Pump seal Pump bearing	Pump seal Pump bearing Motor bearing
Maintenance Type	Running	Running	Shutdown	Shutdown
Downtime (hours/order)	-	-	12	36
Maintenance Time (hours/order)	1	2	15	48
Manpower	Mech.+Elec.	Mech.+Elec.	3 Mech. + 1 Elec.	3 Mech. + 1 Elec.
Effort (Man.Hour)	2	4	60	144
Cost (LE/order/unit)	200	500	10,000	30,000

Labor Availability: 4 workers & 2000 hours/y

Based on this information; discuss the annual estimation for the following

(Cost , PM downtime, Maintenance time, Planned Availability, Labor, Labor Productivity).

Annual Frequency (Number of PM Work Orders):

PM Level	W	M	A	2Y
Annual Frequency 1 Equip.	80	22	1	1
Annual Frequency 8 Equip.	640	176	8	8

Annual Maintenance Cost

Cost / Order/unit	200	500	10,000	30,000

2 Year Maintenance Cost = 536000 **LE**

Annual Maintenance Cost = 268000 **LE**

Annual Cost Per Unit = 268000 /8 = 33500 **LE/unit**

Information For Maintenance Planning:

The maintenance information for a water pumping station is as follows:

System: A Water Pumping Station
(4 units 3 Running & 1 Standby)
Working Conditions: 24 hours/day
Maintenance: Outsource (Subcontractor)

Job Information:

PM Level	Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
Maintenance Task	Check …	Check …	Check …	Check … Change seal	Check … Change seal Change bearing
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Cost Rate LE/order/unit	200	500	1,000	4,000	10,000

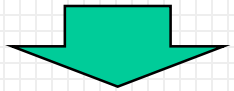
Based on this information; discuss the

Annual Maintenance Schedule , Cost Plan & Resource Plan (Material, … etc.).

Job Information:

PM Level	Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
Maintenance Task	Check …	Check …	Check …	Check … Change seal	Check … Change seal Change bearing
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Cost Rate LE/order/unit	200	500	1,000	4,000	10,000

Maintenance Schedule:



Area: xxxx

ID	Month #											
	1	2	3	4	5	6	7	8	9	10	11	12
P01												
P02												
P03												
P04												
W/O												
Cost												

Job Information:

PM Level	Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
Maintenance Task	Check …	Check …	Check …	Check … Change seal	Check … Change seal Change bearing
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Cost Rate LE/order/unit	200	500	1,000	4,000	10,000

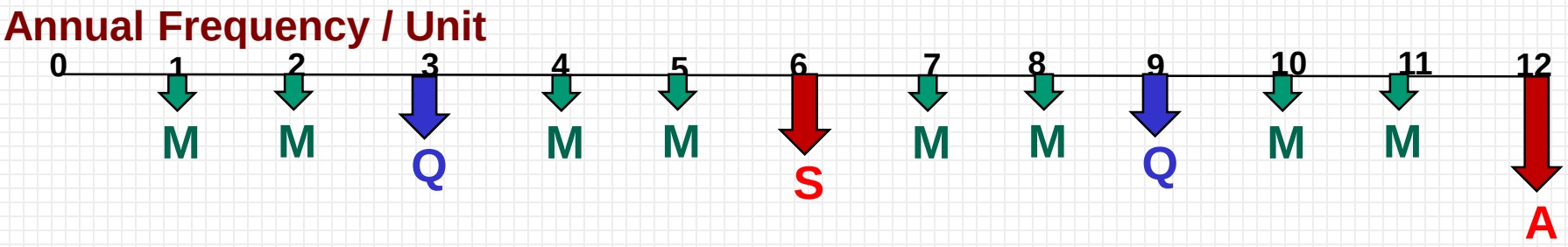
ID	Month #											
	1	2	3	4	5	6	7	8	9	10	11	12
P01	M	M	Q	M	M	S	M	M	Q	M	M	A
P02	M	M	Q	M	M	S	M	M	Q	M	M	A
P03	M	M	Q	M	M	S	M	M	Q	M	M	A
P04	M	M	Q	M	M	S	M	M	Q	M	M	A
W/O	4M 12W	4M 12W	4Q 12W	4M 12W	4M 12W	4S 12W	4M 12W	4M 12W	4Q 12W	4M 12W	4M 12W	4A 12W
Cost	4,400	4,400	6,400	4,400	4,400	18,400	4,400	4,400	6,400	4,400	4,400	42,400

Job Information:

PM Level	Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
Maintenance Task	Check …	Check …	Check …	Check … Change seal	Check … Change seal Change bearing
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Cost Rate LE/order/unit	200	500	1,000	4,000	10,000

ID	Month #											
	1	2	3	4	5	6	7	8	9	10	11	12
P01												A
P02									A			
P03						A						
P04			A									
W/O												
Cost												

Annual Maintenance Schedule



Plant: Water Station | **Equipment Type:** Pumps | **Period:** 2018

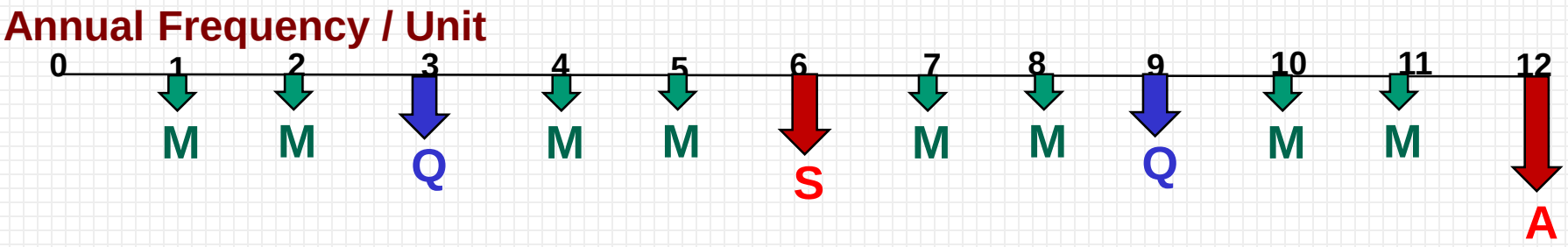
#	Equipment	ID	Last Major Maintenance	Months - 2018											
				1	2	3	4	5	6	7	8	9	10	11	12
1	Pump #1	P1	12/2017												A
2	Pump #2	P2	10/2017									x	A		
3	Pump #3	P3	8/2017						x		A				
4	Pump #4	P4	5/2017			x		A							

Milestones

M: Monthly Q: Quarter S:Semi-Annually A: Annual

Meeting ➔ Must be Accepted (Operation & Maintenance)

Annual Maintenance Schedule



Plant: Water Station | **Equipment Type:** Pumps | **Period:** 2018

#	Equipment	ID	Last Major Maintenance	Months - 2018											
				1	2	3	4	5	6	7	8	9	10	11	12
1	Pump #1	P1	12/2017												A
2	Pump #2	P2	10/2017									A			
3	Pump #3	P3	8/2017						A						
4	Pump #4	P4	5/2017			A									

Milestones

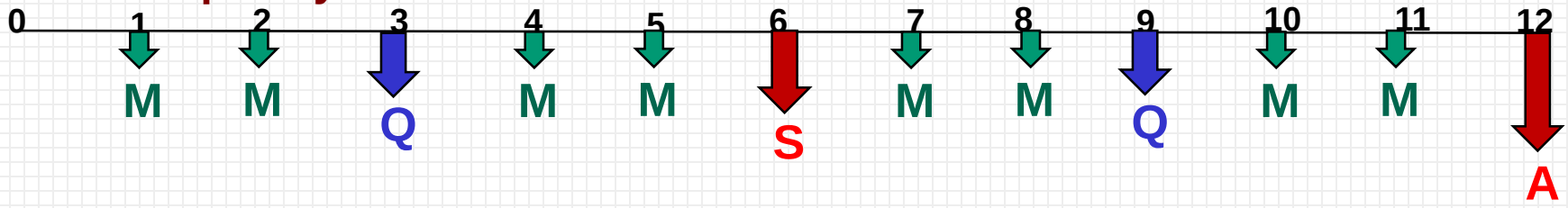
M: Monthly **Q**: Quarter **S**:Semi-Annually **A**: Annual

Meeting ➔ Must be Accepted (Operation & Maintenance)

Annual Maintenance Schedule (Maintenance Matrix)

(52 Weeks or 12 Months)

Annual Frequency / Unit



Plant: Water Station | **Equipment Type:** Pumps | **Period:** 2018

#	Equipment	ID	Ref.	Months - 2018											
				1	2	3	4	5	6	7	8	9	10	11	12
1	Pump #1	P1		M	M	Q	M	M	S	M	M	Q	M	M	A
2	Pump #2	P2		M	M	S	M	M	Q	M	M	A	M	M	Q
3	Pump #3	P3		M	M	Q	M	M	A	M	M	Q	M	M	S
4	Pump #4	P4		M	M	A	M	M	Q	M	M	S	M	M	Q
			Standby #	P1	P2	P3	P4	P1	P2	P3	P4	P1	P2	P3	P4

M: Monthly **Q**: Quarter **S**:Semi-Annually **A**: Annual

Meeting ➔ Must be Accepted (Operation & Maintenance)

Master Maintenance Schedule (3 Areas / 12 Pump Units)

Area	Equipment	ID	Ref.	Months - 2018											
				1	2	3	4	5	6	7	8	9	10	11	12
#1	Pump #1	P1													A
	Pump #2	P2										A			
	Pump #3	P3							A						
	Pump #4	P4				A									
#2	Pump #5	P5												A	
	Pump #6	P6									A				
	Pump #7	P7						A							
	Pump #8	P8			A										
#3	Pump #9	P9											A		
	Pump #10	P10								A					
	Pump #11	P11					A								
	Pump #12	P12		A											

M: Monthly Q: Quarter S:Semi-Annually A: Annual

Meeting ➔ Must be Accepted (Operation & Maintenance)

Master Maintenance Schedule (3 Areas / 12 Pump Units)

Area	Equipment	ID	Ref.	Months - 2018											
				1	2	3	4	5	6	7	8	9	10	11	12
#1	Pump #1	P1		M	M	Q	M	M	S	M	M	Q	M	M	A
	Pump #2	P2		M	M	S	M	M	Q	M	M	A	M	M	Q
	Pump #3	P3		M	M	Q	M	M	A	M	M	Q	M	M	S
	Pump #4	P4		M	M	A	M	M	Q	M	M	S	M	M	Q
#2	Pump #5	P5		M	Q	M	M	S	M	M	Q	M	M	A	M
	Pump #6	P6		M	S	M	M	Q	M	M	A	M	M	Q	M
	Pump #7	P7		M	Q	M	M	A	M	M	Q	M	M	S	M
	Pump #8	P8		M	A	M	M	Q	M	M	S	M	M	Q	M
#3	Pump #9	P9		Q	M	M	S	M	M	Q	M	M	A	M	M
	Pump #10	P10		S	M	M	Q	M	M	A	M	M	Q	M	M
	Pump #11	P11		Q	M	M	A	M	M	Q	M	M	S	M	M
	Pump #12	P12		A	M	M	Q	M	M	S	M	M	Q	M	M

M: Monthly **Q: Quarter** **S:Semi-Annually** **A: Annual**

Meeting ➔ Must be Accepted (Operation & Maintenance)

Annual Cost Plan

PM Level	W	M	Q	S	A
Annual Frequency / Unit	40	8	2	1	1
4 Units	160	32	8	4	4
Cost / Order	200	500	1000	4000	10000

Annual Maintenance Cost = 112,000 LE

Plant: Water Station | **Equipment Type:** Pumps | **Period:** 2018

#	Equipment	ID	Months - 2018											
			1	2	3	4	5	6	7	8	9	10	11	12
1	Pump #1	P1	M	M	Q	M	M	S	M	M	Q	M	M	A
2	Pump #2	P2	M	M	S	M	M	Q	M	M	A	M	M	Q
3	Pump #3	P3	M	M	Q	M	M	A	M	M	Q	M	M	S
4	Pump #4	P4	M	M	A	M	M	Q	M	M	S	M	M	Q
Number of Weekly PM														
Maintenance Cost (1000 LE)			4.5	4.5	19	4.5	4.5	19	4.5	4.5	19	4.5	4.5	19
			28			28			28			28		
			112											

Annual Cost Plan (2018)

System: Water Pump Systems

#	Equipment	ID	Months - 2018												
			1	2	3	4	5	6	7	8	9	10	11	12	Total
1	Water Station	410-P	28			28			28			28			112
2	Water Station	510-P	28			28			28			28			112
3	Water Station	610-P	28			28			28			28			112
Total Cost (1000 LE)			84			84			84			84			336

Annual Material Plan (PM + 20% CM)

System: A Water Pumping Station (4 units 3 Running & 1 Standby)

Policy	#	Maintainable Items	PM Levels					Annual Materials			
			W	M	Q	6M	A	/ Unit	PM	CM	Total
PM	1	Mechanical Seals	C	C	C	R	R	2	8	2	10
	2	Bearing Kit			C	C	R	1	4	1	5
RTF	3	Shaft Sleeve					C			1	1
	4	Shaft					C			1	1
	5	Coupling				C	C			1	1
	6	Impeller				C	C			1	1
	7	Casing				C	C			1	1
	8	Strainers				C	C			1	1
	9	Valves		C	C	C	C			2	2
	10	Electric Motor				C	C			1	1
	11										
	12										

C: Check R: Replace

Based on MTBF & At least one item (safety stock)

Annual Material Plan (PM + 20% CM)

Plant: Water Station | **Equipment Type:** Pumps | **Period:** 2018

#	Equipment	ID	Months - 2018											
			1	2	3	4	5	6	7	8	9	10	11	12
1	Pump #1	P1	M	M	Q	M	M	S	M	M	Q	M	M	A
2	Pump #2	P2	M	M	S	M	M	Q	M	M	A	M	M	Q
3	Pump #3	P3	M	M	Q	M	M	A	M	M	Q	M	M	S
4	Pump #4	P4	M	M	A	M	M	Q	M	M	S	M	M	Q
Maintenance Material			-	-	2 seal 1 bear			2 seal 1 bear			2 seal 1 bear			2 seal 1 bear
			Seal 8+2 = 10 units & Bearing Kit 4+1 = 5 units											

W: (Running) M: (Running) Q: (Running) S: seal (1) A: seal (1) & bearing (2)

Maintenance W/o Elements

What

Should be done?

Job Plan

- Scope of work
- Maintenance levels
- Main activities
- Method of Statement
- Safety Plan

Who?

Responsible Leader

Leading & Close-out

When?

Maintenance Schedule

- Duration / Downtime
- Start Date
- Finish Date

How?

Maintenance Resources

- Spare Parts
- Standard Tool Box (?)
- Special Tools
- Manpower Skills
- Method of Statement
- Subcontractor
- Service Equipment

Where?

Location

- Code
- Area
- Location
-

Maintenance Work Instruction (MWI):

Job	PM Level	Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
	Check	Cleaning Check operation Check seals Check noise	Cleaning Check operation Check seals Check noise Check valves	Cleaning Check operation Check seals Check noise Check valves Check bearing	Cleaning Check operation Check noise Check valves Check bearing Check coupling Check impeller Check casing Check strainers Check motor	Cleaning Check operation Check noise Check valves Check coupling Check impeller Check casing Check shaft Check strainers Check motor
	Replace	-	-	-	Replace seal	Replace seal Replace bearing
	Maintenance Type	Running	Running	Running	Shutdown	Shutdown
	MWI	410-P-W	410-P-M	410-P-Q	410-P-S	410-P-A

Maintenance Work Order Form , for example

Area / Location: 410	**TAG No.:** 410-P-001	**Equipment:** Centrifugal Pump
Criticality: SCE	**Job Type:** Annual PM	**Department:** Mechanical

W/O Number: 2018-0027	**W/o Priority :** High	**Shutdown :** Yes	**Work Permit:** 1234

	Planned Performance	Feedback
Job	**Planned Job:** Refer to MWI ……	**Actual Job:**
Times	Planned Maintenance Duration: Planned Downtime: Planned Repair Time: Planned Start Date: / / 2018 Planned Finish Date: / / 2018	Actual Maintenance Duration: Actual Downtime: Actual Repair Time: Actual Start Date: / / 2018 Actual Finish Date: / / 2018
Resources	**Planned Manpower:**	**Actual Manpower:**
	Planned Materials:	**Actual Materials:**
	Planned Tools:	**Actual Tools:**
Comments:		

Close Out: / / 2018 **Reported by:**

Maintenance Work Order Form , for example

Area / Location: 410	**TAG No.:** 410-P-001	**Equipment:** Centrifugal Pump
Criticality: SCE	**Job Type:** Annual PM	**Department:** Mechanical

W/O Number: 2018-0027	**W/o Priority :** High	**Shutdown :** Yes	**Work Permit:** 1234

	Planned Performance	Feedback
Job	**Planned Job:** Refer to MWI ……	**Actual Job:**
Times	Planned Maintenance Duration: Planned Downtime: Planned Repair Time: Planned Start Date: / / 2 Planned Finish Date: / /	Actual Maintenance Duration: Actual Downtime: Actual Repair Time: te: / / 2018 ate: / / 2018
Resources	**Planned Manpower:**	er:
	Planned Materials:	s:
	Planned Tools:	
Comments:		
Close Out: / / 2018		Reported by:

6 Questions?

What?	Job	√
When?	Schedule	√
How?	Resources	√
Where?	Location	√
Who?	Responsible	√
Feedback?		√

Work Order Priority

Low	Medium	High	Very High
P4 **Planned Overhaul** **(2 Weeks)** **(within 14 days)**	**P3** **Normal (Routine or PM)** **(Week)** **(within 7 days)**	**P2** **Critical** **(Do Today)** **(within 24 hours)**	**P1** **Emergency** **(Start Now)** **(within 2 hours)**
Low Production losses	**Medium Production losses**	**High Production losses**	**Safety Critical Elements (SCE)**

Refer to ISO 14224

Overdue % SCE

Refer to (ISO 14224):

W/O Types:

CM	Corrective
MM	Modification
SM	Service
PM	Preventive
PD	Predictive
RP	Repair Work
OM	Overhaul

Operational Condition:

OVH	GENERAL OVERHAUL
RUN	RUNNING
STB	STANDBY
STP	STOPPED
SUP	START UP

W/O Priority:

- P1. Emergency (within 2 hours)
- P2. Critical (within 24 hours)
- P3. Normal (routine or PM)
- P4. Planned Overhaul

W/O Status:

- CANCELLED
- CLOSED
- IN PROGRESS
- ON HOLD
- PLANNED
- COMPLETED
- REQUESTED

- **Planned** will be the summation of all **(Preventive + Predictive)**
- **Unplanned** will be summation of all **(Corrective)**
- **Uncompleted** will be the summation of all **(Planned + In progress + On hold)**

FEED BACK WORK ORDER

PLANNING DEPARTMENT

Work Order No. :	2019-003682	Medium Critical WO	ssue Date :	17/02/2019	Date Due : 17/02/2019
Priority :	Routine	Job Type :	P	Planned Preventive Maintenanc	PTW No. :
Permits :	CLD	Department :	E	Electrical	
Shut Down :	Y		Criticality:	S	Safety Critical Element (SCE)

System :	SSS / 510 / 8000	Description :	Power Generation System
Equip :	E / BCH-8001-2	Description :	Diesel Starting Battery Charger No. 2
Task :	EBCH1M013	Description:	1-Month P.M for Battery Charger

Actual Duration / Aux : 2.00 / 0.00 Hrs

Work Scope

CARRY OUT MONTHLY PM ACCORDING TO:
MWI: EUPS1M013

Work Done

As per MIWI

MAN POWER

Trade Code	Desc.	Emp. Code	Emp. Desc	ACT_H	AUX_H
E03	Electrical Engineer			0.00	0.00
E04	Electrical Supervisor			0.00	0.00
E05	Electrical Technision	EPS24	Mahmoud Ahmed Elshazly	2.00	0.00
E06	Electrical Helper			0.00	0.00

SPARES

STORE CODE	M.E.S.C. CODE	Act_QTY

TOOLS

TOOL	HRS

Tool Box (Standard)

Crew:

#	Item	Description
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		

Special Tools

#	Job	Special Tools	Description
1			
2			
3			
4			
5			

Service Equipment

#	Job	Service Equipment	Description
1			
2			
3			
4			
5			

Material Planning (Spare Parts Planning)

Work Types

Planned Work

Dependent Demand

Material Requirements Planning

MRP:

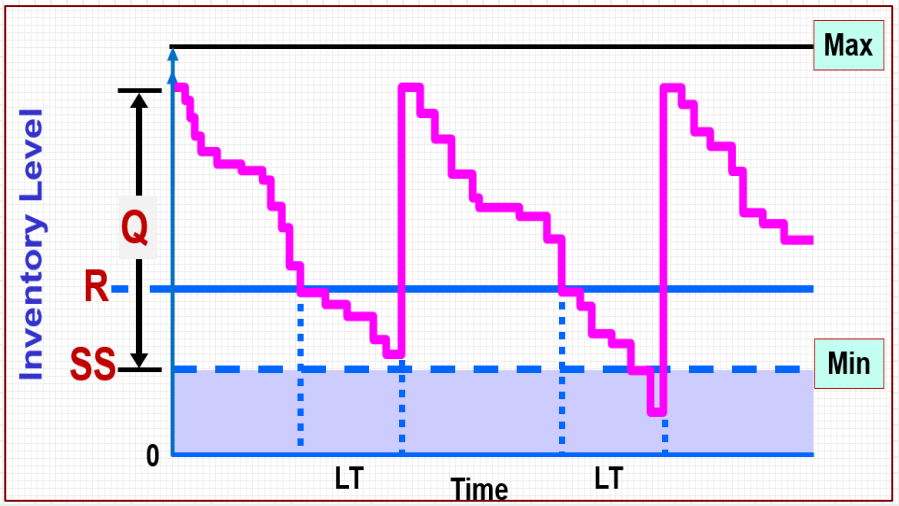
Period (month)	0	1	2	3	…
Gross Requirements					
Schedule Receipts					
Stock On Hand					
Net Requirements					
Planned Order Receipt					
Planned Order Release					

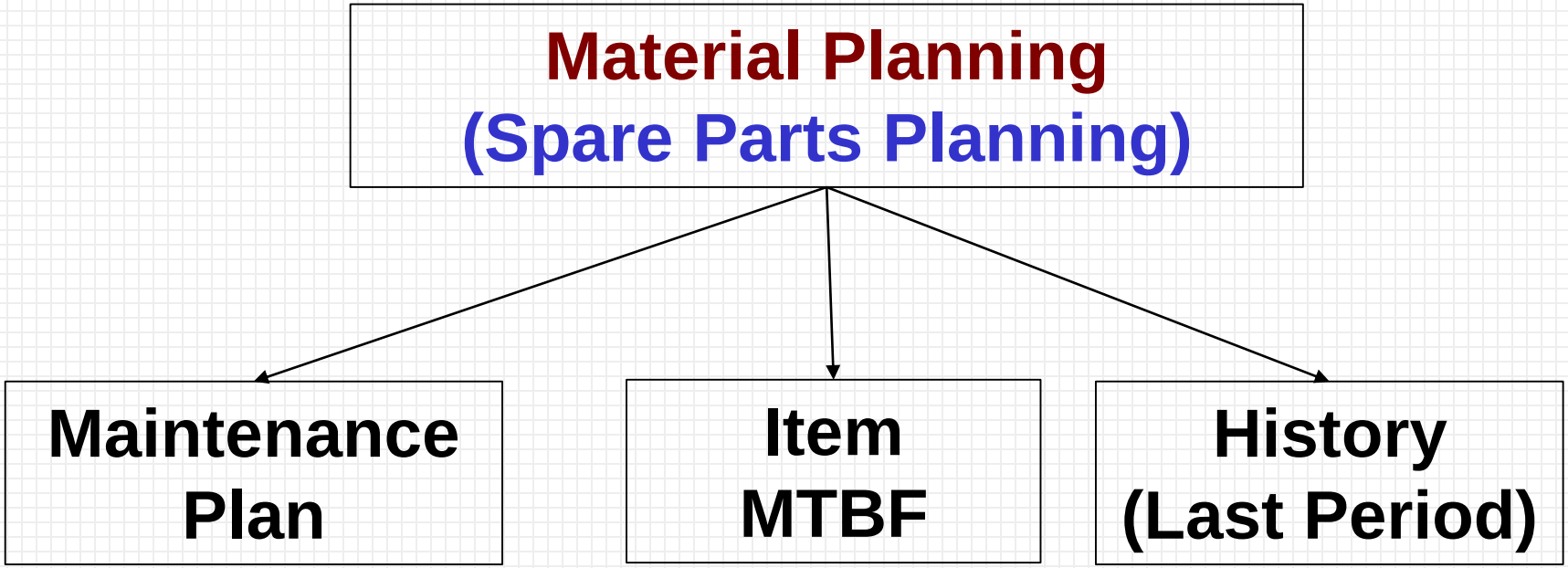
Unplanned Work

Independent Demand

Inventory Control

Policy:




Material Planning
(Spare Parts Planning)
Maintenance Plan
Item MTBF
History (Last Period)

Example: One Item & Single Level

Item Information:

Equipment: Water Pumps
Item: Bearing (2 units/pump)
Item Cost: 1000 $/unit

Number of Equipment: 60
Item Code: BXX
Maintenance Policy: Annual

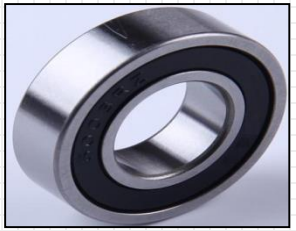
Annual Demand:

Period (month)	1	2	3	4	5	6	7	8	9	10	11	12
Gross Requirements	20	0	20	0	20	0	20	0	20	0	20	0

Inventory Data:

On Hand = 20 units
Safety Stock = 10 units
Lot Size = 24 units
Lead Time = 1 Month

Schedule Receipts =
(24 units , Month#1)



Item Information:

Equipment: Water Pump
Item: Bearing (2 units/pump)
Item Cost: 1000 $/unit
Number of Equipment: 60
Item Code: BXX
Maintenance Policy: Annual

Inventory Data:

On Hand = 20 units **Safety Stock** = 10 units **Lot Size** = 24 units
Lead Time = 1 Month **Schedule Receipts**= (24 units , Month#1)

Material Plan:

Period (month)	0	1	2	3	4	5	6	7	8	9	10	11	12	0
Gross Requirements		20	0	20	0	20	0	20	0	20	0	20	0	
Schedule Receipts		24												
Stock On Hand	20	24	24	28	28	32	32	12	12	16	16	20	20	
Net Requirements				6		2				18		14		
Planned Order Receipt				24		24				24		24		
Planned Order Release			24		24				24		24			

Item Information:

Equipment: Water Pump
Item: Bearing (2 units/pump)
Item Cost: 1000 $/unit
Number of Equipment: 60
Item Code: BXX
Maintenance Policy: Annual

Inventory Data:

On Hand = 20 units **Safety Stock** = 10 units **Lot Size** = 24 units
Lead Time = 1 Month **Schedule Receipts**= (24 units , Month#1)

Material Plan:

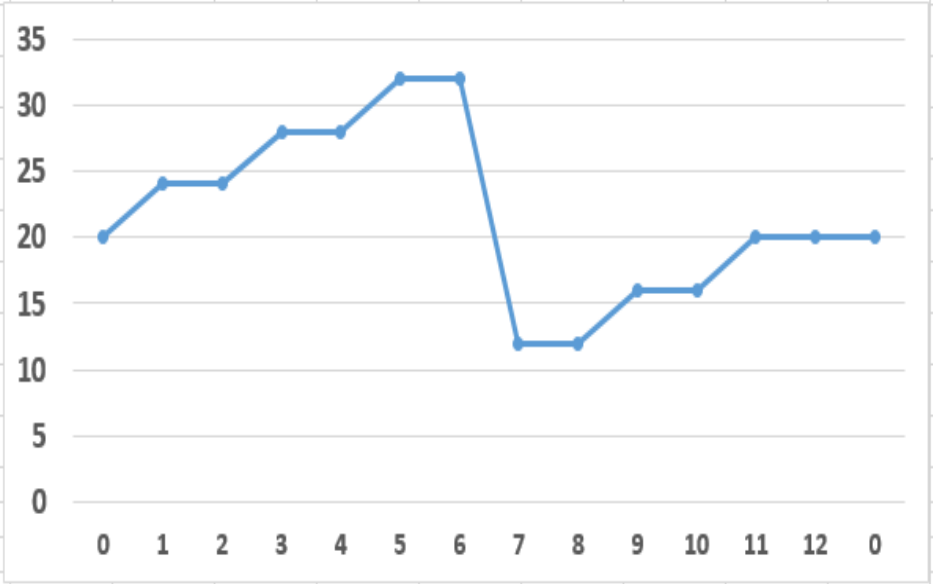
Period (month)		0	1	2	3	4	5	6	7	8	9	10	11	12	0
Gross Requirements			20	0	20	0	20	0	20	0	20	0	20	0	
Schedule Receipts			24												
Stock On Hand	20	20	24	24	28	28	32	32	12	12	16	16	20	20	
Net Requirements					6		2				18		14		
Planned Order Receipt					24		24				24		24		
Planned Order Release				24		24				24		24			

Material Plan:

Part name =	Bearing		Unit Cost =	1000 $/unit
Lead time =	1	month		
Lot size =	24	units		
Safety stock =	10	units		

		Periods (Months)												
Periods	0	1	2	3	4	5	6	7	8	9	10	11	12	0
Gross Requirements	0	20	0	20	0	20	0	20	0	20	0	20	0	0
Schedule Receipts	0	24	0	0	0	0	0	0	0	0	0	0	0	0
Stock on hand	20	24	24	28	28	32	32	12	12	16	16	20	20	20
Net requirements		0	0	6	0	2	0	0	0	18	0	14	0	0
Planned Order Receipts		0	0	24	0	24	0	0	0	24	0	24	0	0
Planned Order Release		0	24	0	24	0	0	0	24	0	24	0	0	0

Average Inventory Quantity =	20	
Average Inventory Cost =	20000	$ (CAPEX)
Gross Requirement	120	units
Material Cost =	120000	$ (OPEX)
Total Inventory Cost =	140000	$

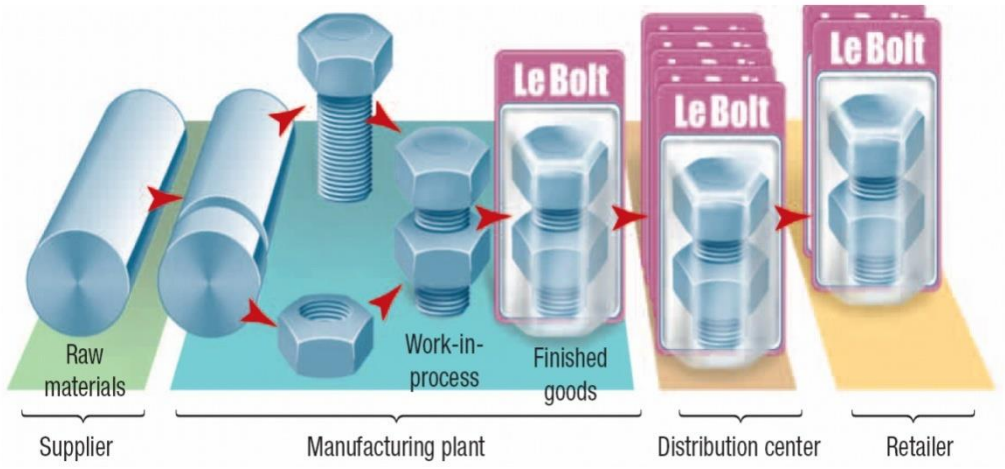


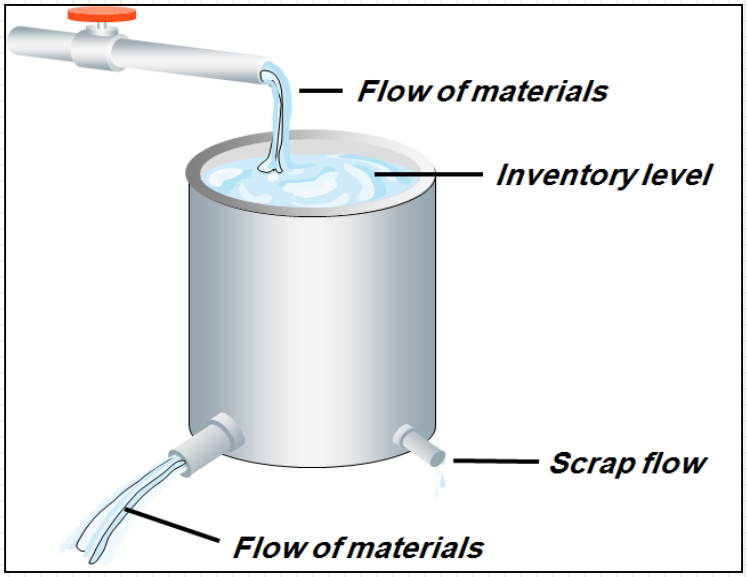
Inventory Control (Stock Control)

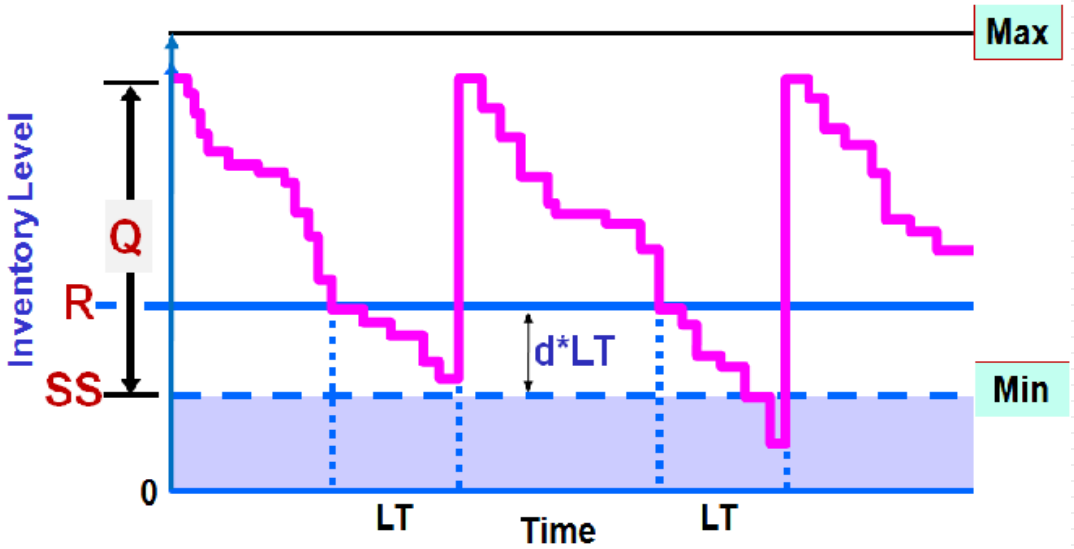
Ford Whitman Harris first presented the familiar economic order quantity (EOQ) model, 1913

Types of Inventory:

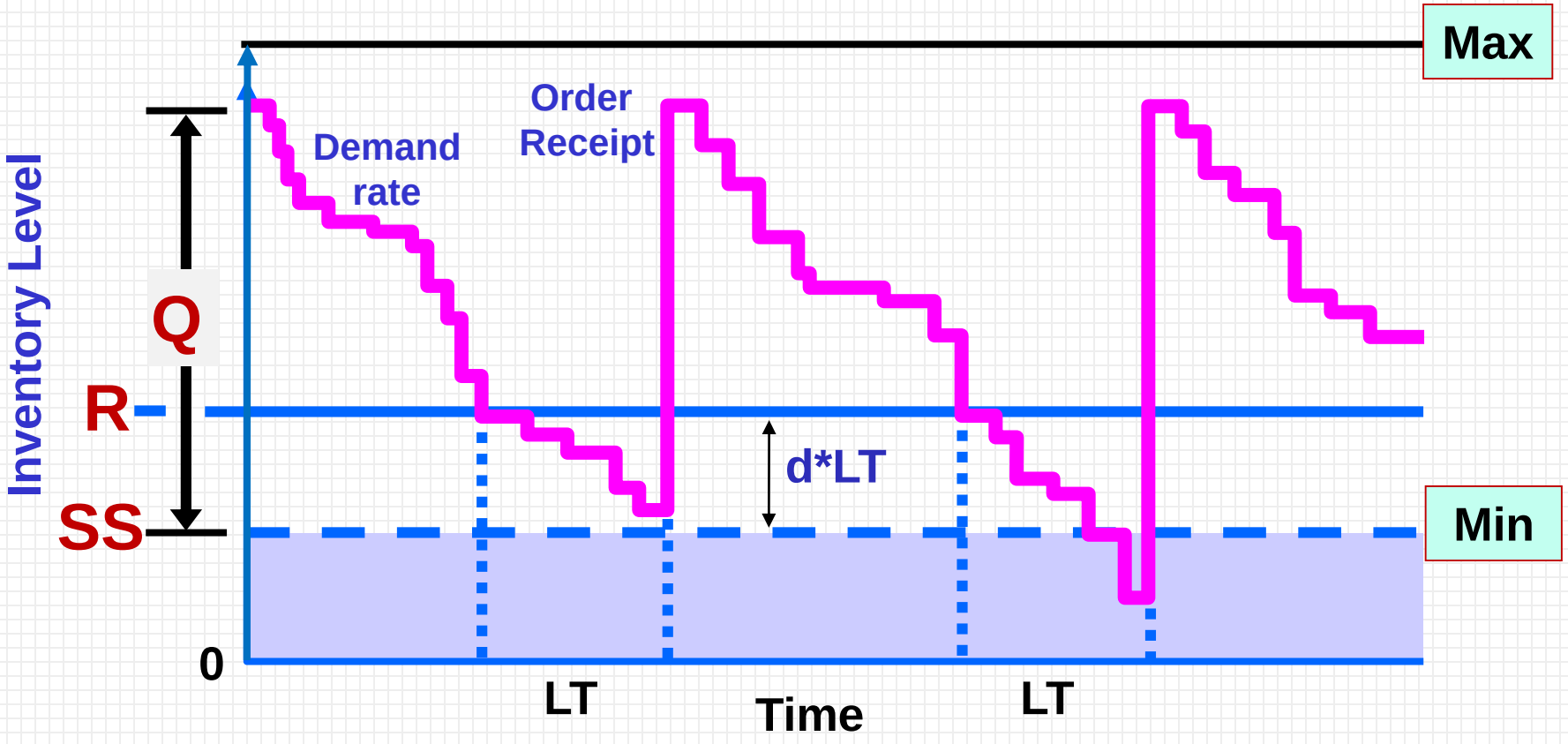
- Raw materials
- Work-in-process
- Finished goods







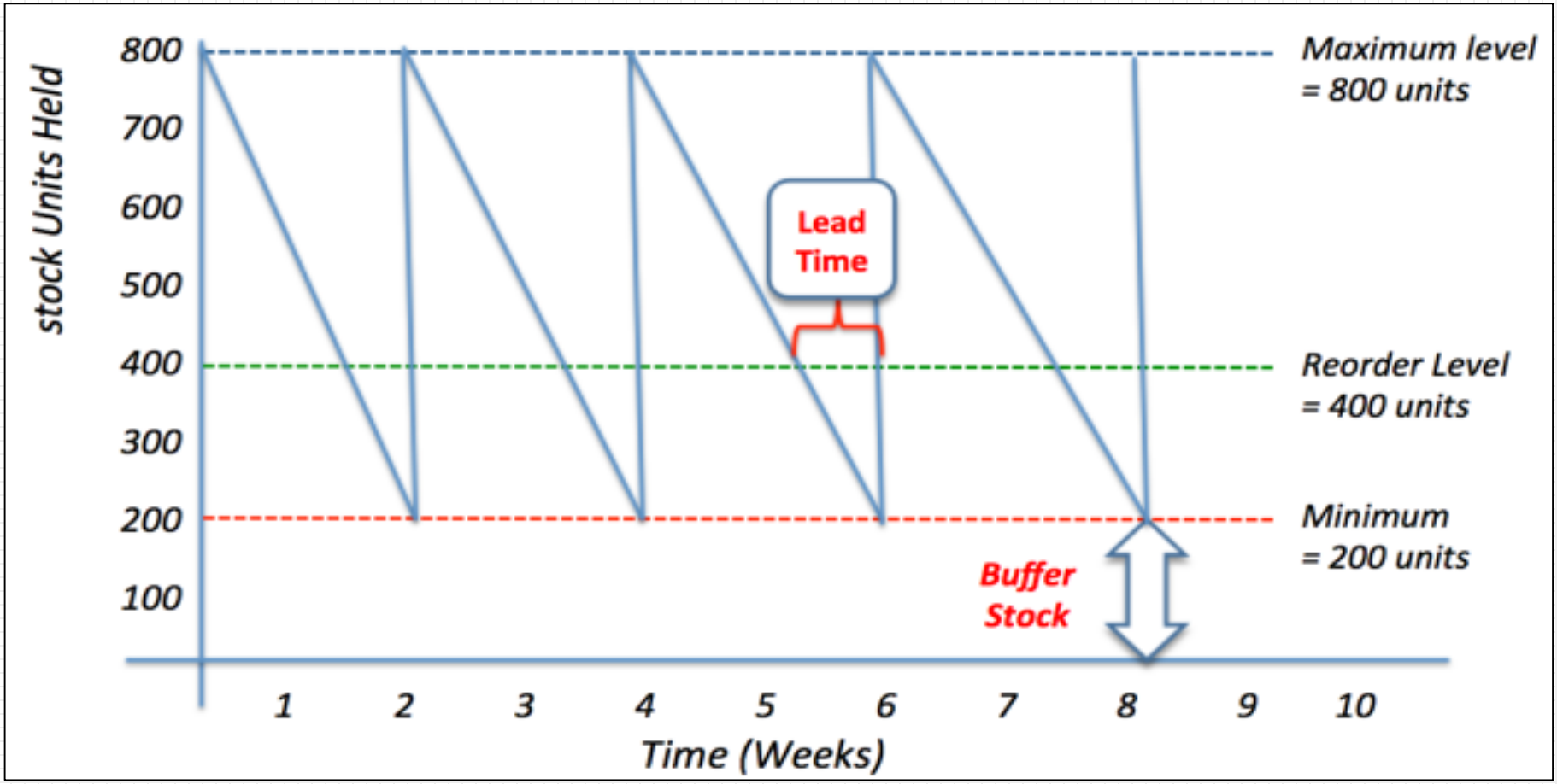
Inventory Policy:



Q = Order Quantity LT = Lead Time d = Demand rate

R = Reorder Point SS = Safety Stock

Inventory Policy:



Q = Order Quantity=600 units

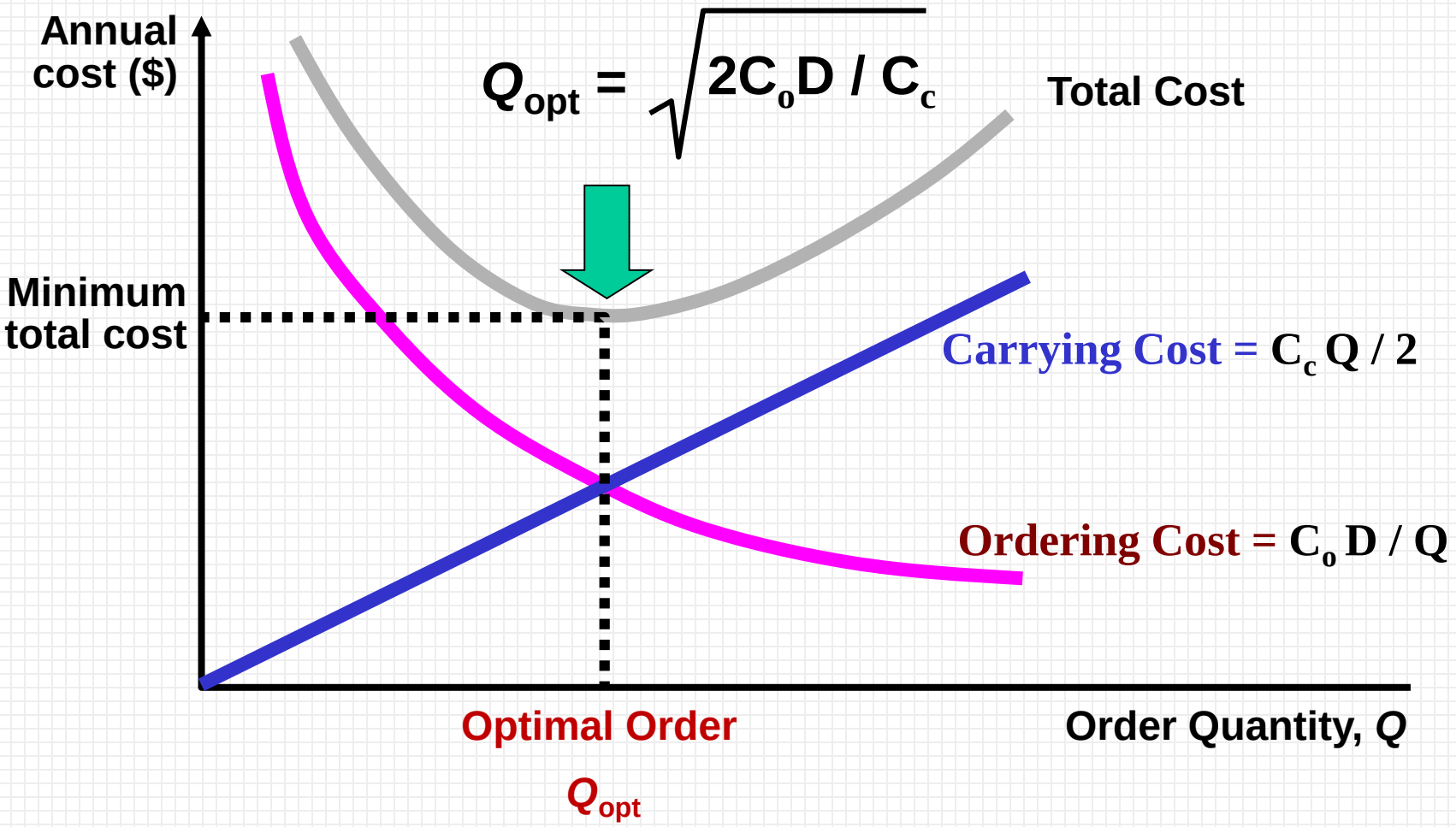
LT = Lead Time = 2 weeks

R = Reorder Point = 400 units

SS = Safety Stock = 200 units

Economic Order Quantity (EOQ or Q_{opt})

Ford Whitman Harris first presented the familiar economic order quantity (EOQ) model, 1913



Economic Order Quantity:

$$Q_{opt} = \sqrt{2C_oD / C_c}$$

Annual Demand = D = 1000 units
Order Cost = $5 / order
Holding Cost = H = $ 1 /unit / year

$$Q_{opt} = \sqrt{2*5*1000/1}$$

= 100

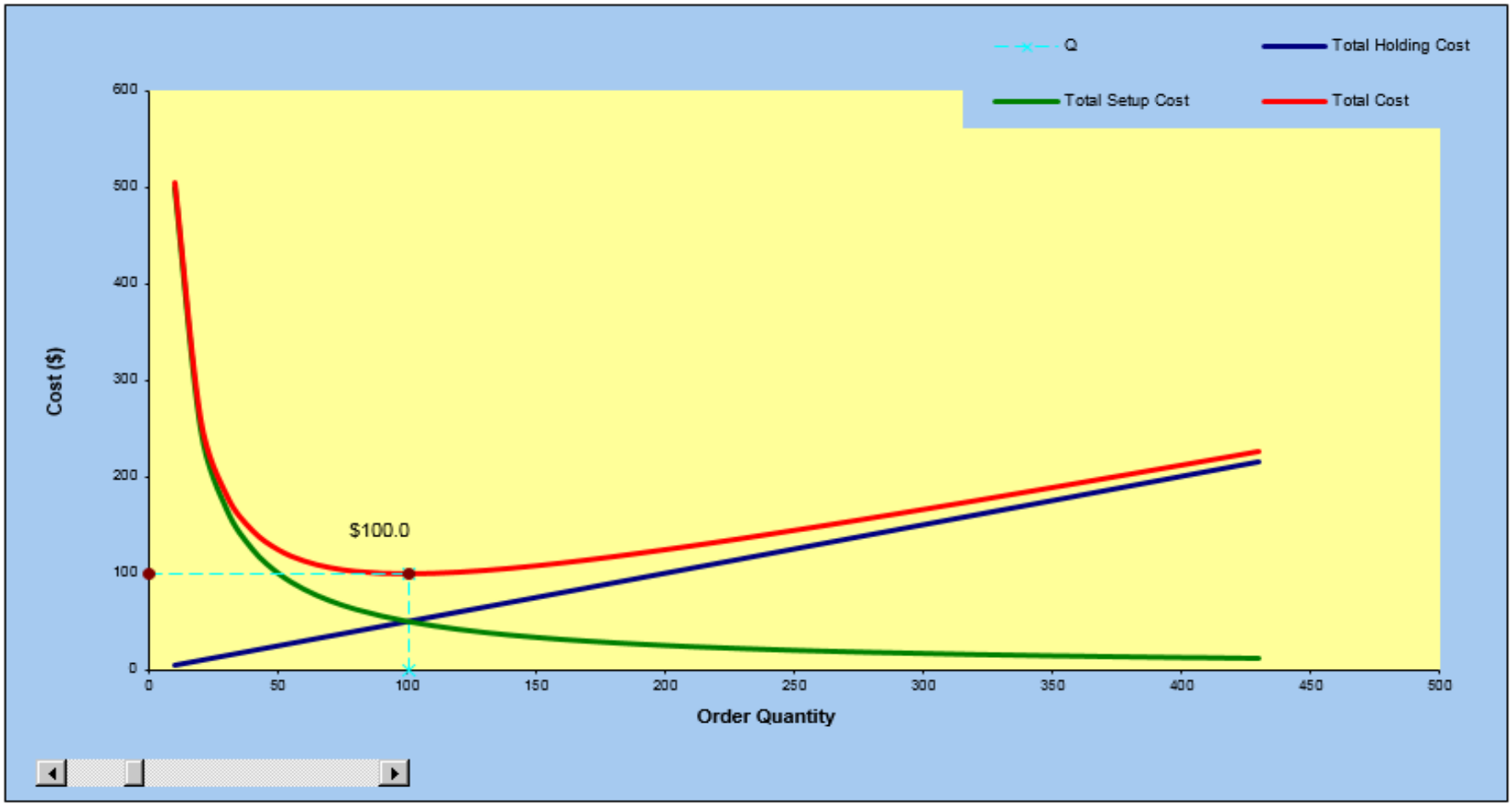
Order Quantity Q	Number of orders = D/Q	Annual Order Cost	Average Stock = Q/2	Annual Holding Cost	Annual Inventory Cost	Min. Cost
50	20	100	25	25	125	
100	10	50	50	50	100	100
200	5	25	100	100	125	
…	…	…	…	…	…	…
500	2	10	250	250	260	
…	…	…	…	…	…	…
1000	1	5	500	500	505	

EOQ and Total Cost Graph

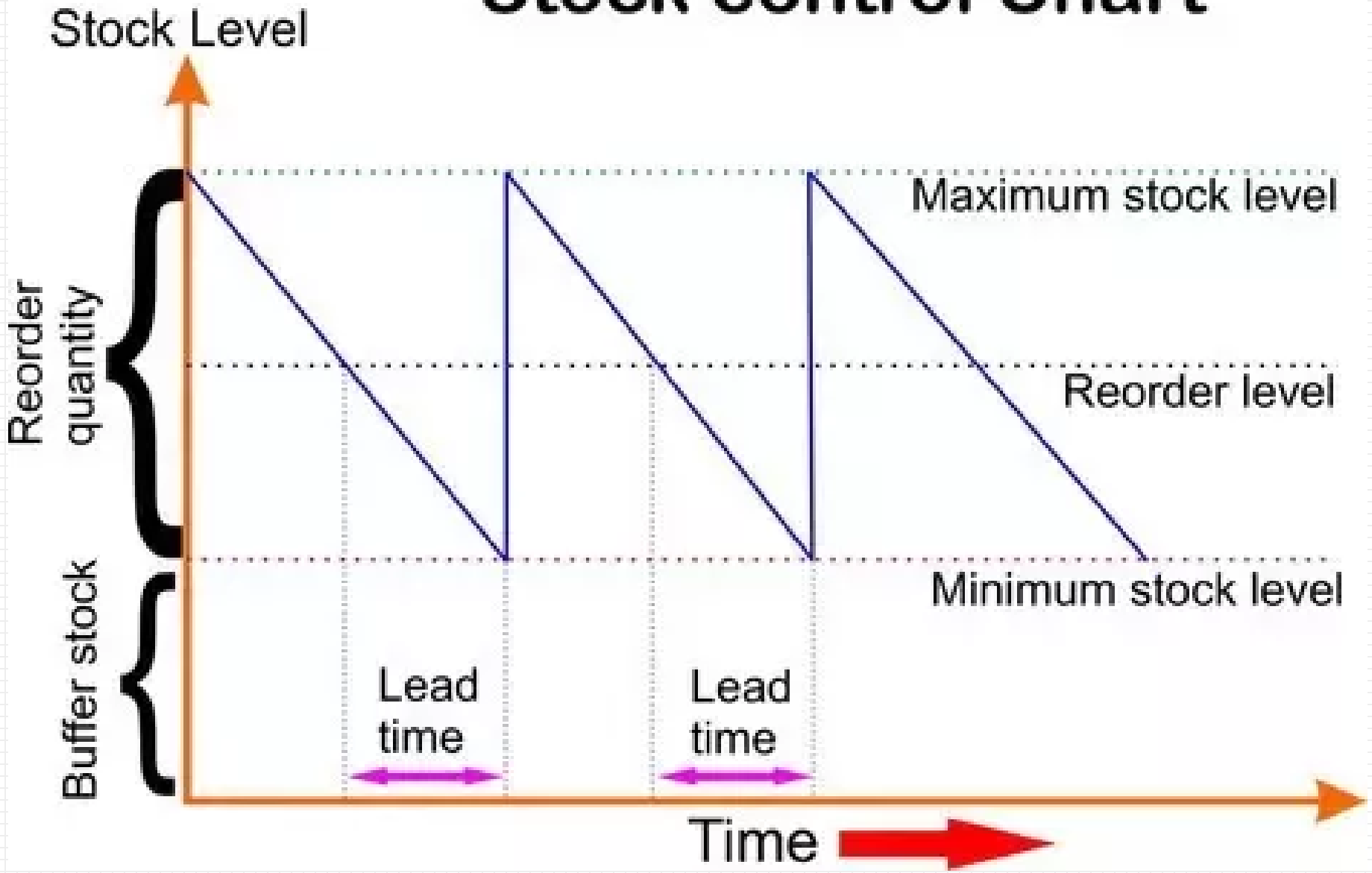
Annual demand (D)	1000
Per Order cost (S)	$5.00
Holding cost per unit per year (H)	$1.00

$$Q_{opt} = \sqrt{2C_oD / C_c}$$

Q_{opt} = 100

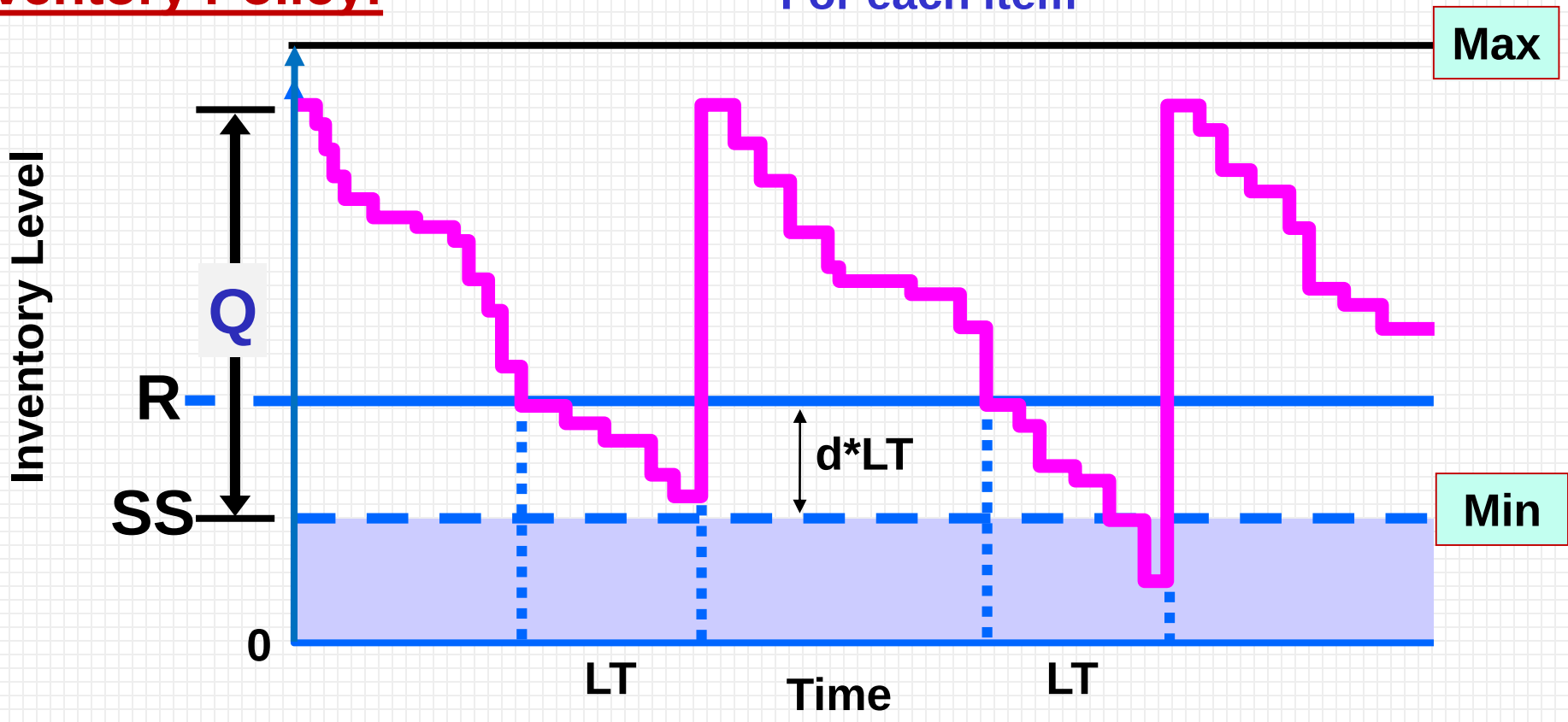


Stock control Chart



Inventory Policy:

For each item



$$Q_{opt} = \sqrt{2C_oD / C_c}$$

D = Annual demand

C_o = Order Cost

C_c = Annual carrying cost per-unit

R = SS + d*L

SS = Safety Stock = (5 to 10%) Annual Demand

Inventory Control:

Item Information:

Equipment: Water Pump
Item: Bearing (2 units/pump)
Item Cost: 1000 $/unit

Number of Equipment: 60
Item Code: BXX
Maintenance Policy: RTF

Annual Demand = 60*2 = 120 Items

Inventory Data:

1. Annual demand = 120 unit/year
2. Unit Material Cost = $1000 / unit
3. Average Order Cost = $20 / order
4. Average Carrying Cost per Unit = $3/year
5. Lead Time = 1 Month

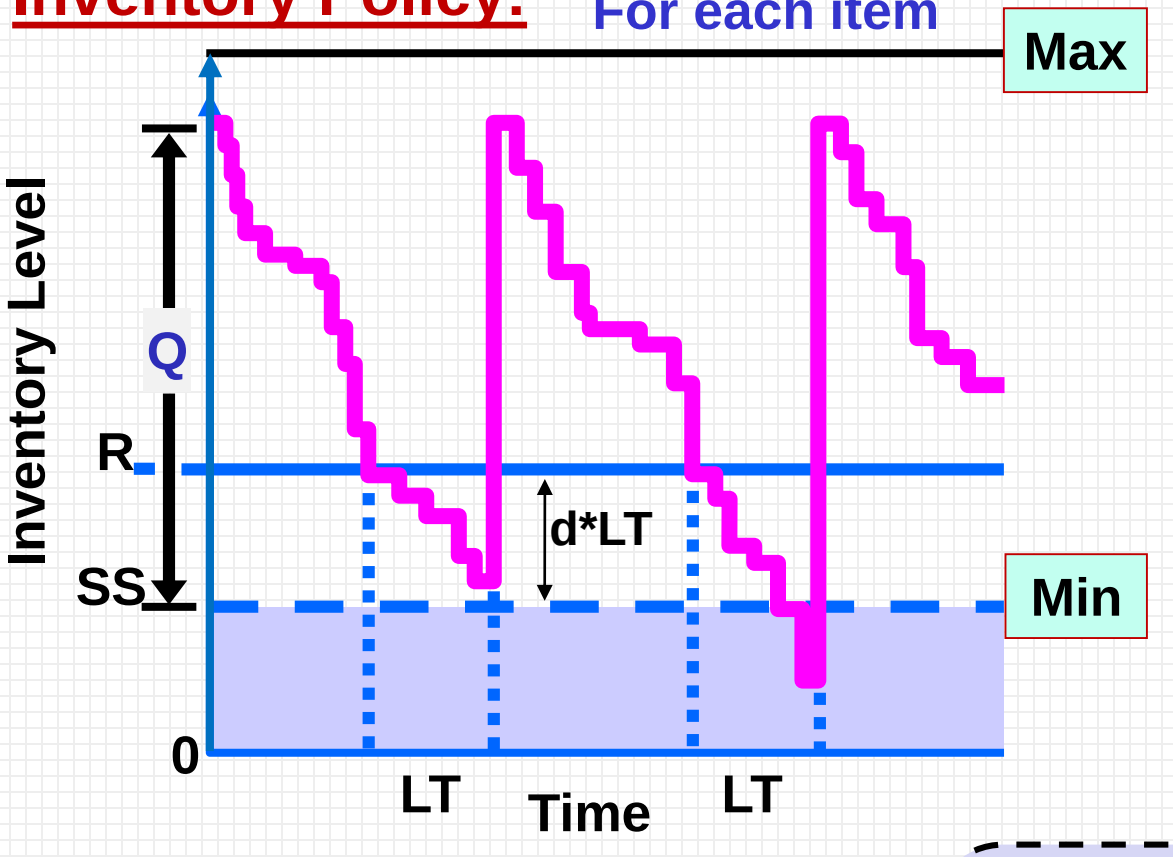
Based on this information, discuss the following:

1) Optimal order quantity
2) Number of Orders
3) Reorder level
4) Stock Control Chart
5) Annual Material Cost (Direct)
6) Annual Inventory Cost (Overhead)

$$Q_{opt} = \sqrt{2C_oD / C_c}$$

Inventory Policy:

For each item



$$Q_{opt} = \sqrt{2C_oD / C_c}$$

$$Q = \sqrt{2*20*120/3}$$

Q = 40 SS = 0

R = SS + d*L

= 0 + 10*1 = 10

Min = SS = 0

Max = Q + SS = 40

Inventory Data:

1. Annual demand = D = 120 unit/year
2. Unit Material Cost = $1000 / unit
3. Order Cost = C_o = $20 / order
4. Carrying Cost = C_c = $3/year
5. Lead Time = LT = 1 Month

Carrying Cost = C_c Q / 2 = 3*40/2 = 60

Ordering Cost = C_o D / Q = 20*120/40 = 60

Inventory Cost = 60+60 = 120

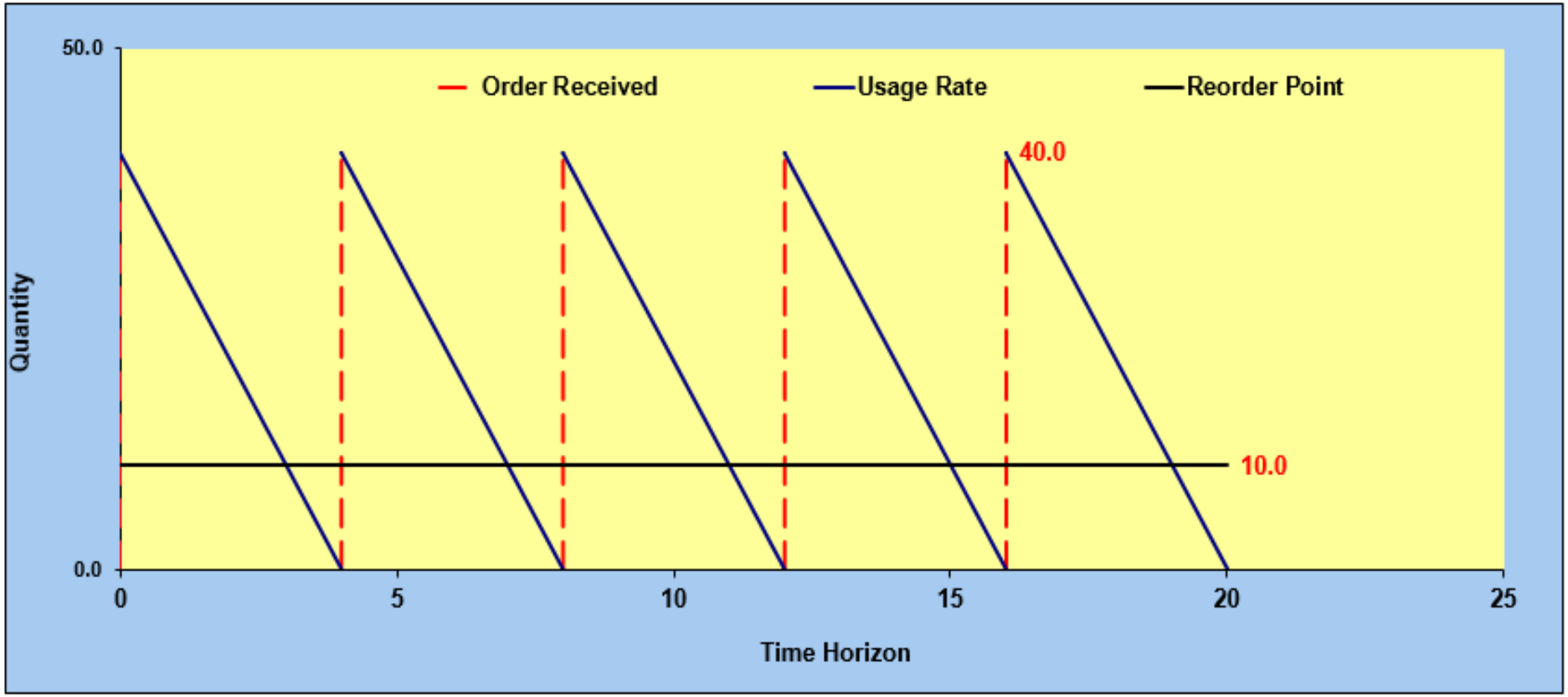
Material Cost = 120*1000 = 120,000

Total Cost = 120,000+120 = 120,120

Fixed Quantity Model

Annual demand (D)	120
Ordering cost (S)	$20.00
Holding cost per unit per year (H)	$3.00
Period in operation per year =	12
Lead time (L)	1
Cost per unit (C)	$1,000.00

Q_0 =		40
Average Inventory =		20.0
Reorder point =		10.0
Periods per cycle =		4.0
Number of cycles per year =		3.0
Total Annual Holding and Ordering Cost =	$	120.00
Total Cost =		120,120.00



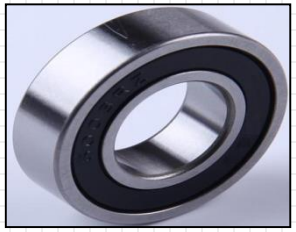
Example:

Item Information:

Equipment: Water Pumps **Item:** Bearing

Inventory Data:

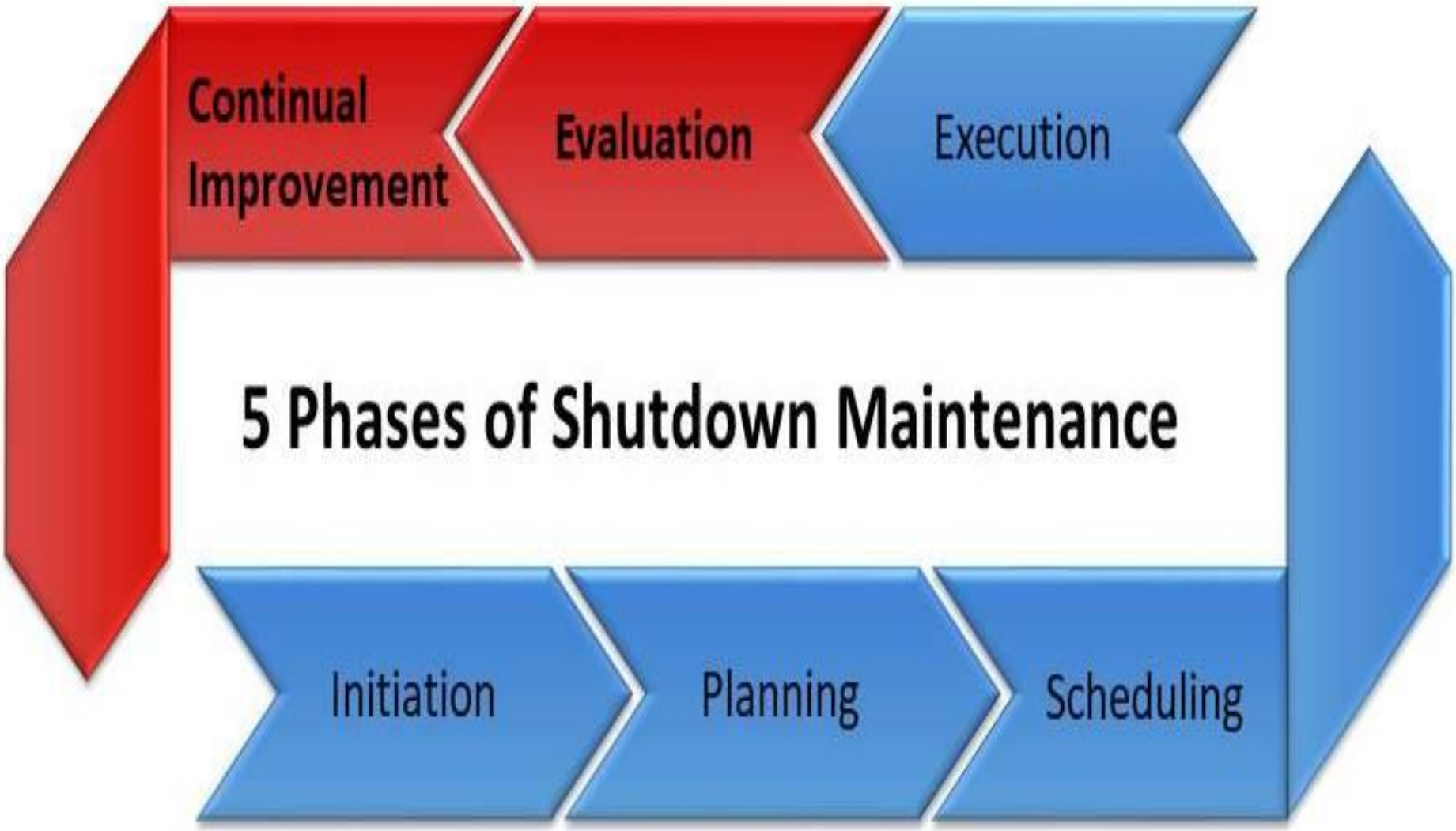
1. Annual demand = 120 unit/year
2. Unit Material Cost = $1000 / unit
3. Average Order Cost = $20 / order
4. Average Carrying Cost per Unit = $3/year
5. Lead Time = 1 Month
6. Safety Stock = 10 units



Based on this information, discuss the following:

1) Optimal order quantity
2) Number of Orders
3) Reorder level
4) Stock Control Chart
5) Average Inventory
6) Annual Material Cost
7) Annual Inventory Cost

Shutdown Maintenance Planning



Project Planning

Inputs

1) Project Description / Charter
2) Work Breakdown Structure
3) Responsibility Matrix
4) Project Estimation
5) Main Activities

Scope Of Work

6) Network
7) Critical Path
8) Schedule / Gantt Chart
9) Material Plan
10) Resource Plan
11) Cost Plan
12) Payment Plan
13) Milestones Plan
14) Risk Plan
15) Quality Plan / QA / QC
16) Contractor / Supplier Selection

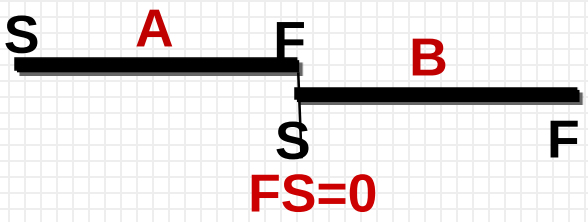
Outputs

End Objectives

Activity Relations:

By default

(FS 0)

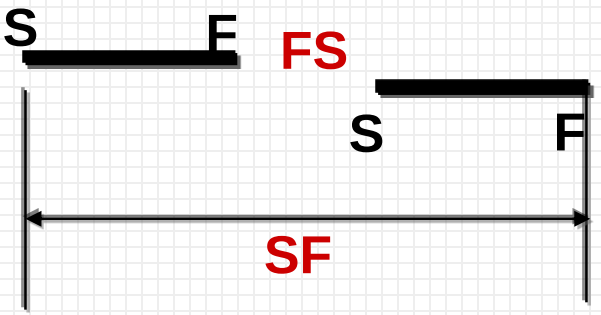


FS – Finish to Start

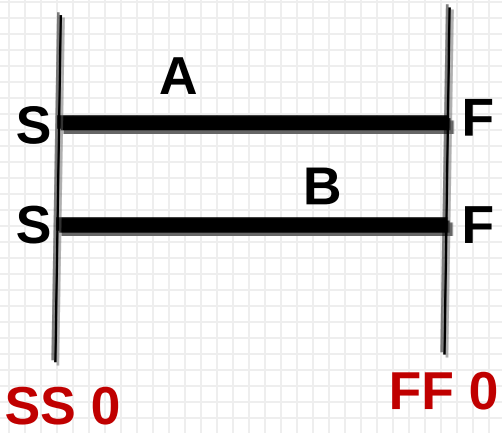
SS – Start to Start

SF – Start to Finish

FF – Finish to Finish



For Example;



Case Study:

Project: Shutdown Planning for Computer Lab 507

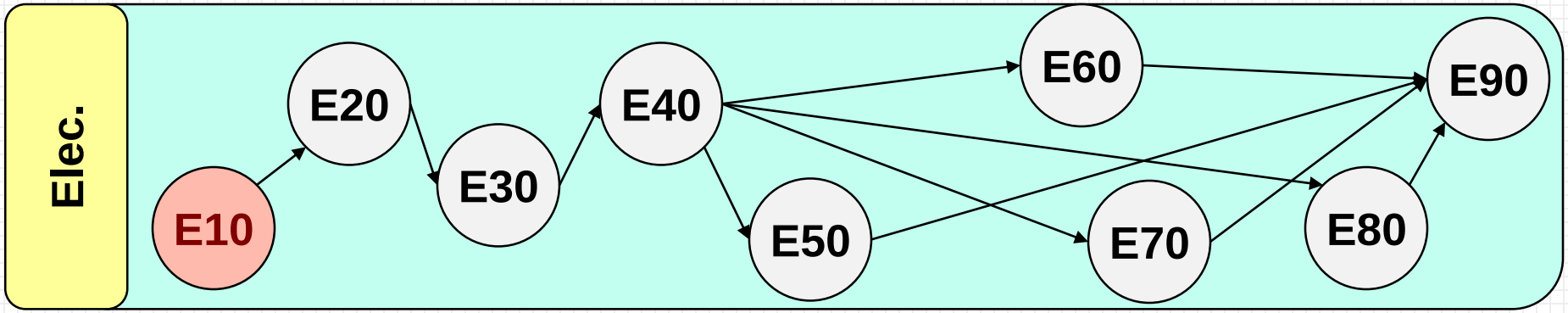
WBS	ID	Activity	Days	Predecessors	Workers	Mat. Cost 1000 LE
Electrical Works	E10	Wiring	2	-	4	10
	E20	Terminals	1	E10 , FS15	4	5
	E30	Control Panel	1	E20	4	20
	E40	Lighting System	2	E30	4	20
	E50	Fire Alarms	1	E40	2	15
	E60	Sound System	2	E40	2	16
	E70	Network	1	E40	2	10
	E80	Datashow	1	E40	2	20
	E90	Final Test	1	E50, E60, E70, E80	2	4

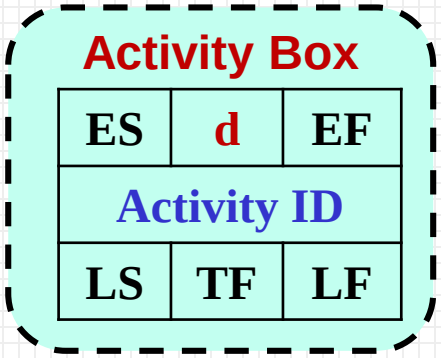
Constraints: Max. # Workers = 4 Workers Cost Rate: 200 LE/man-day

Based on this information, discuss the following:

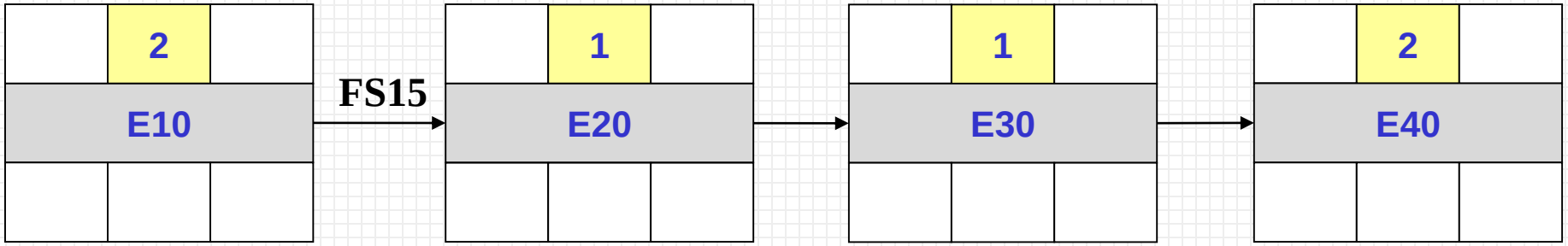
1- Network 2- Critical Path 3- Gantt Chart 4- Resource Plan 5- Cost Plan

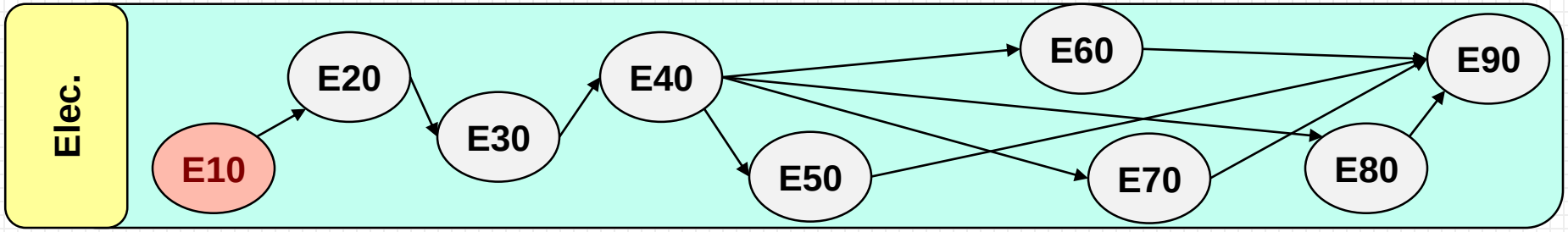
Network:

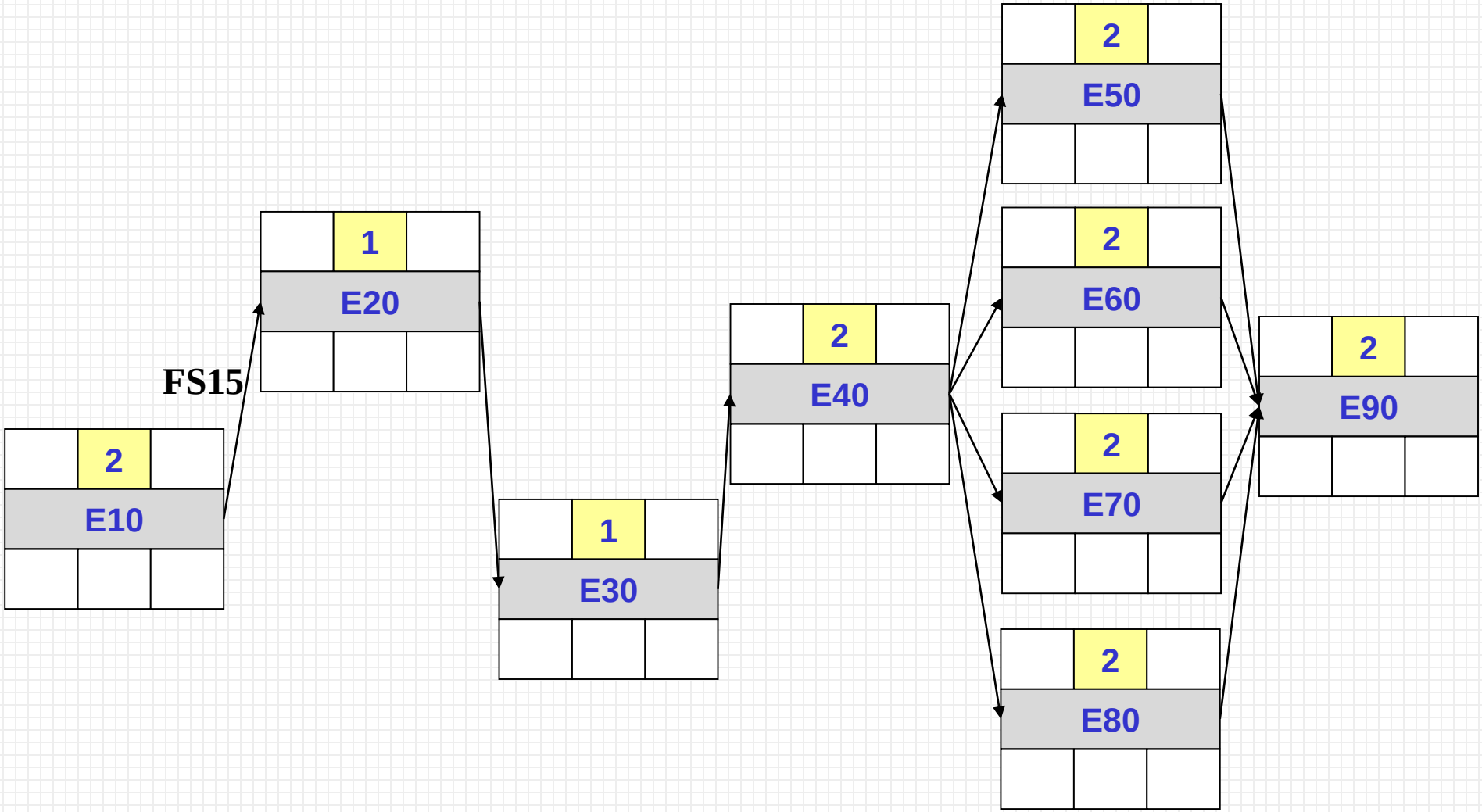


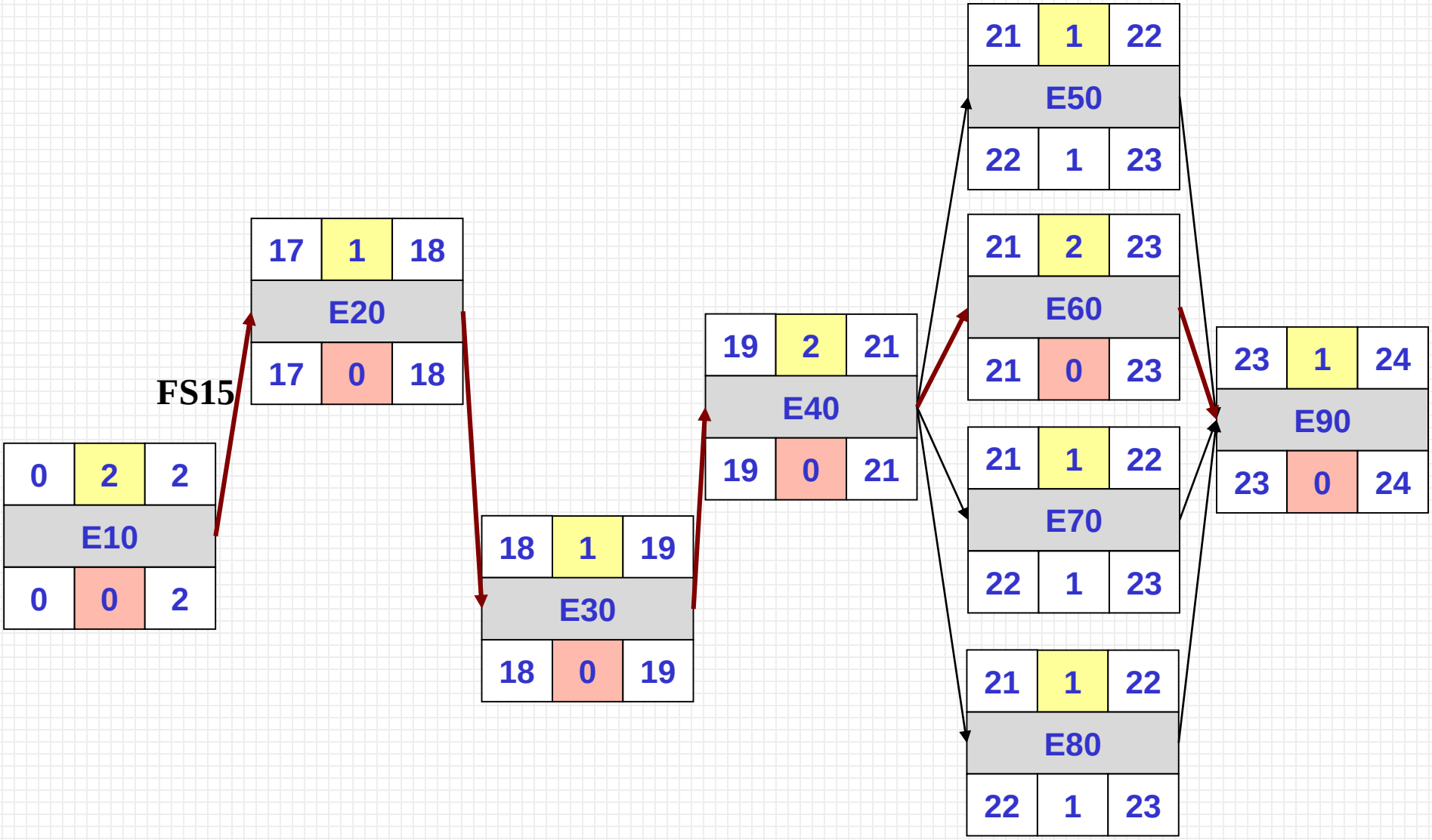


d: Duration (given)
ES: Early Start
EF: Early Finish
LF: Late Finish
LS: Late Start
TF: Total Float




Elec.
E10
E20
E30
E40
E50
E60
E70
E80
E90


2
E10
FS15
1
E20
1
E30
2
E40
2
E50
2
E60
2
E70
2
E80
2
E90



Min. Duration = 24 days **Critical Path: E10, E20, E30, E40, E60, E90**

Schedule / Gantt Chart

ID	Days	Crews	Material 1000 LE	Duration (Days)										
				1	2	…	18	19	20	21	22	23	24	
E10	2	4	10	4	4									
E20	1	4	5				4							
E30	1	4	20					4						
E40	2	4	20						4	4				
E50	1	2	15								2	- -		
E60	2	2	16								2	2		
E70	2	2	10								2	- -		
E80	1	2	20								2	- -		
E90	1	2	4										2	
# of Workers				4	4		4	4	4	4	8	2	2	
Cost 1000 LE														

Schedule / Gantt Chart

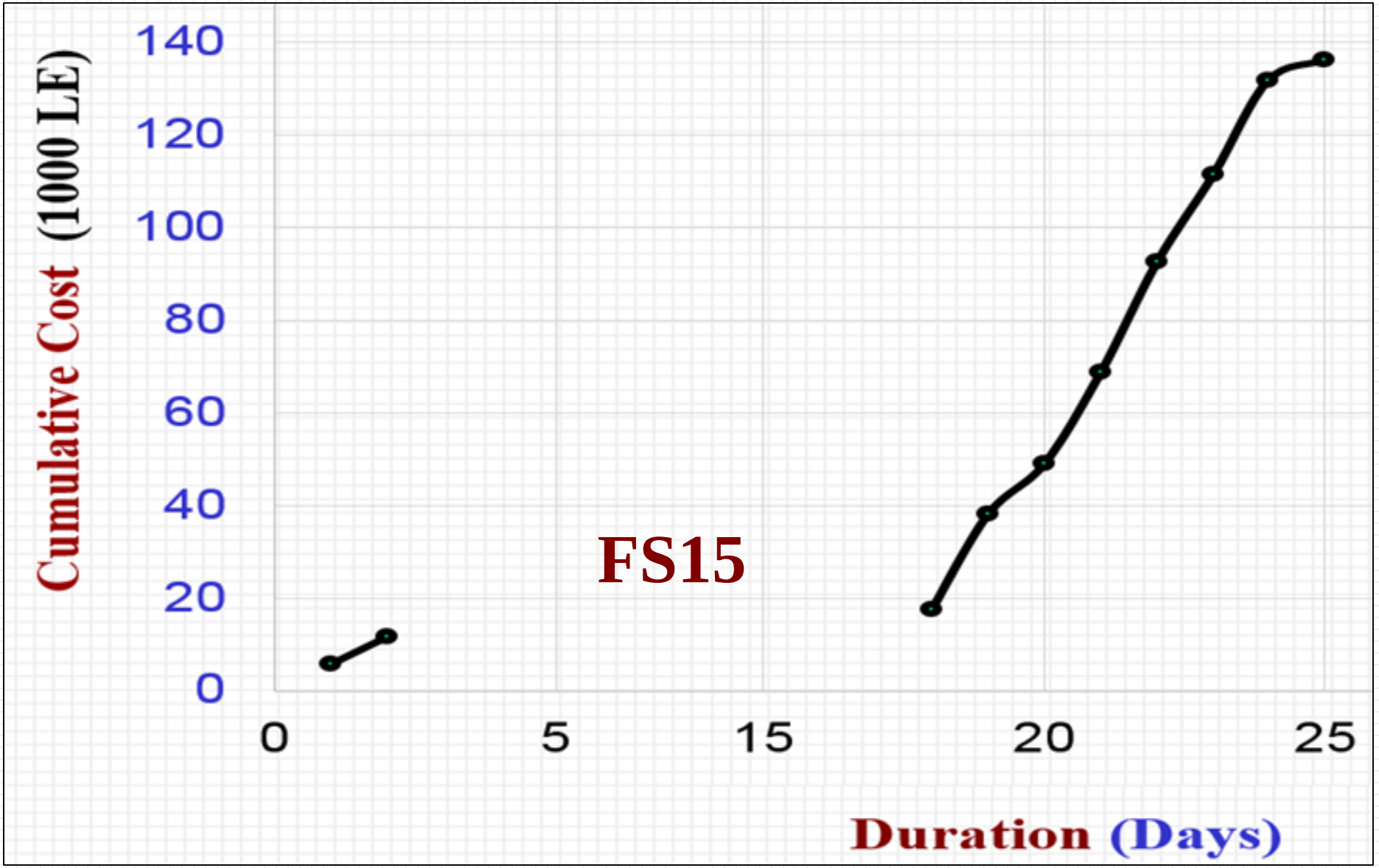
ID	Days	Crews	Material 1000 LE	Duration (Days)										
				1	2	…	18	19	20	21	22	23	24	
E10	2	4	10	4	4									
E20	1	4	5				4							
E30	1	4	20					4						
E40	2	4	20						4	4				
E50	1	2	15								2	- -		
E60	2	2	16								2	2		
E70	2	2	10									2		
E80	1	2	20									2		
E90	1	2	4										2	
# of Workers				4	4		4	4	4	4	4	6	2	

Resource Smoothing

Target Schedule / Resource Plan / Cost Plan

ID	Days	Crews	Material 1000 LE	Duration (Days)										
				1	2	…	18	19	20	21	22	23	24	25
E10	2	4	10	5	5	…								
E20	1	4	5			…	5							
E30	1	4	20			…		20						
E40	2	4	20			…			10	10				
E50	1	2	15			…					15	- -		
E60	2	2	16			…					8	8		
E70	2	2	10			…						10		
E80	1	2	20			…							20	
E90	1	2	4			…								4
						…								
# of Workers				4	4	…	4	4	4	4	4	4	2	2
Labor Cost				0.8	0.8	…	0.8	0.8	0.8	0.8	0.8	0.8	0.4	0.4
Material Cost				5	5	…	5	20	10	19	23	18	20	4
Total Cost				5.8	5.8	…	5.8	20.8	10.8	19.8	23.8	18.8	20.4	4.4
Cumulative Cost				5.8	11.6	11.6	17.4	38.2	49	68.8	92.6	111	132	136

Total Cost: S Curve



Case Study:

Project: Shutdown Maintenance Project

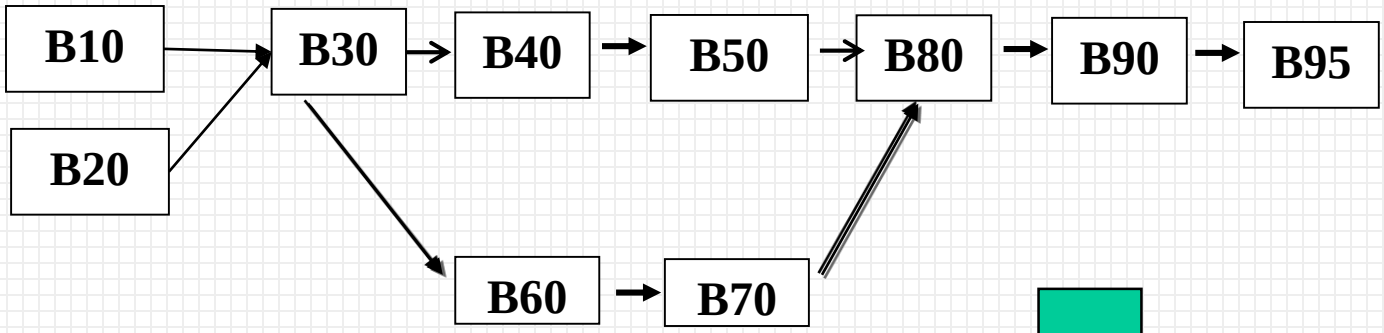
Main Item: Boiler Maintenance (Annual Inspection)

WBS	ID	Activity description	Days	Predecessor	Mech. Workers
Mechanical Works	**B10**	Moblization	1	-	2
	B20	Shut down & cool down boiler	1	-	2
	B30	Open man ways & clean boiler	1	B10 , B20	2
	B40	Inspect refractory	2	B30	2
	B50	Repair damaged refractory	4	B40	2
	B60	Replace bad tubes	2	B30	2
	B70	Perform hydrostatic test on tubes	1	B60	2
	B80	Close man ways	1	B50 , B70	2
	B90	Fire up boiler & Run test	1	B80	2
	B95	Demobilization	1	B90	2

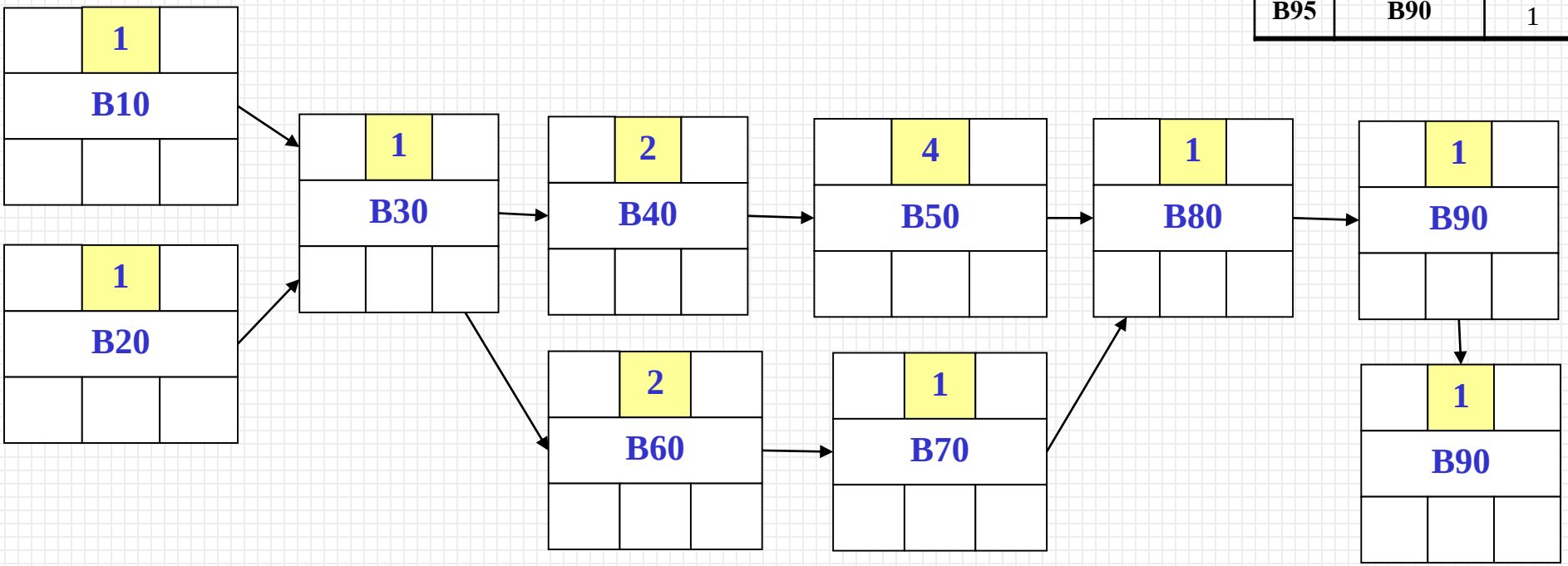
Constraints:

Maximum duration = 12 days **Maximum Resources = 4 Mech. Labors**

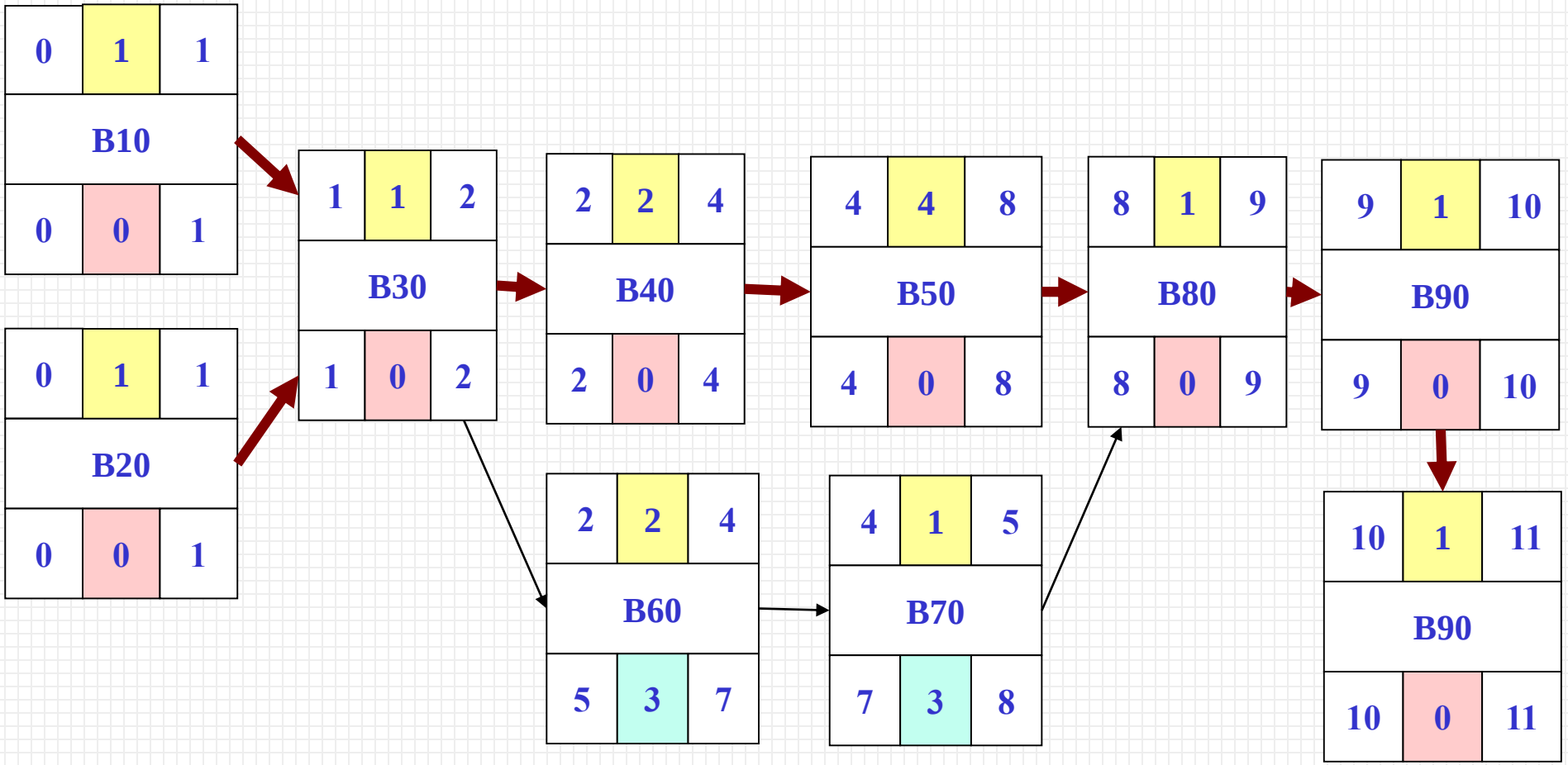
Network Diagram:



ID	Pred.	Days
B10	-	1
B20	-	1
B30	B10 , B20	1
B40	B30	2
B50	B40	4
B60	B30	2
B70	B60	1
B80	B50 , B70	1
B90	B80	1
B95	B90	1



Network Diagram:



Planned Duration = 11 days
Critical Path: B10-B20-B30-B40-B50-B80-B90-B95
Noncritical Activities: B60-B77

Gantt Chart: (Critical Resources)

Main Item: Boiler Maintenance (Annual Inspection)

ID	Pred.	Days	Workers	Duration (Days)											
				1	2	3	4	5	6	7	8	9	10	11	12
B10	-	1	2	2											
B20	-	1	2	2											
B30	B10 , B20	1	2		2										
B40	B30	2	2			2	2								
B50	B40	4	2					2	2	2	2				
B60	B30	2	2			2	2	--	--	--					
B70	B60	1	2					2	--	--	--				
B80	B50 , B70	1	2									2			
B90	B80	1	2										2		
B95	B90	1	2											2	
# of Workers				4	2	4	4	4	2	2	2	2	2	2	

Constraints:

Maximum duration = 12 days

Maximum Resources = 4 Mech. Labors

Case Study:

Project: Maintenance & Repair for Mobile Crane 50 ton

Main Item: Engine Overhaul

Case Study:

Project: Maintenance & Repair for Mobile Crane 50 ton

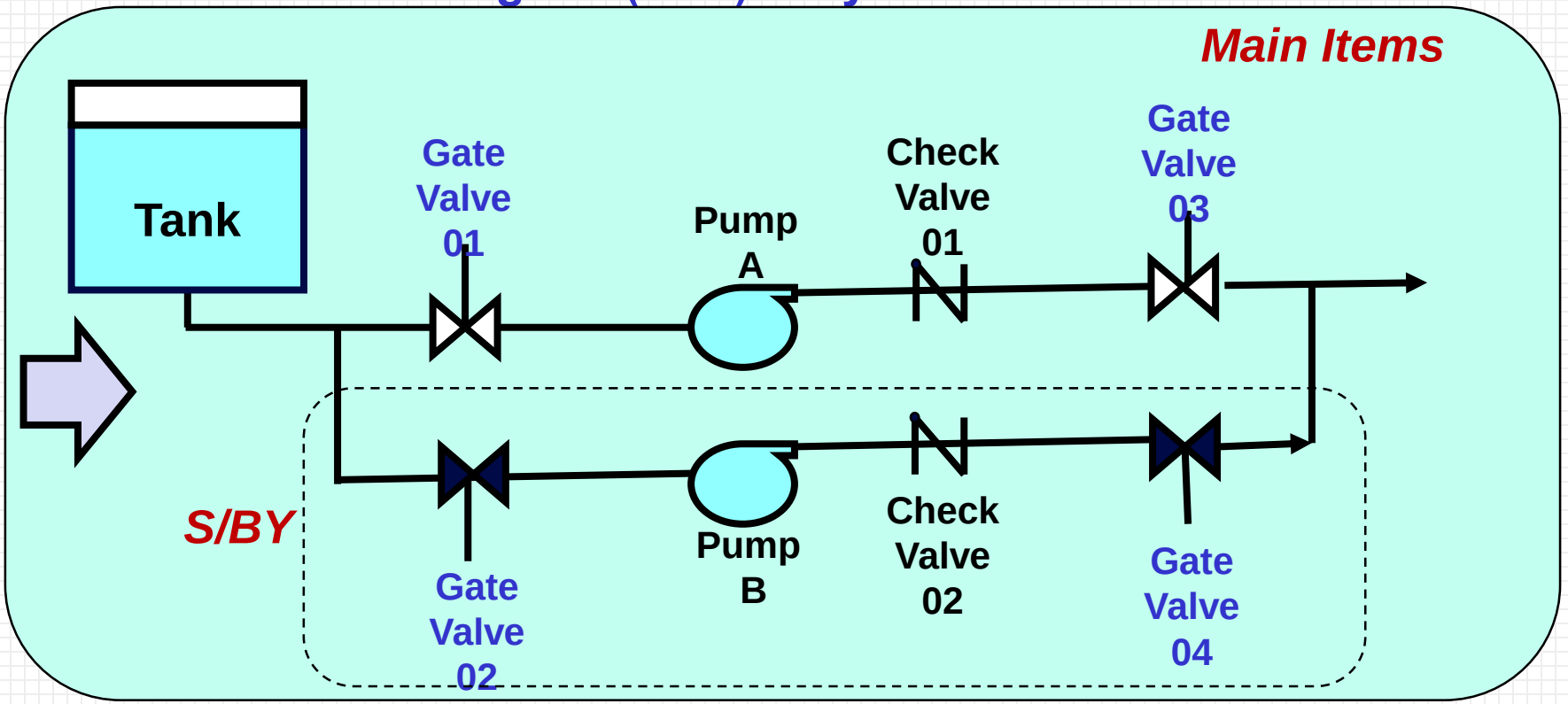
Main Item: Engine Overhaul

ID	Activity Description	Duration (day)	Predecessors	Resource (workers)
E00	Inspection	1	-	2
E01	Disassembly	1	E00	2
E02	Cleaning	1	E01	2
E03	Visual Inspection	1	E02	2
E04	Dimension Inspection	1	E03	2
E05	Non Destructive Test (NDT)	1	E03	2
E06	Part Request	2	E04, E05	2
E07	Repair	2	E05	2
E08	Replacement	2	E06	2
E09	Assembly	2	E07,E08	2
E10	Test & Operation	1	E09	2

Constraints: Max. # Workers = 4 Workers **Cost Rate:** 100 LE/man-hour

System / Area: Crude Oil Pump Station

Process Flow Diagram (PFD) "Layout":



Equipment List (Tree):

#	Equipment Type	Short Description	Main Function Parameters	Numbers	TAG No.
1	Pump	Centrifugal		2	410-P-01A 410-P-01B
2	Tank	Water Cooling		1	410-TK-01

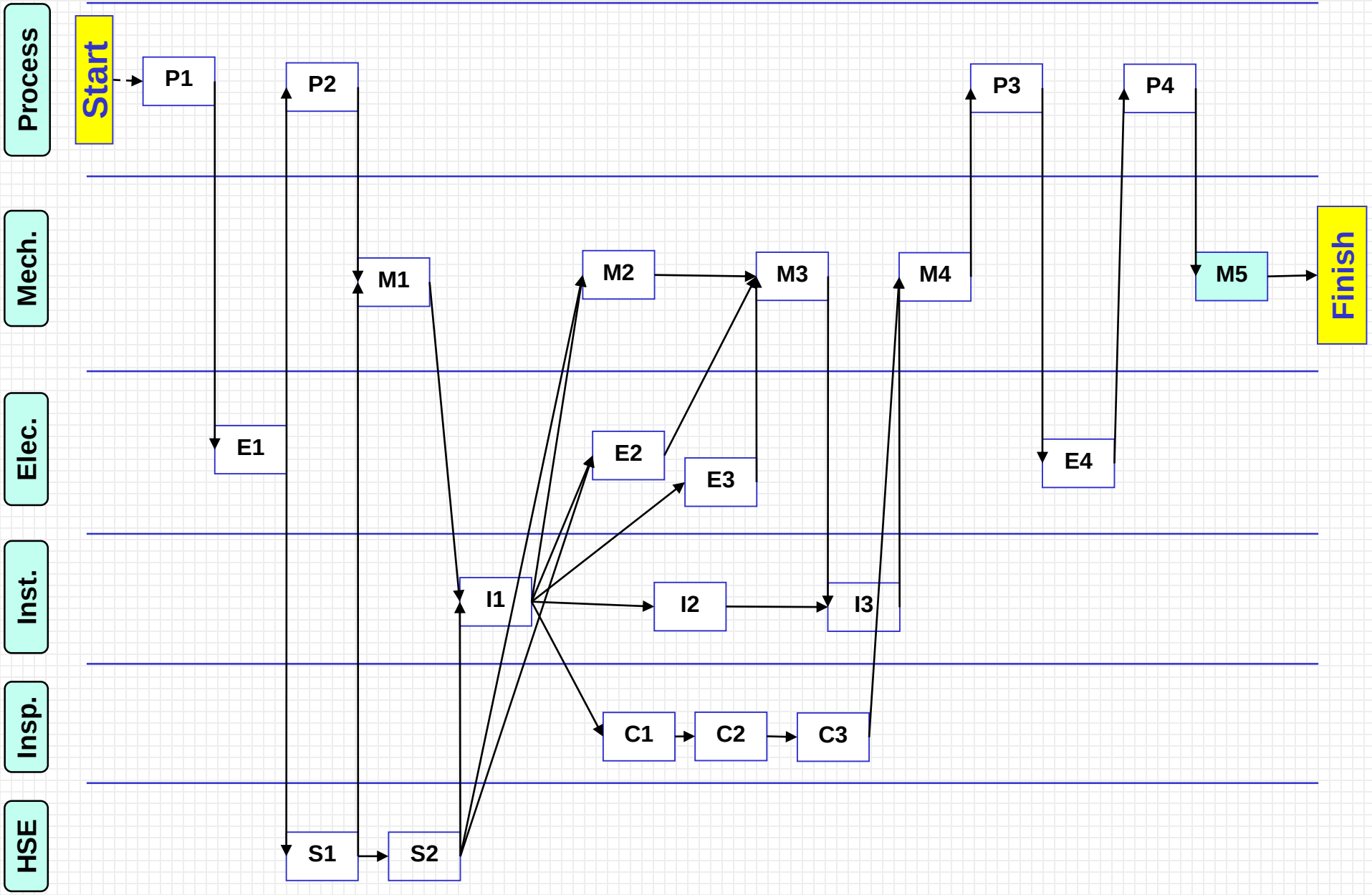
Shutdown Activity Matrix

Work Types	Stages				
	Shutdown	Isolation	Maintenance & Inspection	De-isolation	Start up
Process	Pre-shutdown	Process Isolation		Process De-isolation	Run Test
Mech. Maintenance		Mech. Isolation	Pump Overhauling Pump Alignment	Mech. De-isolation	Vibration Test
Elec. Maintenance		Elec. Isolation	Motor Overhauling SWG Check	Elec. De-isolation	
Instruments			Inst. Disconnect Inst. Check & Repair Inst. Re-connect		
Inspection			Open Tank Man-way Tank Insp. & Repair Close Tank Man-way		
HSE	Work Permits	Isolation Check			Gas Check

Project: Shutdown for Crude Oil Pump Station XXX

WBS	ID	Activity Description	Duration (Hrs.)	Predecessors	Workers
Process	P1	Pre-shutdown	2	-	1 P, 1 M, 1 E
	P2	Process Isolation	3	E1	2 P
	P3	Process De-isolation	3	M4	2 P
	P4	Run Test	12	E4	1 P
Mech.	M1	Mech. Isolation	3	P2	4 M
	M2	Pump Overhauling	36	E1, I1, S2	2 M
	M3	Pump Alignment	12	M2 , E2, E3	2 M
	M4	Mech. De-isolation	3	I3 , C3	4 M
	M5	Vibration Test	3	P4 (SS2)	1 M
Elec.	E1	Elec. Isolation	3	P1	1 E
	E2	Motor Overhauling	24	I1, S2	2 E
	E3	SWG Check	24	I1,	2 E
	E4	Elec. De-isolation	3	P3	1 E
Inst.	I1	Instruments Disconnect	8	M1 , S2	2 I
	I2	Instruments Check & Repair	24	I1	1 I
	I3	Instruments Re-connect	12	M3 , I2	2 I
Insp.	C1	Open Tank Man-way	2	I1	1 M
	C2	Tank Inspection & Repair	24	C1	2 C
	C3	Close Tank Man-way	2	C2	1 M
HSE	S1	Isolation Check	2	E1, M1	1 S
	S2	Gas Check	1	S1	1 S

Logic Diagram:



Maintenance Control & KPIs

Key Objective:

Improve Quality (RAMS) at Low Cost

Maintenance Feedback

W/o Feedback

OK / Done / Complete

Quantitative
"Measurable"
➔ Indicators??

Qualitative
"Comments"

Close-out

Operational Availability & Reliability & Utilization Analysis

KPIs

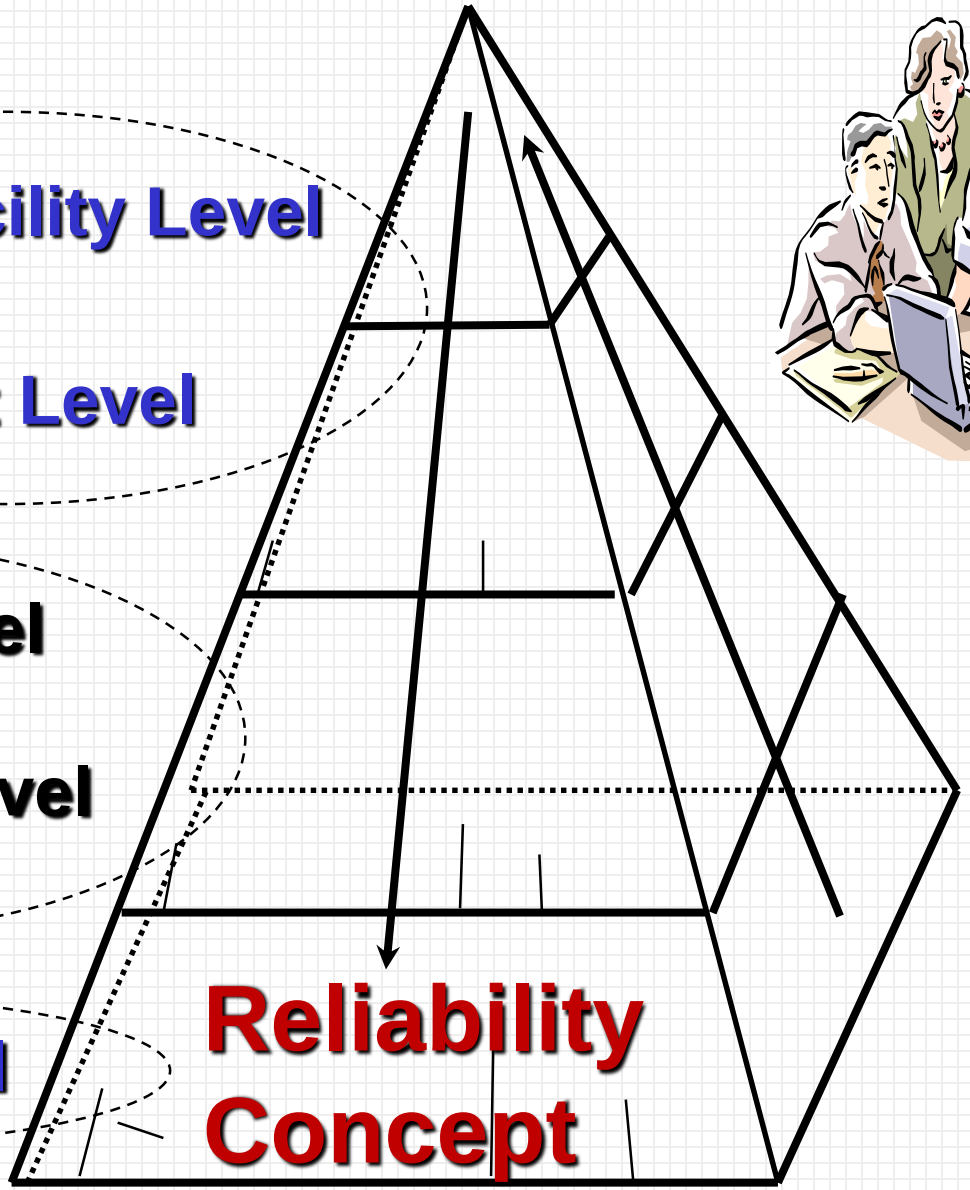
Facility Level

Plant Level

System Level

Equipment Level

Component Level

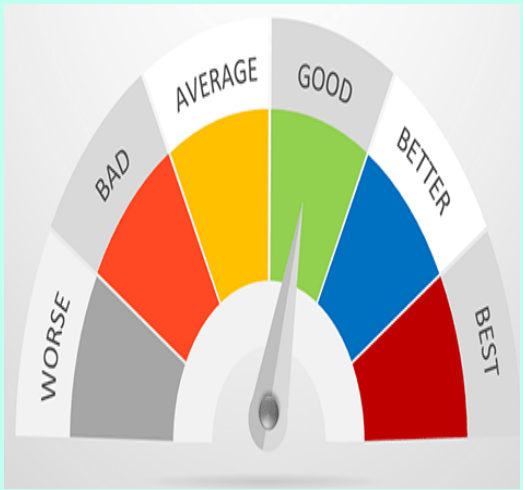


Feedback & Performance Indicators

1) W/o Feedback

-

-



2) Performance Indicators

-

-

3) Conclusion & Recommendations

-

Maintenance Record / Maintenance Feedback

System / Equipment: **ID:** **Criticality:**

W/O	Type	Level	Policy	Target Finish	Actual Finish	Downtime Hours	Maintenance Time Hours	Spare Parts	Direct Cost	..
#1										
#2										
#3										
#4										
#5										
#6										
#7										
#8										
#9										
…										
…										

Level: **M01:** Monthly **M03:**Quarter **M06:** Semi Annual **M12:** Annually

Maintenance Record / Maintenance Feedback

System: Fire Fighting Pump **ID:** XX/XX/A **Criticality:** SCE

M01: Monthly **M03:**Quarter **M06:** Semi Annual **M12:** Annually

W/ O	Type	Level	Policy	Target Finish	Actual Finish	Downtime Hours	Maintenance Time hours	Spare Parts	Direct Cost LE
#1	PM	M01	R	25/1/2018	24/1/2018	-	2	-	1,000
#2	PM	M01	R	22/2/2018	27/2/2018	-	3	-	1,000
#3	PM	M03	S/D	29/3/2018	01/4/2018	4	6	Seal	4,000
#4	PM	M01	R	26/4/2018	24/4/2018	-	3	-	1,000
#5	PM	M01	R	31/5/2018	30/5/2018	-	2	-	1,000
#6	PM	M06	S/D	28/6/2018	30/6/2018	16	19	Bearing	6,000
#7	PM	M01	R	26/7/2018	29/7/2018	-	3	-	1,000
#8	CM	-	S/D	20/8/2018	20/8/2018	10	16	Seal	10,000
#9	PM	M01	R	30/8/2018	-	-	-	-	-
#10	PM	M03	S/D	27/9/2018	20/10/2018	6	7	Seal	4,000
#11	PM	M01	R	25/10/2018	22/10/2018	-	1	-	1,000
#12	PM	M01	R	29/11/2018	26/11/2018	-	4	-	1,000
#13	PM	M12	S/D	27/12/2018	30/12/2018	24	36	Bearing	20,000

Based on this information; discuss maintenance performance indicators

Maintenance Performance Indicators & KPIs

Maintenance Performance Indicators
(Department Level – Operational Level)

1. MTTR ➔ Item Level
2. MTTM ➔ PM Level
3. CM / PM ➔ S/D W/o
4. CM % , PM% ➔ S/D W/o
5. CM / PM ➔ # , Time, Cost
6. MTBF ➔ Item Level
7. Availability % ➔ (T-D)/T
8. Reliability % ➔ RH/(RH+CD)
9. Utilization % ➔ Running/Calendar
10. Maintenance Cost Rate ➔ $/hour or $/unit
11. Breakdown Losses ➔ units/hour or $/hour
12. Overdue % ➔ Delay & On hold %
13. Backlog % ➔ Delay but finish
14. Canceled % ➔ Non critical
15. Compliance % ➔ PM Efficiency
16. … etc.

Maintenance KPIs
(Facility Level)

1. Reliability %
2. Availability %
3. Compliance %
4. Overdue SCE %
5. Breakdown Losses
6. Maintenance Cost Rate
7. … etc.

(Max. 8 Indicators)
"Most Effective"

Data Collection Plan *For example:*

Performance Metric(s)	Definition of metric	Data	Data source	Frequency	Responsibility
Availability %	A = (T-D)/T D=PMD + CMD	T=Total Time	Calendar	Annual	Planner
		PMD= PM Downtime	PM W/o	Annual	Planner
		CMD= CM Downtime	CM W/o	Annual	Planner
Reliability %	R = (T-D)/ (T-PMD)	≈	≈	Annual	Planner
Unplanned %	CM/PM %	CM = summation of all CM W/o	CM W/o	Annual	Planner
		CM = summation of all PM W/o	PM W/o	Annual	Planner
Overdue %					

Feedback (W/o Analysis)

Work Order Status

Weekly:
Start: Sunday 8 Am
End: Saturday 4 Pm

- **Completed**
  - **On Schedule**
  - **Overdue**
- **Waiting**
  - **Backlog (On Hold)**
- **Cancelled**

Routine maintenance for non-critical equipment

Why?

(Cause, root cause, consequence, … etc.)

Feedback (W/o Analysis)

100 W/o

Work Order Status

Weekly:
Start: Sunday 8 Am
End: Saturday 4 Pm

80 **Completed**

5 **Waiting**

60 **On Schedule**

20 **Overdue**

5 **Backlog**

15 **Cancelled**

PM Efficiency
(Compliance%)
80/100 = 80%

On Schedule
60/100 = 60%

Overdue %
20/100 = 20%

Backlog %
5/100 = 5%

Cancelled %
15/100 = 15%

Why?

(Cause, root cause, consequence, … etc.)

Safety Critical Elements (SCE)

100 W/o

Work Order Status

Fire Fighting Pumps / Boilers / Turbine / ..

80 Completed

5 Waiting

60 On Schedule

20 Overdue

5 Backlog

15 Cancelled

PM Efficiency (Compliance%) 80/100 = 80%

On Schedule 60/100 = 60%

Overdue % 20/100 = 20%

Backlog % 5/100 = 5%

Cancelled % 15/100 = 15%

For SCE ➔ Safety Risk Indicators (Target = 0)

Near Miss

Process Critical Elements (PCE)

100 W/o

Work Order Status

PCE
Equipment without standby

80 **Completed**

5 **Waiting**

60 **On Schedule**

20 **Overdue**

5 **Backlog**

15 **Cancelled**

PM Efficiency
(Compliance%)
80/100 = 80%

Overdue %
20/100 = 20%

Backlog %
5/100 = 5%

Cancelled %
15/100 = 15%

For PCE ➔ Process Risk Indicators
(Target ≤ 5%)

On Schedule
60/100 = 60%

Schedule Compliance Score

Time Period	Scheduled Jobs	Completed Jobs	Compliance Score
Week 1	7	5	2 jobs missed
Week 2	3	3	0 jobs missed
Week 3	5	4	1 job missed
Week 4	6	3	3 jobs missed
Total	**21**	**15**	**70 percent**

Compliance Score = (Completed jobs) / (Scheduled jobs)

= (5+3+4+3) / (7+3+5+6) = 0.7 = **70%**

Annual Maintenance Control

System: A Water Pumping Station (8 units 6 Running & 2 Standby)

Annual PM Performance:

PM Level	Weekly	Monthly	Annual
Check	Check …	Check …	Check …
Replace	-	-	Pump seal Pump bearing
Maintenance Type	Running	Running	Shutdown

Actual # of PM W/o	250	60	6
Overdue W/o	25	10	2

Annual CM Performance:

Item	Total	Minor CM	Pump seal	Pump bearing	Coupling	Impeller	Motor bearing
Number of CM Work Orders	18	10	3	2	1	1	1
Maintenance Type	-	Running	Shutdown				

Based on this information, discuss performance indicators

Feedback (W/o Analysis)

Work Order Types

- **PM**
  - **Running** — "Check"
  - **Shutdown** — "Downtime"
- **CM**
  - **Running** — "Minor CM"
  - **Shutdown** — "Major CM"
- **Design Change**
  - R&D
  - Projects

Feedback (W/o Analysis)

100 W/o

Work Order Types

- 80 PM
  - 70 Running "Check"
  - 10 Shutdown "Downtime"
- 17 CM
  - 12 Running "Minor CM"
  - 5 Shutdown "Major CM"
- 3 Design Change

Total W/o:
PM% = 80%
CM% = 17 %
CM/PM = 21%

Shutdown Work Oders:
PM% = 10/(10+5)= 67%
CM% = 5/(10+5) = 33%
CM/PM = 5/10 = 50%

Running Work Orders:
PM% = 70/(70+12)= 85%
CM% = 12/(70+12)= 15%
CM/PM = 12/70 = 17%

CM / PM Ratio (#, hours, downtime, man-hour, cost, … , overall)

Annual Maintenance Control

System: A Water Pumping Station (4 units 3 Running & 1Standby)

PM Program / Unit:

PM Level	Weekly	Monthly	Annual
Maintenance Cost LE/order/unit	200	500	10,000
Maintenance Type	Running	Running	S/D

Annual CM Work Orders:

Running = 10 Work Orders & 5,000 LE Total

Shut Down = 2 Work Orders & 30,000 LE Total

Based on this information; discuss performance Indicators

Annual Maintenance Control

System: A Water Pumping Station (8 units 6 Running & 2 Standby)

PM Program / unit:

PM Level	Weekly	Monthly	Annual
Check	Check …	Check …	Check …
Replace	-	-	Pump seal Pump bearing
Maintenance Type	Running	Running	Shutdown

Annual CM Performance:

Item	Total	Minor CM	Pump seal	Pump bearing	Coupling	Impeller	Motor bearing
Number of CM Work Orders	18	10	3	2	1	1	1
Type	-	Running	Shutdown				

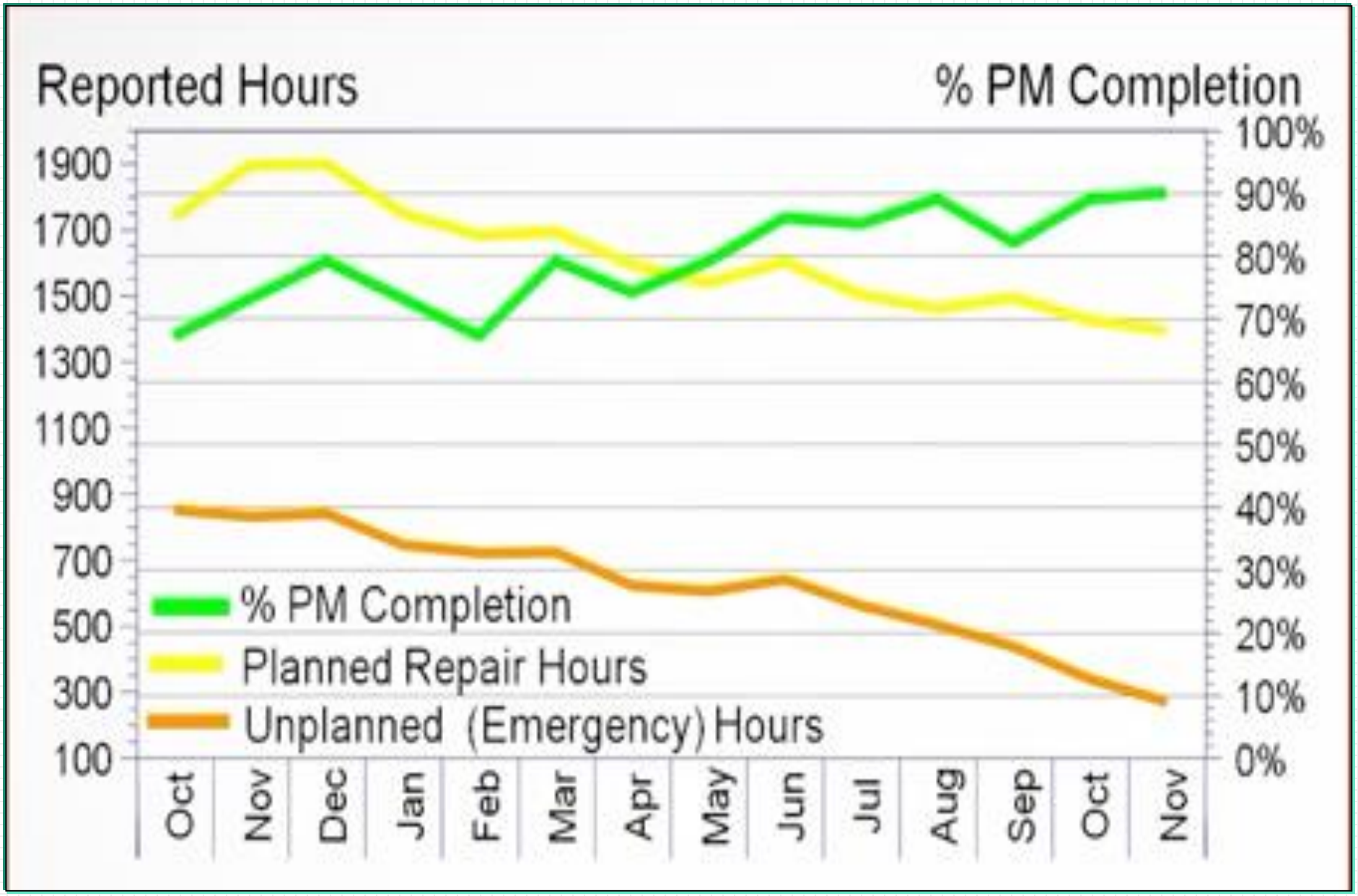
Based on this information, discuss performance indicators

Feedback (W/o Analysis)

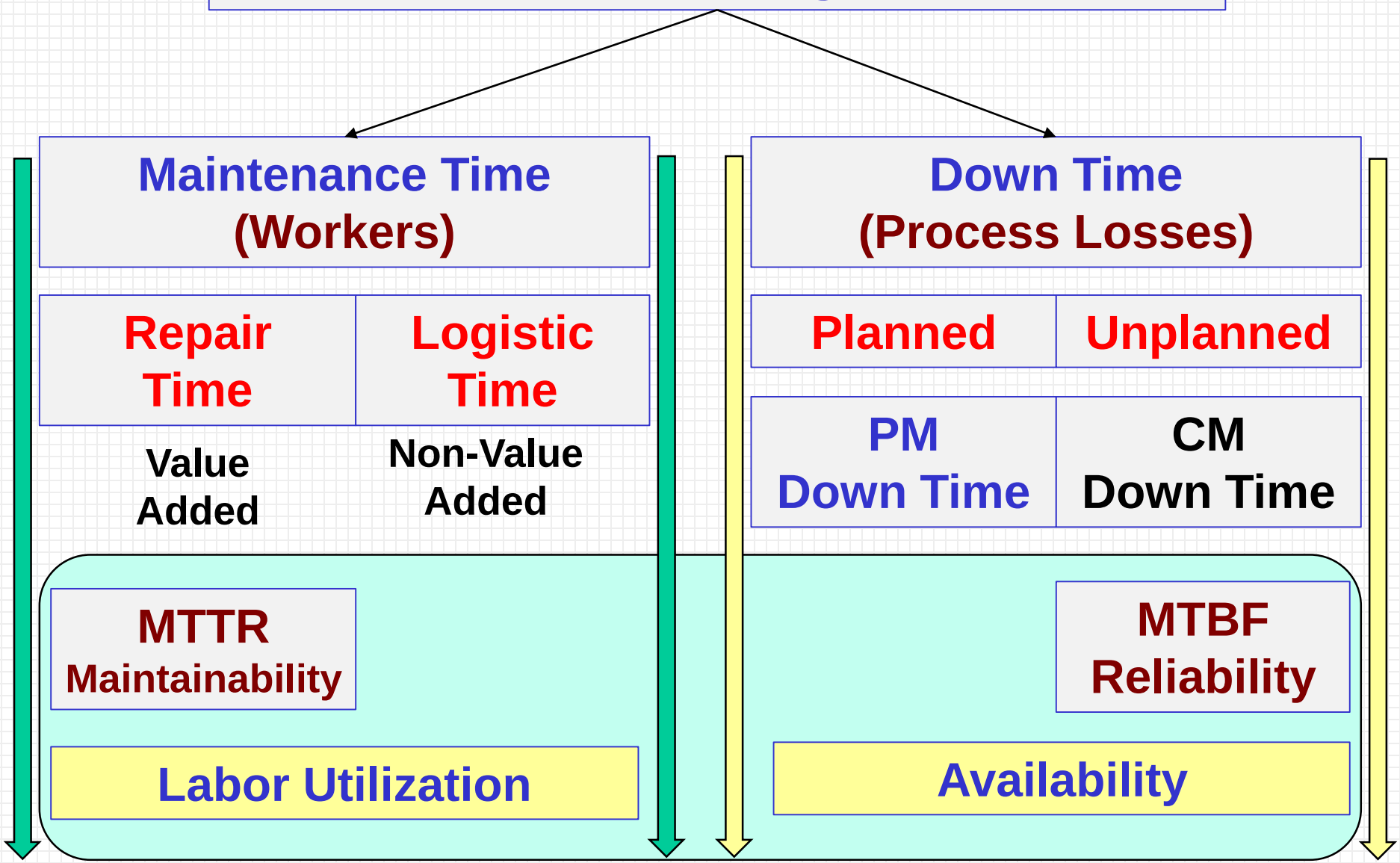
Work Order Types

- Planned
  - Routine "Minor PM"
  - Preventive
  - Predictive
  - Planned CM
- Unplanned
  - CM
  - RTF
  - B/d
- Design Change

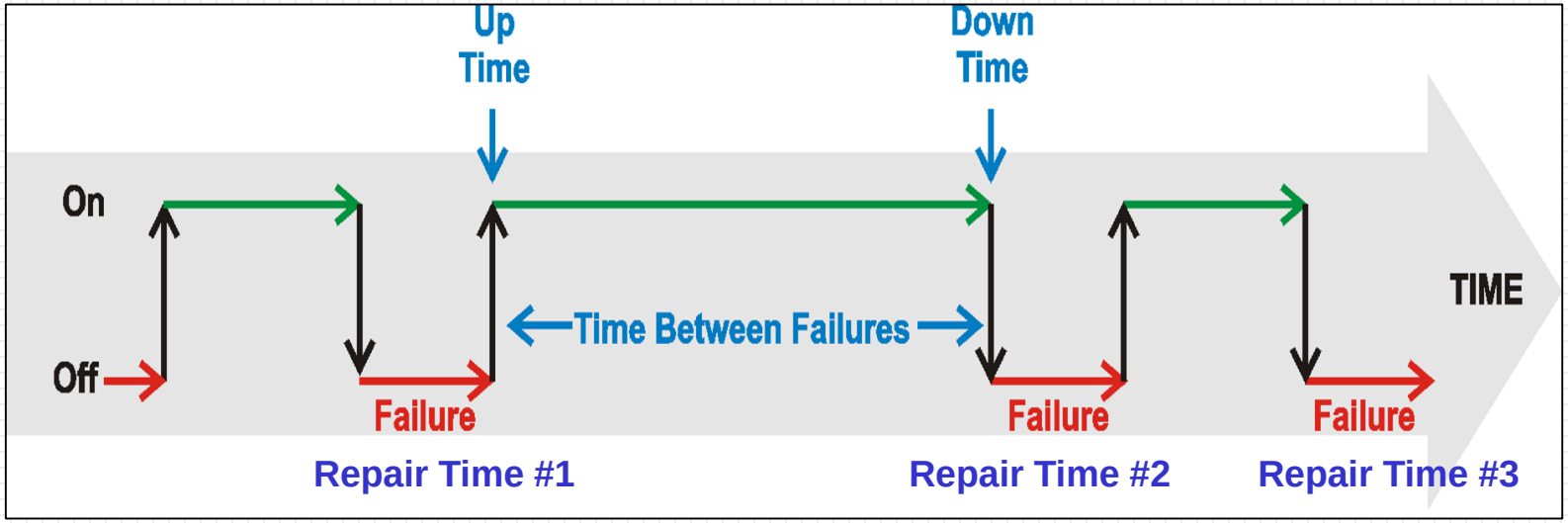
For example; KPIs Report for critical equipment:



Time Analysis



Mean Time to Repair (MTTR) & Mean Time to Maintain (MTTM)



Mean Time to Repair (MTTR) (CM Only):

MTTR = Total Repair Time / Number of Repairs

MTTR = Total CM Repair Time / Number of CMs

Mean Time to Maintain (MTTM) (PM Only):

MTTM = Total PM Maintenance Time / Number of PMs

Maintainability is the probability of performing a maintenance action during certain time.

Maintainability is measured by mean time to repair MTTR

To calculate the probability of performing a maintenance action within an allowable time interval use:

$$M(t) = 1 - e^{-t / MTTR}$$

Where:

t = Allowable downtime

MTTR= Expected downtime (MTTR)

Example : What is the probability of completing an action within 5 hours if the MTTR = 7 hours?

Solution : $M(t) = 1 - e^{-t/MTTR} = 1 - e^{5/7}$

$= 1 - .4895 = .5105$

There is approximately a 51% probability of completion.

Mean Time Between Failure (MTBF)

Brainstorming:

Water Pump Station # P1

- Maintenance Policy: RTF
- Running Time: 20,000 RH
- 5 CM Orders

Based on this information, discuss MTBF

MTBF = 20,000 / 5 = 4000 hours /failure

➔ **Proposed Maintenance Policy:**

PM W/o ➔ Change Bearing Every 4000 RH

Mean Time Between Failure (MTBF)

Brainstorming:

Water Pump Station # P1

- **PM Work Order: Replace Bearing Every 4000 RH**
- **Running Time: 20,000 RH**
- **2 CM Orders**

Based on this information, discuss MTBF

MTBF = 20,000/2= 10,000

➔ **Proposed Maintenance Policy:**

PM W/o ➔ Change Bearing Every 10,000 RH

Mean Time Between Failure (MTBF)

Brainstorming:

Water Pump Station # P1

- PM Work Order: Replace Bearing Every 4000 RH
- Running Time: 20,000 RH
- 4 PM Work Orders
- 2 CM Work Orders

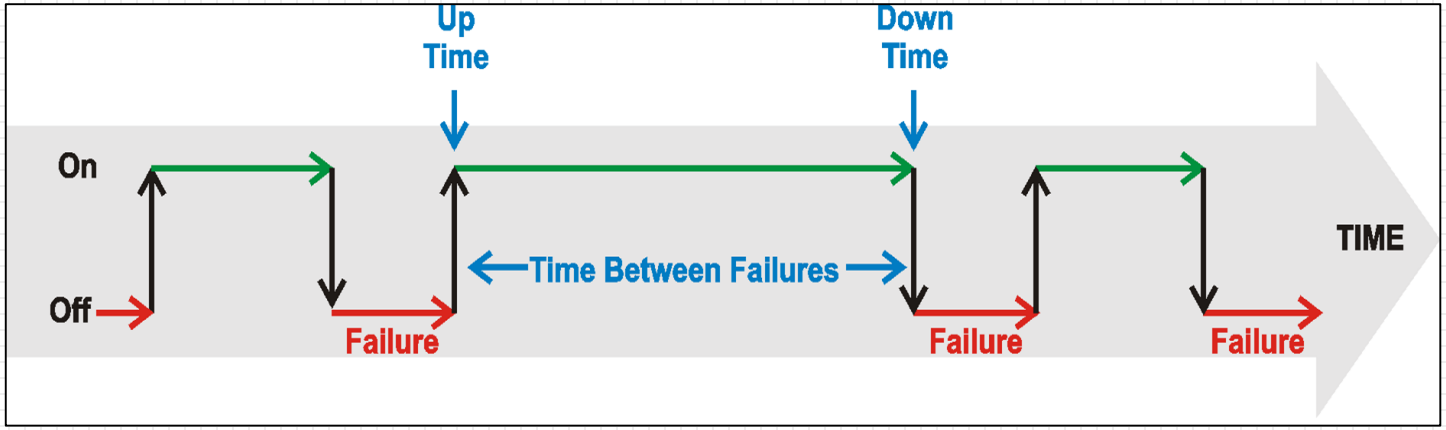
Based on this information, discuss MTBF

MTBF =

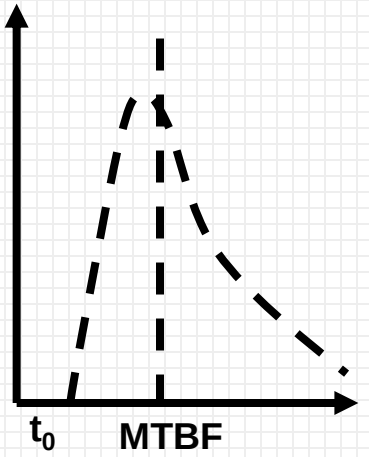
➔ **Proposed Maintenance Policy:**

PM W/o ➔ Change Bearing Every ??? RH

Mean Time Between Failure (MTBF)



Based on MTBF:
CM → → PM



Policy RTF (CM Only):

MTBF = Total Operating Time / Number of Failures

Policy PM & CM:

MTBF = Total Time Between Failures / Number of CMs

Check:

MTBF ≤ PM Interval

Policy PM & CM:

MTBF ≈ Total Operating Time / Number of (CMs + PMs)

Mean Time To Failure (MTTF)

1

System: Water Pumps **Item:** Bearing

Maintenance Policy: Run To Fail

Number of Bearing Failures: 20 CM Work Orders

Time To Failure (hours):

8400	7600	7500	8200	7900
7500	8100	7800	7700	8000
7700	7800	7600	8000	7400
8300	7800	8200	7800	7300

Based on this information; discuss the MTTF

MTTF = 7830

➔ **Proposed Maintenance Policy:**

PM W/o ➔ Change Bearing Every 8000 RH (Annual PM)

Mean Time To Failure (MTTF)

2

System: Water Pumps **Number of units:** 10

Item: Bearing

Number of Failures: 200 CM Work Orders

Time To Failure (hours):

TTF	8400-8300	8200-8100	8000-7900	7800-7700	7600-7500	7400-7300
Frequency	20	30	30	60	40	20

Based on this information; discuss the MTTF

MTTF = 7820

➔ **Proposed Maintenance Policy:**

PM W/o ➔ Change Bearing Every 8000 RH (Annual PM)

Mean Time To Failure (MTTF)

3

System: Water Pumps **Item:** Bearing

Maintenance Policy: Planned Maintenance

History (5 years):

Working Condition: 156,400 Running Hours

Planned Work Orders: 12 PM Work Orders

Number of Failures: 8 CM Work Orders

Based on this information; discuss the MTTF

MTTF = 7820

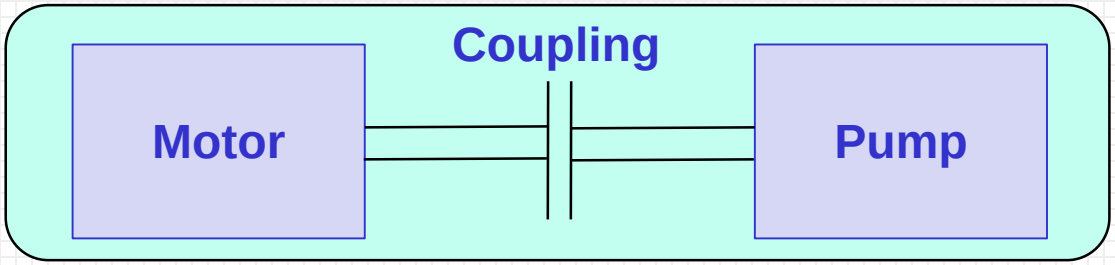
➔ **Proposed Maintenance Policy:**

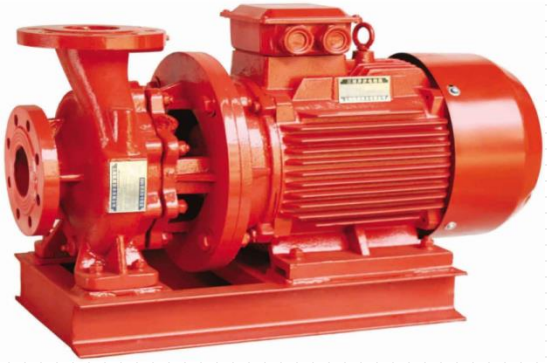
PM W/o ➔ Change Bearing Every 8000 RH (Annual PM)

Mean Time To Failure (MTTF)

 # 1

Feed Water Pump ##





History (5 years):

Working Condition: 20,000 Running Hours

Number of Failures: 10 CM Work Orders

Based on this information; discuss the MTBF

MTBF =

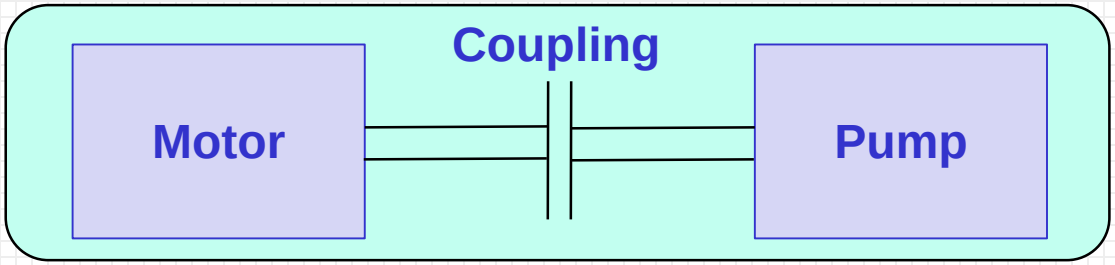
➔ **Proposed Maintenance Policy:**

PM W/o ➔ Change ??? Every ???

Mean Time To Failure (MTTF)

 # 2

Feed Water Pump ##



History (5 years):

Working Condition: 20,000 Running Hours

Number of Failures: 10 CM Work Orders

	Motor	Coupling	Pump
Number of major failures	2	3	5

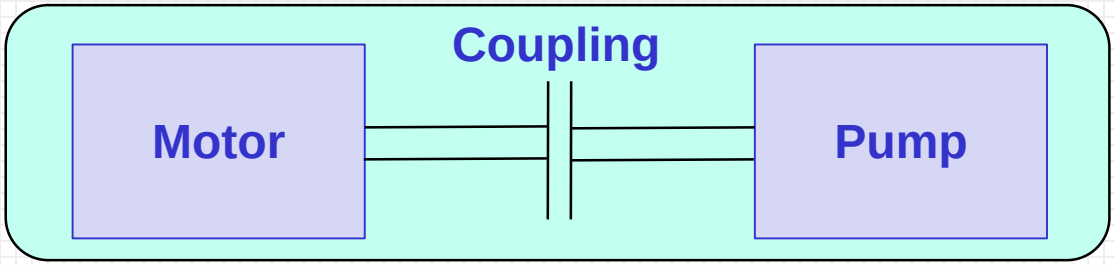
Based on this information; discuss the MTBF

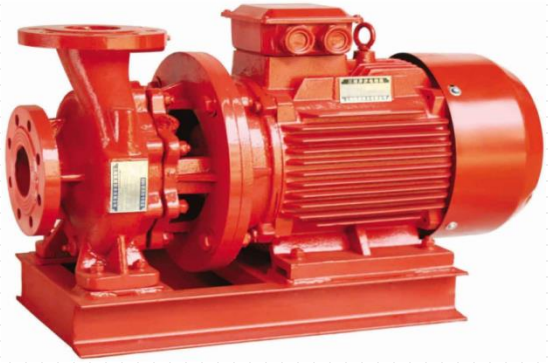
	Motor	Coupling	Pump
MTBF			
Policy			

Mean Time To Failure (MTTF)

 # 3

Feed Water Pump ##





History (5 years): Working Condition = 20,000 Running Hours

Running Hours	Work Order Type	Item	Running Hours	Work Order Type	Item	Running Hours	Work Order Type	Item
5000	PM	Pump-seal	10000	PM	Motor-bearing	19000	CM	Motor-bearing
8000	CM	Misalignment	13000	CM	Misalignment	19000	CM	Misalignment
8000	PM	Pump-bearing	13000	PM	Pump-seal	20,000	PM	Pump-seal
9000	CM	Pump-seal	15000	CM	Pump-bearing	20,000	CM	Pump-bearing

Based on this information; discuss the MTTF

Running Hours	Work Order Type	Item	Running Hours	Work Order Type	Item	Running Hours	Work Order Type	Item
5000	PM	Pump-seal	10000	PM	Motor-bearing	19000	CM	Motor-bearing
8000	CM	Misalignment	13000	CM	Misalignment	19000	CM	Misalignment
8000	PM	Pump-bearing	13000	PM	Pump-seal	20,000	PM	Pump-seal
9000	CM	Pump-seal	15000	CM	Pump-bearing	20,000	CM	Pump-bearing

Mean Time Between Failure (MTBF):

Eq. MTBF	20,000/12 = 1666	Check 2000
Pump Seal	(5000 + 4000 + 4000 + 7000)/4 = 5000	Every 6000
Pump Bearing	(8000+7000+5000)/3 = 6666	
Coupling	(8000+5000+6000)/3= 6333	
Motor Bearing	(10000+9000)/2 = 9500	Every 10000

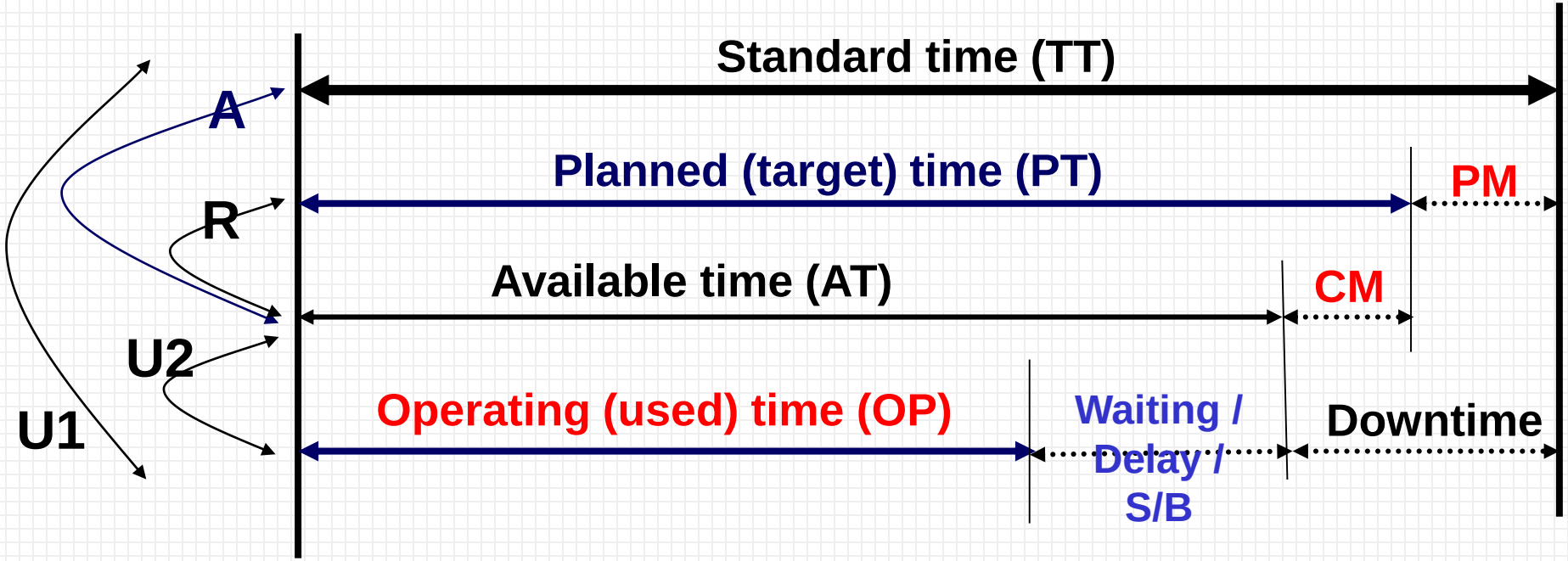
Standard Period; Running Hours

1000	2000	4000	6000	8000	10000	12000

Maintenance Program:

Main Items	Standard Period; Running Hours					
	2000	4000	6000	8000	10000	12000
Pump Bearing	C	C	R	C	C	R
Pump Seal	C	C	R	C	C	R
Coupling	C	C	R	C	C	R
Shaft	C	C	C	C	C	C
….	C	C	C	C	C	C
Motor Bearing	C	C	C	C	C	R
Motor Fan	C	C	C	C	C	C
….	C	C	C	C	C	C

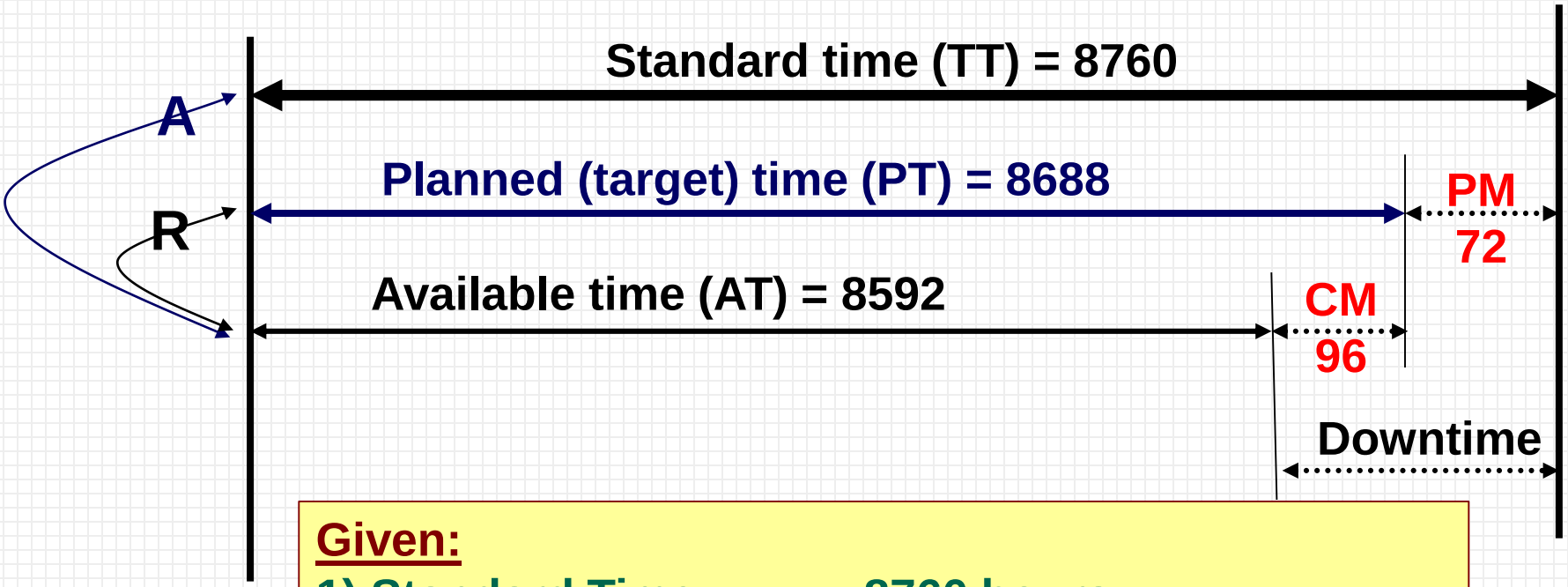
Operational Availability & Reliability & Utilization Analysis



PM = Planned downtime
CM = Corrective downtime
S/B =Standby time
OP = Operating time
AT = Available Time
PT = Planned Time

A= Equipment Availability = AT/TT
= Available time / Total Time
= (Total Time – Downtime) / Total Time
= (OP + S/B) / (OP+S/B+PM+CM)
R= Equipment Reliability = AT / PT
= (OP+S/B) (OP + S/B + CM)
= Running / (Running + CM)
U= Equipment Utilization
= OP / AT or = OP / TT

Operational Availability & Reliability



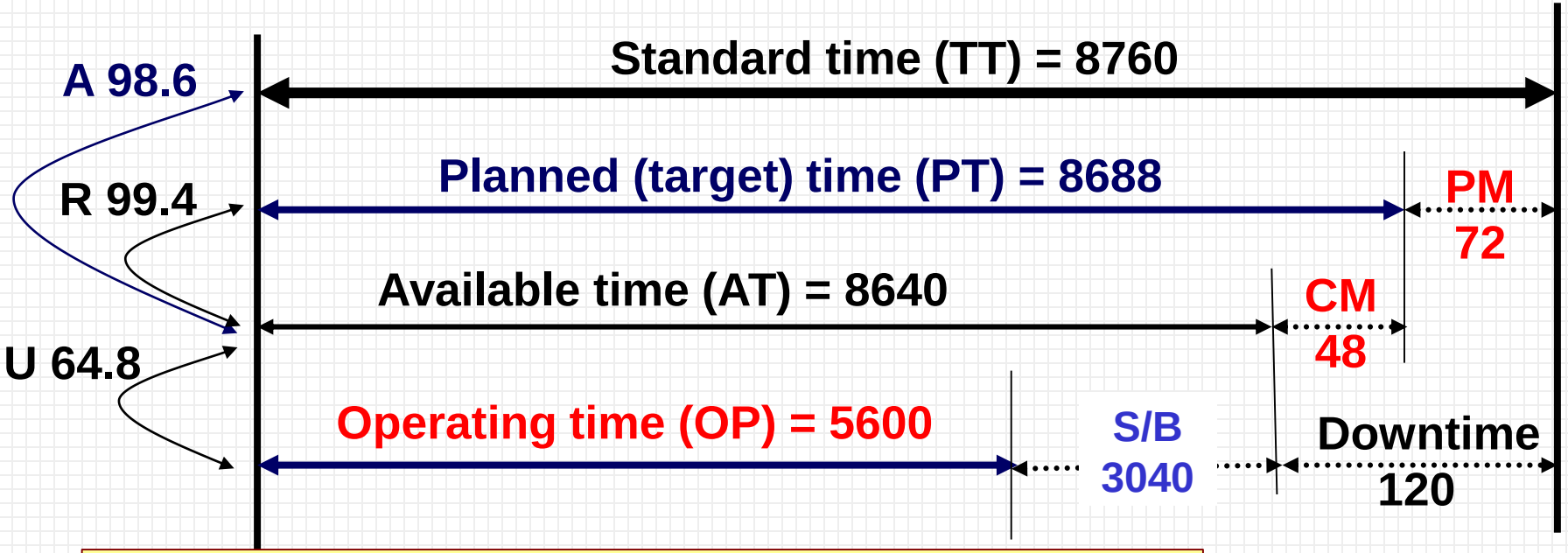
Given:

1) Standard Time = 8760 hours
2) PM Downtime = 3 days = 72 hours
3) CM Downtime = 4 days = 96 hours

Indicators:

A = Availability = 98.1 % Downtime=1.9%
R = Reliability = 98.9 % Unplanned D.= 1.1%

Operational Availability & Reliability & Utilization Analysis



Given:

1) Standard Time	= 8760 hours/year
2) PM Downtime	= 3 days = 72 hours
3) CM Downtime	= 2 days = 48 hours
4) Operating Time	= 5600 hours

Indicators:

A = Availability	= 98.6%
R = Reliability	= 99.4%
U = Utilization	= 64.8%

Maintenance Control (KPIs):

Objective: High Quality (RAMS) at Low Cost

Objective	KPIs		Actual	Target	Recommendations
(Outputs) High Quality (RAMS)	Reliability	System Reliability			
		MTBF seal MTBF bearing			
		CM/PM seal CM/PM bearing			
	Availability	System Availability			
	Maintainability	PM Efficiency			
		MTTR seal MTTR bearing MTTR seal & bearing			
	Safety	Overdue for SCE			
(Inputs) Low Cost	Resources	Labor Productivity			
	Capacity	Operation Efficiency			
	Cost	Maintenance Cost Rate			

Key Performance Indicator (KPIS) Target Values:

	Measure	Target
1.	Facility Availability	≥ 98%
2.	Operation Efficiency	≥ 85%
3.	Reliability of Critical Equipment	≥ 99%
4.	Availability of Critical Equipment	≥ 98%
5.	Planned v Unplanned	≥ 90%
6.	Maintenance Cost per Capacity	Site specific
7.	…. etc.	Site specific

Oil & Gas Site:

Monthly KPIs

Measure	Target	Month (#4)	Month (#3)	Month (#2)
Schedule Compliance (PM% on time)	≥ 90 %	93.2	94.5	90.15
Un-Scheduled Fill-in ratio (CM%)	≤ 10 %	2.3	11.4	3.28
Emergency Work (CM% for SCE)	≤ 5 %	4.1	3.6	3.28
M-hrs. estimation variance	≤ 10 %	6.67	17.48	1.82
PM backlog for SCE (PM waiting)	< 1 week	0.32	0.32	0.53
CM backlog for SCE (CM waiting)	≤ 1 week	0.87	0.91	0.44

Information For Annual Control (KPIs):

The maintenance information for a water pumping station is as follows:

System: A Water Pumping Station
(4 units 3 Running & 1 Standby)
Working Conditions: 24 hours/day

Manpower:
4 Workers
2000 h/y

Annual PM Work Orders	Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
Maintenance Task	Cleaning Check …	Cleaning Check … Check …	Cleaning Check … Check …	Check … Check … Replace seal	Check … Replace seal Replace bearing
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Actual PM W/o	132	26	6	3	3
Total PM Downtime	-	-	-	24	36
Total maintenance time	160	65	24	36	51
Manpower	2 Mech.	2 Mech.	2 Mech.	2 Mech. + 1 Elec.	3 Mech. + 1 Elec.

Annual CM Work Orders	Seal Failure	Bearing Failure
CM Work Orders	3	2
Time Between Failure; hours	3400, 3200, 3600	6400, 6200
Repair Time; hours	33	30
CM Downtime; hours	30	25
Total Repair Time	36	30
Manpower	2 Mech. + 1 Elec.	3 Mech. + 1 Elec.

Based on this information; discuss the Maintenance KPIs.

Information For Annual Control (KPIs):

The maintenance information for a water pumping station is as follows:

System: A Water Pumping Station
(4 units 3 Running & 1 Standby)

Wo

KPIs

Current Feedback

Future Feedback

Reactive Analysis

1. CM / PM
2. PM Efficiency
3. MTTR & MTTM
4. MTBF
5. Availability
6. Reliability
7. Labor Productivity

Proactive Analysis

- Overdue of SCE
- Canceled of SCE
- Operation Efficiency
- System OEE
- Maintenance Cost Rate
- .....

CM / PM (#/#):

Annual PM Performance:

PM Level	Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
Maintenance Task	Cleaning Check …	Cleaning Check … Check …	Cleaning Check … Check …	Check … Check … Change seal	Check … Change seal Change bearing
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Number of Actual PM W/o	132	26	6	3	3

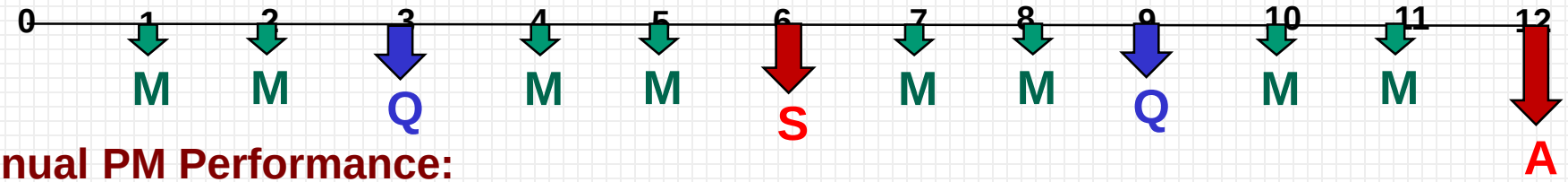
Annual CM Performance:

CM Task	Seal Failure	Bearing Failure
Number of CM W/o	3	2

Item	Unit	Seal	Bearing
Actual CM / PM	5/6 = 83%	3/6 = 50%	2/3 = 67%
Target CM / PM	< 20%	< 20%	< 20%
Recommendations	Updating PM	RCFA	RCFA

PM Efficiency: (PM% on time) or PM Compliance %

Planned Frequency / Unit



Annual PM Performance:

PM Level	Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
Maintenance Task	Cleaning Check …	Cleaning Check … Check …	Cleaning Check … Check …	Check … Check … Change seal	Check … Change seal Change bearing
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Number of Actual PM W/o	132	26	6	3	3
Planned PM Frequency	160	32	8	4	4
	200			8	

Item	Total PM	Running Maintenance	Shutdown Maintenance
PM Efficiency	170/208= 82%	164/200= 82%	6/8= 75%
Backlog (waiting) %	18%	18%	25%
Target PM Eff.	100%		100%
Recommendations	Updating PM		RCFA

Mean Time to Maintain (MTTM) & Mean Time to Repair (MTTR):

Mean Time to Maintain (MTTM): Assume; PM downtime = PM Maintenance time

Annual PM Performance:

PM Level	Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
Maintenance Task	Cleaning Check ….	Cleaning Check … Check …	Cleaning Check … Check …	Check … Check … Change seal (1)	Check … Change seal (1) Change bearing (2)
Maintenance Type	Running	Running	Running	Shutdown	Shutdown
Number of Actual PM W/o	132	26	6	3	3
Total PM Downtime, hours	-	-	-	24	36
MTTM (Standard time)				8	12

Mean Time to Repair (MTTR): Assume; CM downtime = repair time

Annual CM Performance:

CM Task	Seal Failure	Bearing Failure
Number of CM W/o	3	2
Total CM Downtime, hours	30	25
MTTR	10	12.5

Mean Time Between Failure (MTBF):

Standard PM Hours:

Item	Replace Seal	Replace Bearing
PM Level	Semi-Annual	Annual
Standard PM Hours	4000	8000

Annual CM Performance:

CM Work Orders	3S , 2B
Time Between Failure; hours	S (3400,3200,3600) B (6400,6200)
Repair Time; hours	33 , 30
CM Downtime; hours	30S , 25B
CM Labor; man-hours	250

Item: S:Seal B:Bearing

MTBF = Total Operating Time / Number of Failures ➔ RTF

Seal (S) ➔ (3400+3200+3600) / (3 CMs) = 3400 hours/failure
Bearing (B) ➔ (6400+6200) / (2 CMs) = 6300 hours/failure
Unit ➔ (3400+3200+3600+ 6400+6200) / (5CMs)= 4560 hours/failure

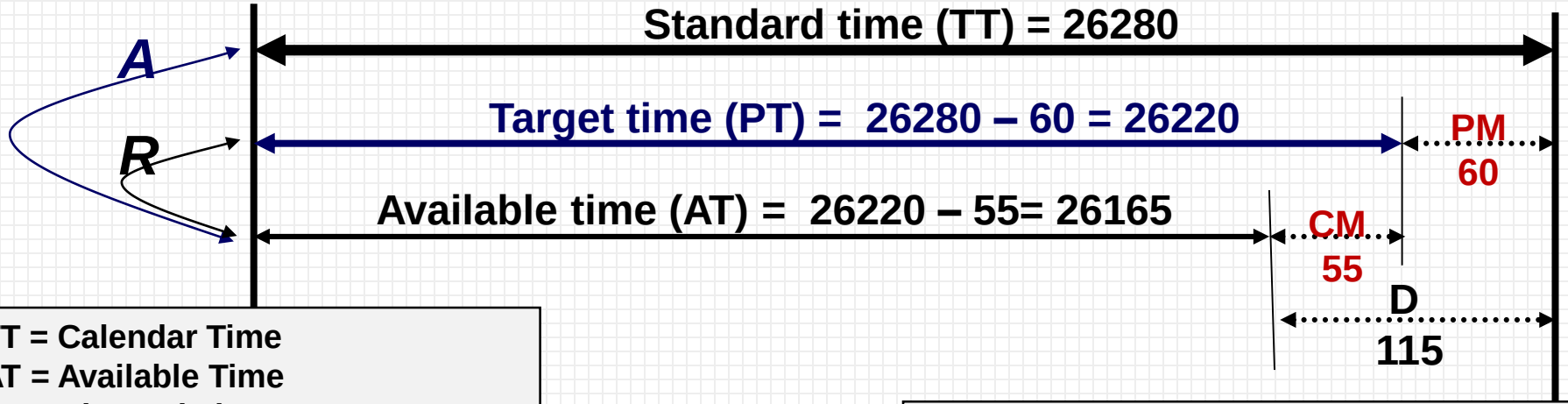
Item	Unit	Seal	Bearing
MTBF	4560	3400	6300
Target MTBF	Semi-Annual	Semi-Annual	Annual
Recommendations	Updating PM	RCFA	RCFA

Operational Availability & Reliability (Based on Downtime)

Feed Water Pump Station ➔ 4 Units (3 Running &1 standby)

Standard Time = 8760*3 = 26280 hour/year,

PM Downtime = 60 hours , CM Downtime= 55 hours , Total Downtime = 115 hours



TT = Calendar Time
AT = Available Time
PT = Planned Time
PM = Planned Downtime
CM = Corrective Downtime
D = Total Downtime

D = Total Downtime = 115 hours

A= Equipment Availability = AT/TT

= 26165 / 26280 = 99.56%

R= Equipment Reliability = AT / PT

= 26165 / 26220 = 99.79%

(R ≥ A ≤100%)

Labor Productivity

Available Manpower:

4 Workers * 2000 h/y = 8000 man-hours

Annual PM Work Orders	Weekly	Monthly	Quarter (2000 RH)	Semi-Annual (4000 RH)	Annual (8000 RH)
Total maintenance time	160	65	24	36	51
Manpower	2 Mech.	2 Mech.	2 Mech.	2 Mech. + 1 Elec.	3 Mech. + 1 Elec.
Total PM man-hours	320	130	48	108	204
	810				

Annual CM Work Orders	Seal Failure	Bearing Failure
Total Repair Time	36	30
Manpower	2 Mech. + 1 Elec.	3 Mech. + 1 Elec.
Total CM man-hours	108	120
	228	

Labor Productivity = Actual man-hours / Available man-hours

= 1038 / 8000 = 13%

Maintenance Control (KPIs)

Objective	KPIs		Actual	Target	Rec.
(Outputs) High Quality	Reliability	System Reliability	99.79%	99.9%	
		MTBF seal MTBF bearing	3400 6300	4000 8000	
		CM/PM seal CM/PM bearing	50% 67%	20% 20%	
	Availability	System Availability	99.56%	99.9%	
	Maintainability	PM Efficiency	82%	90%	
		MTTR seal MTTR bearing	10 15	8 12	Repair time
	Safety	Overdue for SCE	-	-	Finish date
(Inputs) Low Cost	Resources	Labor Productivity	13%	15%	Man-hour
	Capacity	System OEE			Time analysis
	Cost	Maint. Cost Rate			LE / ton

Feedback

Continuous Improvement

Information For Annual Control (KPIs):

The maintenance information for a water pumping station is as follows:

System: A Water Pumping Station
(4 units 3 Running & 1 Standby)
Working Conditions: 24 hours/day

Manpower:
4 Workers
2000 h/y

Annual PM Performance:

Unit	P1	P2	P3	P4	Total (4 units)
Actual Operating Time; hours	6900	6300	6200	6880	8760*3
Running PM Work Orders	50	34	35	45	164
Semi-Annual PM Work Orders (S)	1	-	-	2	3
Semi-Annual PM Downtime; Hours	9	-	-	15	24
Annual PM Work Orders (S,B)	1	1	1	-	3
Annual PM Downtime; Hours	14	10	12	-	36
PM Labor; man-hours	340	270	290	300	1,200

Annual CM Performance:

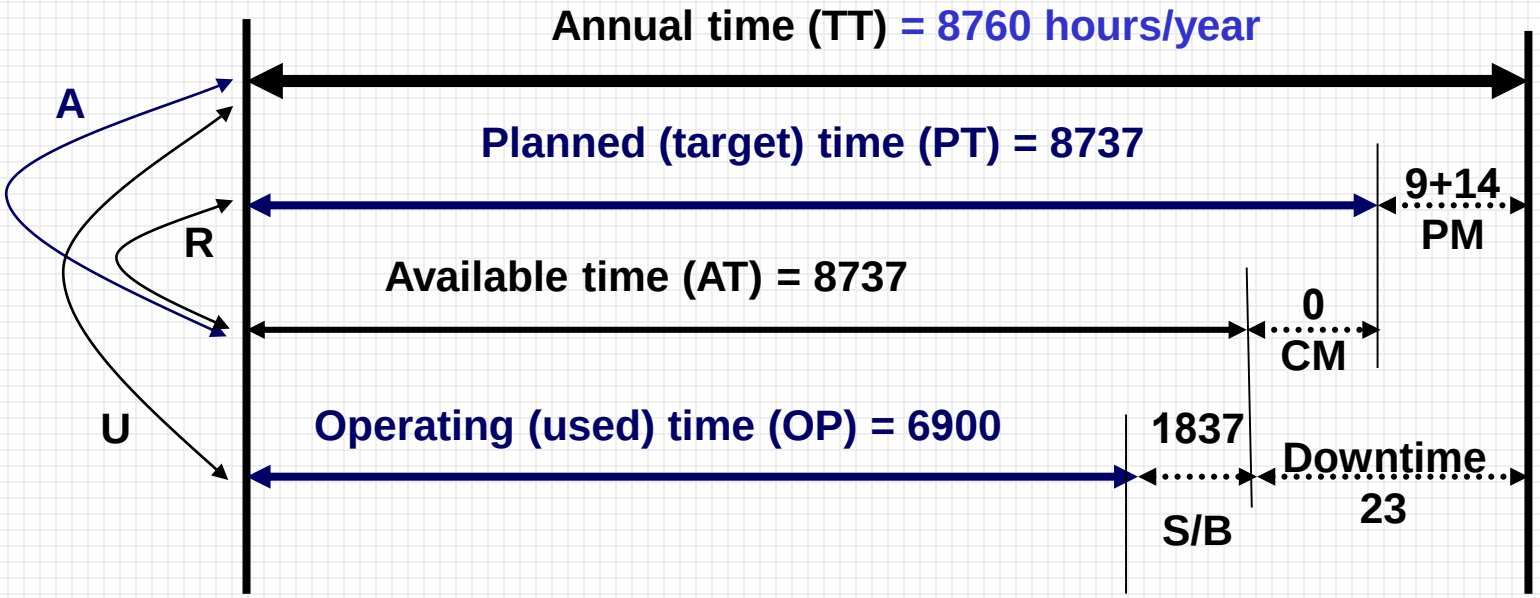
Item: S:Seal B:Bearing

Unit	P1	P2	P3	P4	Total (4 units)
CM Work Orders	-	2S	1S , 1B	1B	3S , 2B
Time Between Failure; hours	-	3400,3200	3600,6400	6200	(3400,3200,3600) (6400,6200)
Repair Time; hours	-	10,12	11,14	16	33 , 30
CM Downtime; hours	-	9,10	10,14	12	30S , 25B
CM Labor; man-hours	-	70	100	80	250

Operational Availability & Reliability (Based on Downtime)

KPIs Report

Pump #1 Availability Analysis



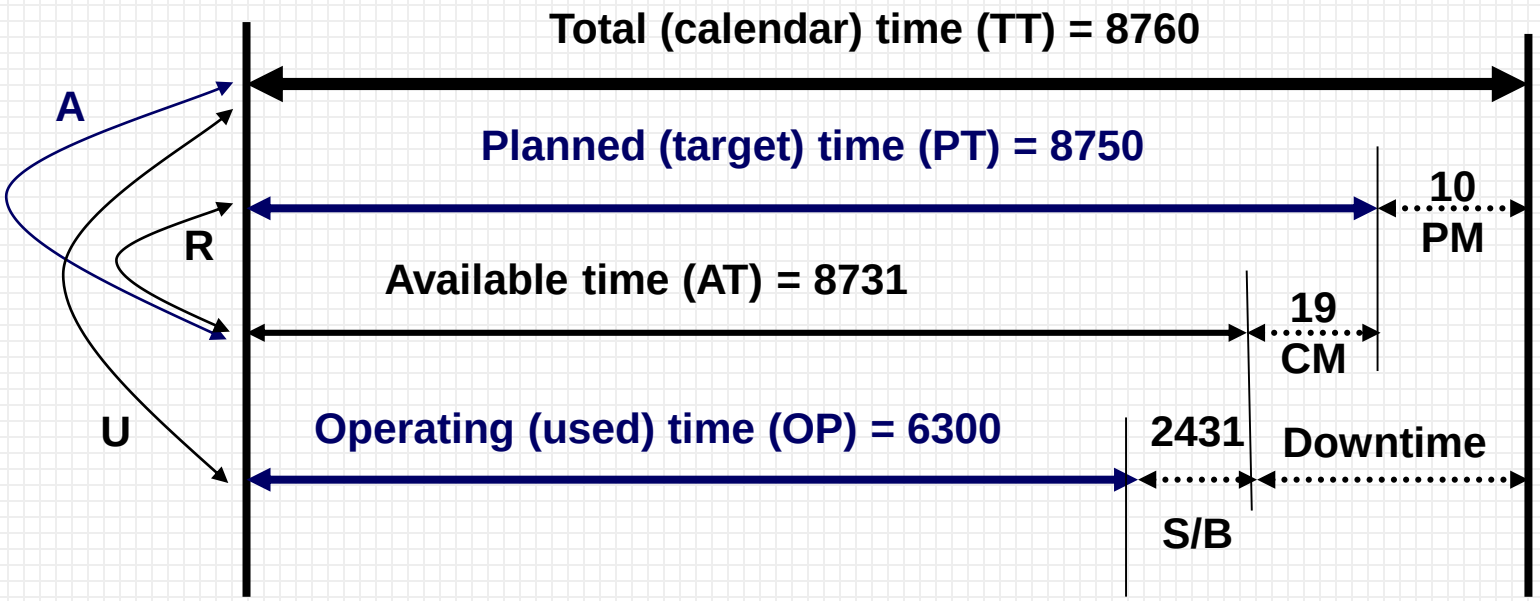
Total Hours	Planned downtime	Unplanned downtime	Total downtime	Available time	Standby time	Operating time
8760	9+14	0	14	8746	1846	6900

Availability %	Reliability %	Utilization %
99.74%	100 %	78.76 %

Operational Availability & Reliability (Based on Downtime)

KPIs Report

Pump #2 Availability Analysis



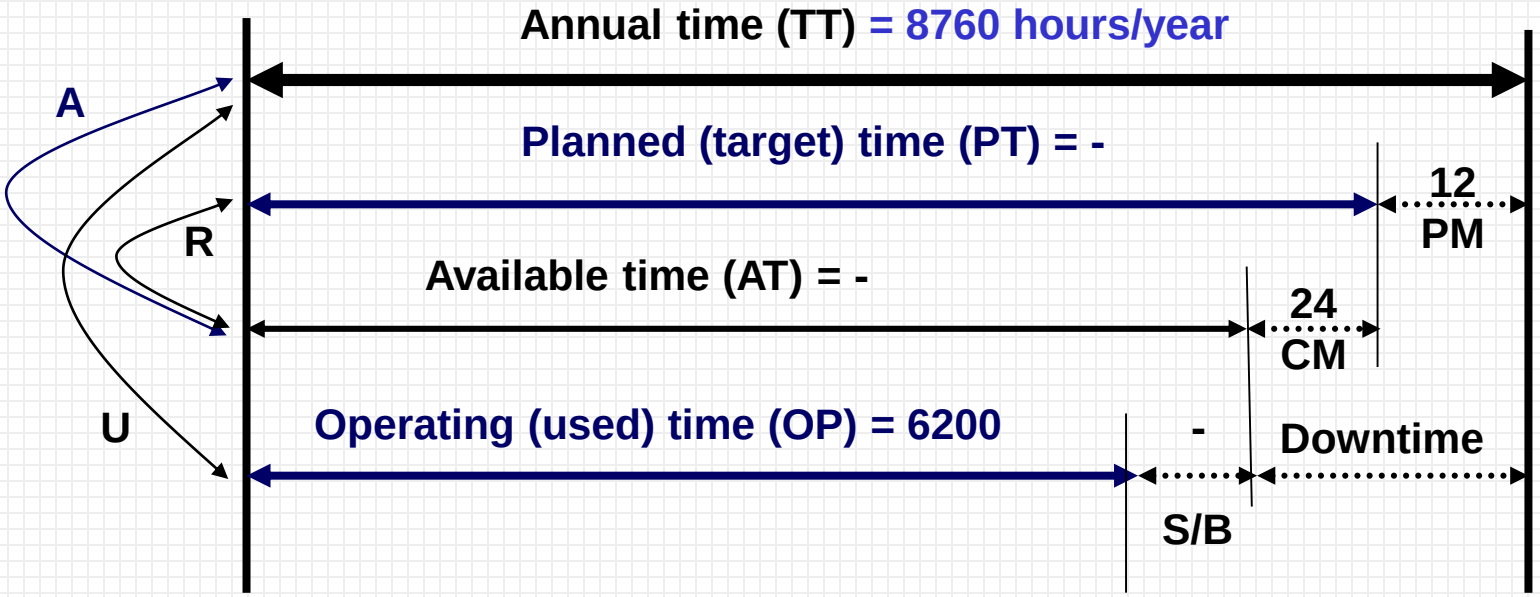
Total Hours	Planned downtime	Unplanned downtime	Total downtime	Available time	Standby time	Operating time
8760	10	9+10	29	8731	2431	6300

Availability %	Reliability %	Utilization %
99.67%	99.78 %	71.91 %

Operational Availability & Reliability (Based on Downtime)

KPIs Report

Pump #3 Availability Analysis



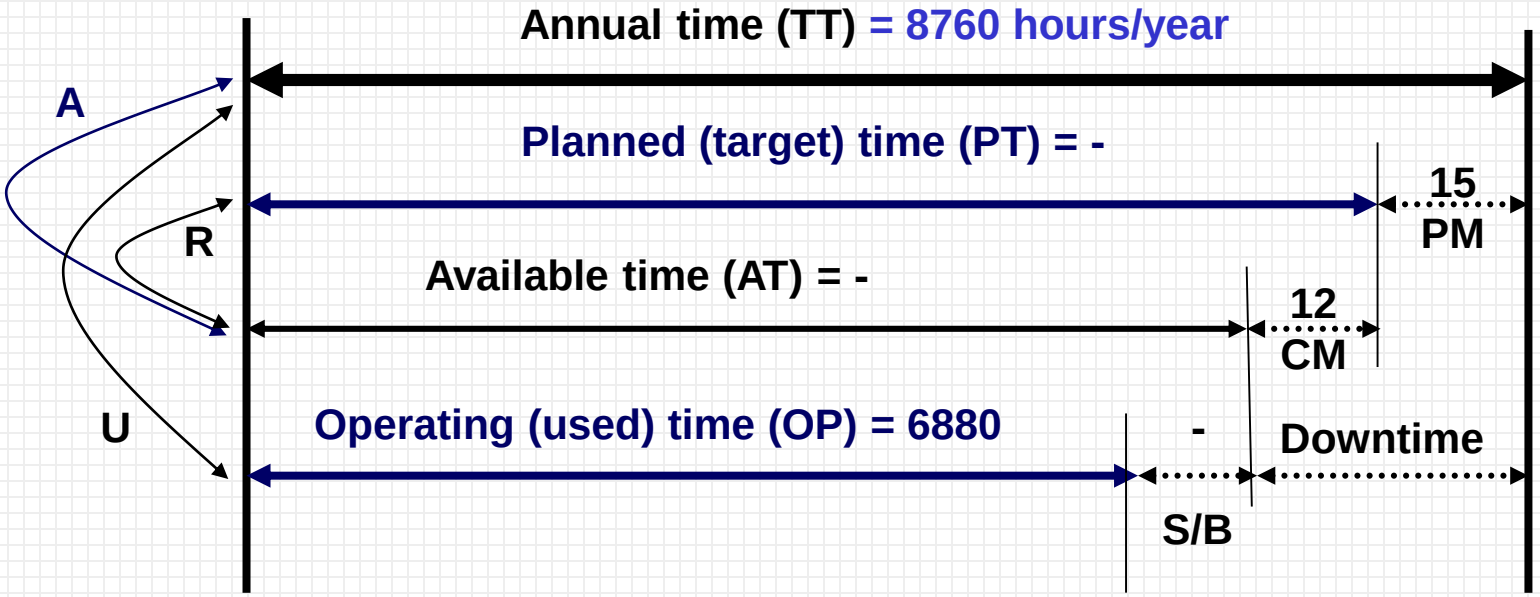
Total Hours	Planned downtime	Unplanned downtime	Total downtime	Available time	Standby time	Operating time

Availability %	Reliability %	Utilization %
99.58%	99.72%	70.78%

Operational Availability & Reliability (Based on Downtime)

KPIs Report

Pump #4 Availability Analysis

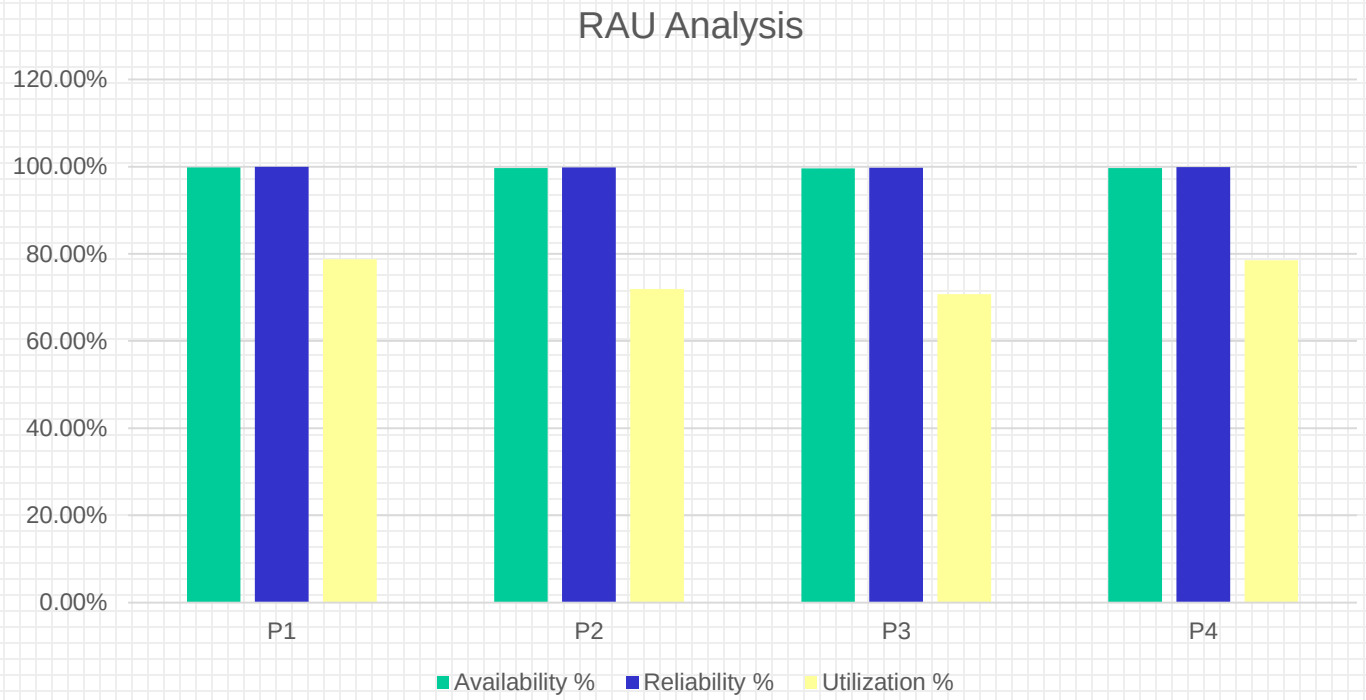


Total Hours	Planned downtime	Unplanned downtime	Total downtime	Available time	Standby time	Operating time

Availability %	Reliability %	Utilization %
99.69%	99.86%	78.53%

Operational Availability & Reliability (Based on Downtime)

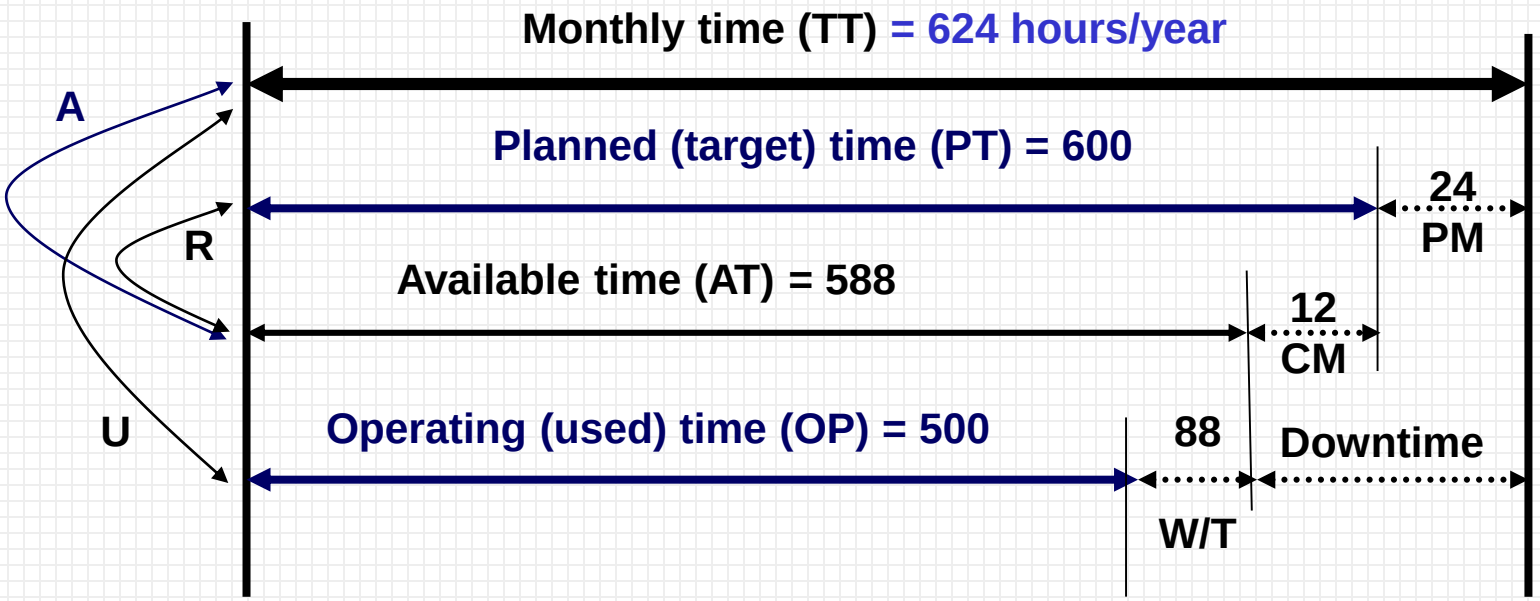
Pump #	Availability %	Reliability %	Utilization %
P1	99.84%	100 %	78.76 %
P2	99.67%	99.78 %	71.91 %
P3	99.58%	99.72%	70.78%
P4	99.69%	99.86%	78.53%



Operational Availability & Reliability (Based on Downtime)

KPIs Report

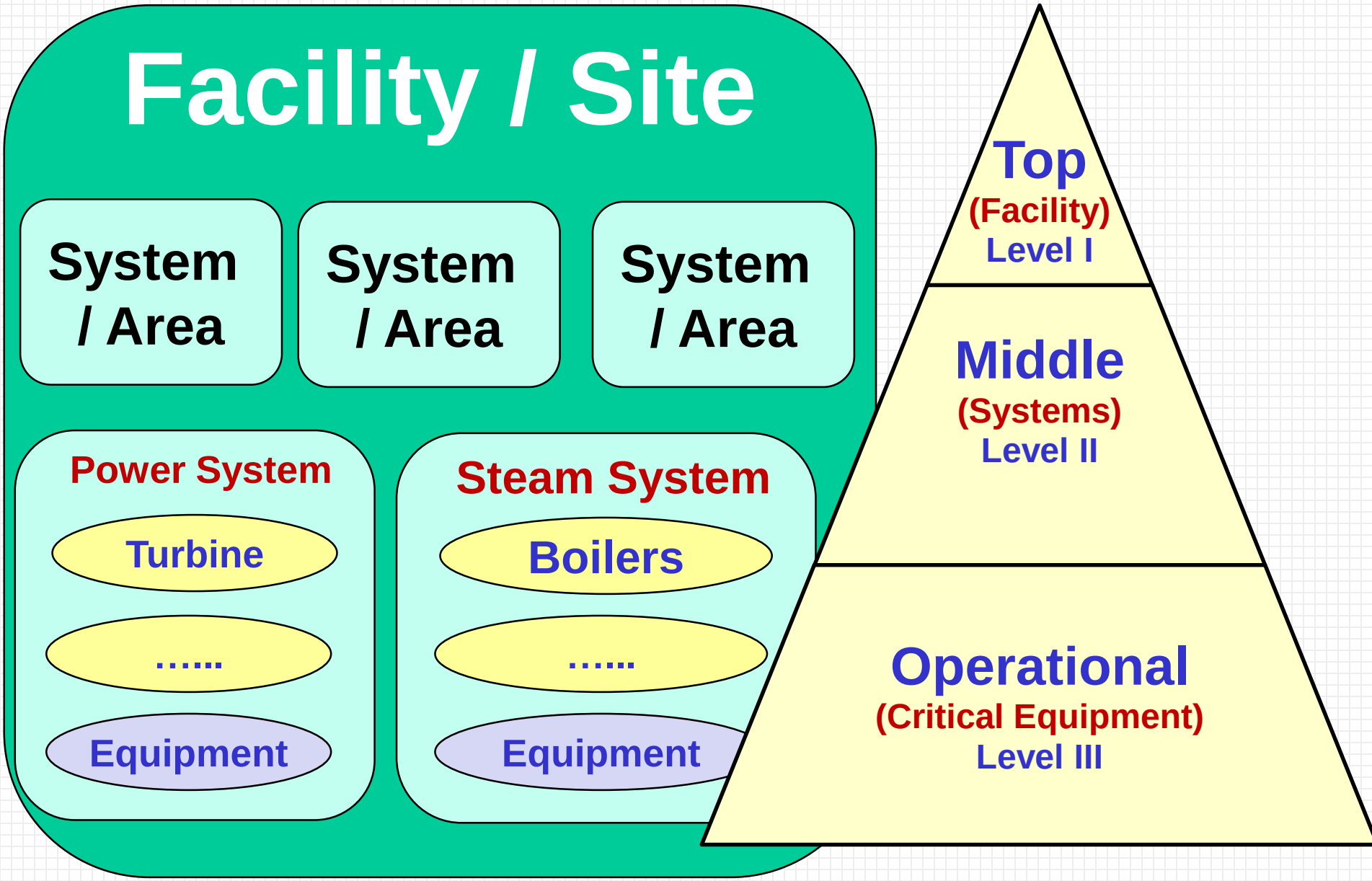
Air Compressor #1 Availability Analysis



Standard Hours	Planned downtime	Unplanned downtime	Total downtime	Available time	Waiting time	Operating time
624	24	12	36	588	88	500

Availability %	Reliability %	Utilization %
588/624=94.2%	588/600= 98%	500/624=80%

Annual KPIs Report For Top Management



KPIs Report

KPIs - Level I

KPIs Report

Plant Availability

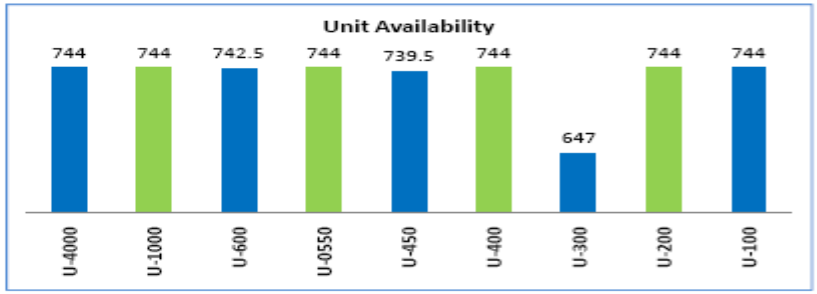
Critical Equipment Availability

Production Performance Efficiency

Monthly Plant Availability

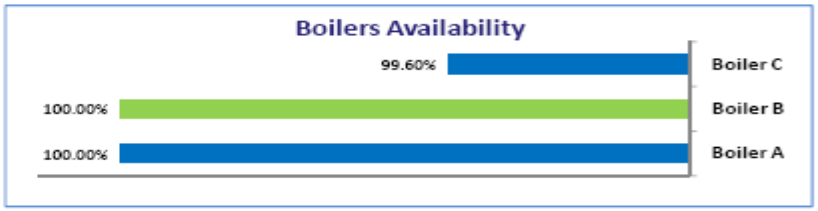
	Down hrs	Up. Hrs	Availability
U-100	0	744	100.00%
U-200	0	744	100.00%
U-300	97	647	86.96%
U-400	0	744	100.00%
U-450	4.5	739.5	99.40%
U-0550	0	744	100.00%
U-600	1.5	742.5	99.80%
U-1000	0	744	100.00%
U-4000	0	744	100.00%

* Standard operating hours = 744



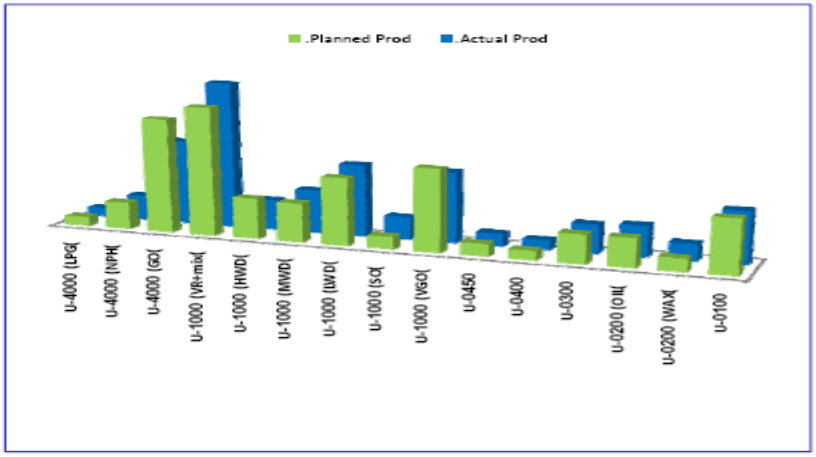
Monthly Boilers Availability

	Down hrs	Up. Hrs	Availability
Boiler A	0	744	100.00%
Boiler B	0	744	100.00%
Boiler C	3	741	99.60%



Monthly Production Performance Efficiency

	Target	Actual	Efficiency
U-0100	15080.65	14468.186	95.94%
U-0200 (WAX)	3600	4703.599	130.66%
U-0200 (OIL)	8000	8687.392	108.59%
U-0300	8000	8049.118	100.61%
U-0400	2536.364	2750.883	108.46%
U-0450	3428.6	3546.5	103.44%
U-1000 (VGO)	22916	19790.285	86.36%
U-1000 (SO)	3438	6275.105	182.52%
U-1000 (LWD)	18750	20144.321	107.44%
U-1000 (MWD)	10833	12077.519	111.49%
U-1000 (HWD)	11333	8422.207	74.32%
U-1000 (VR+mix)	35958	40917.354	113.79%
U-4000 (GO)	32000	23776.588	74.30%
U-4000 (NPH)	7500	7080.803	94.41%
U-4000 (LPG)	2400	2505.17	104.38%



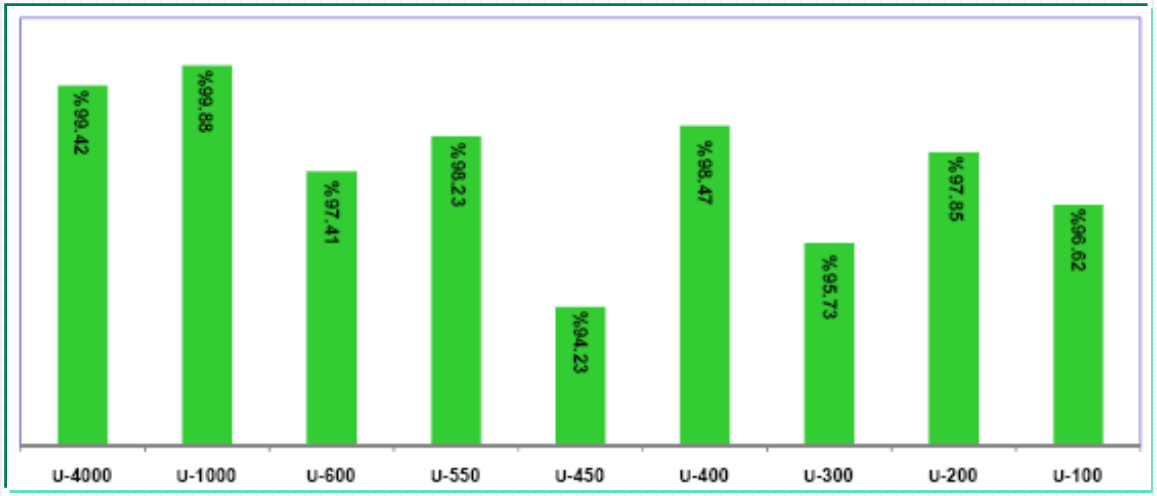
KPIs - Level I

KPIs Report

Accumulative Plant Availability

Acc. Plant Availability

	U-100	U-200	U-300	U-400	U-450	U-550	U-600	U-1000	U-4000	Std. Hrs
Jan-14	744	744	744	744	744	744	744	744	740	744
Feb-14	672	672	672	672	672	672	672	672	672	672
Mar-14	744	744	744	744	744	744	725	744	713	744
Apr-14	693	720	720	720	715	720	720	720	720	720
May-14	725	744	744	744	744	744	744	744	737	744
Jun-14	720	720	720	720	720	720	688	720	720	720
Jul-14	744	744	667	744	660	744	744	744	733	744
Aug-14	469	540	512	599	300	576	552	744	744	744
Sep-14	720	720	720	720	720	720	720	709	720	720
Oct-14	744	744	744	744	737	744	742.66667	744	744	744
Nov-14	720	720	720	720	720	720	720	720	717.5	720
Dec-14	744	744	744	744	740	744	744	744	744	744
Jan-15	744	744	647	744	739.5	744	742.5	744	744	744
Total	9183	9300	9098	9359	8955.5	9336	9258.1667	9493	9448.5	9504
Acc. Availability	96.62%	97.85%	95.73%	98.47%	94.23%	98.23%	97.41%	99.88%	99.42%	100.00%



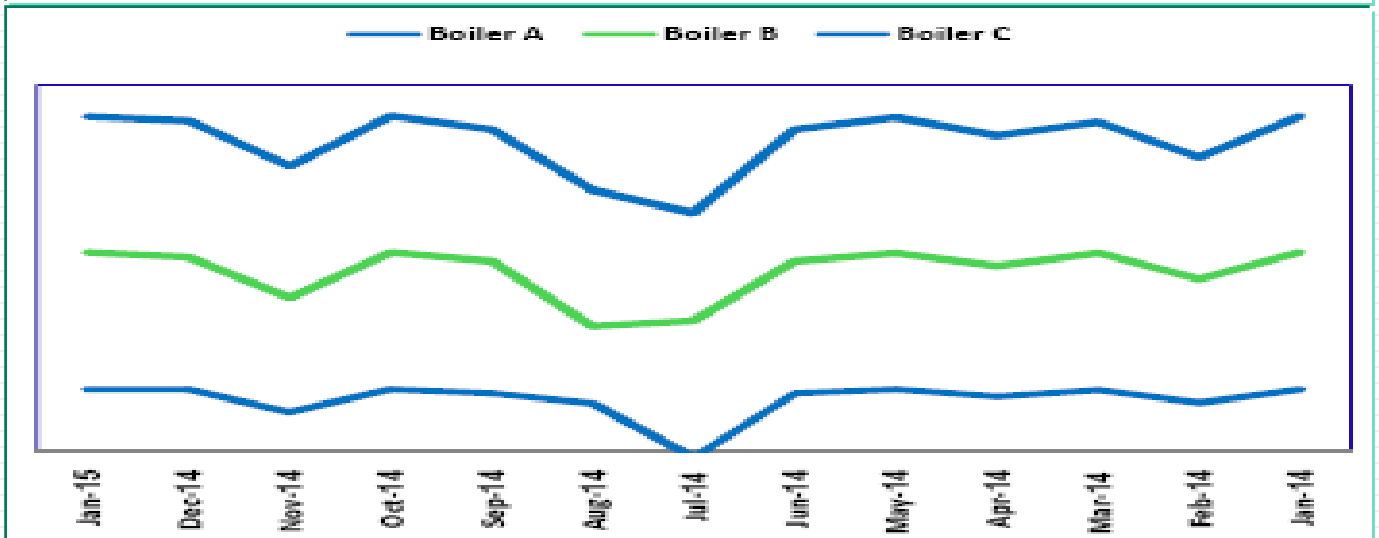
KPIs - Level II

KPIs Report

Accumulative Boiler Availability

Acc. boilers Availability

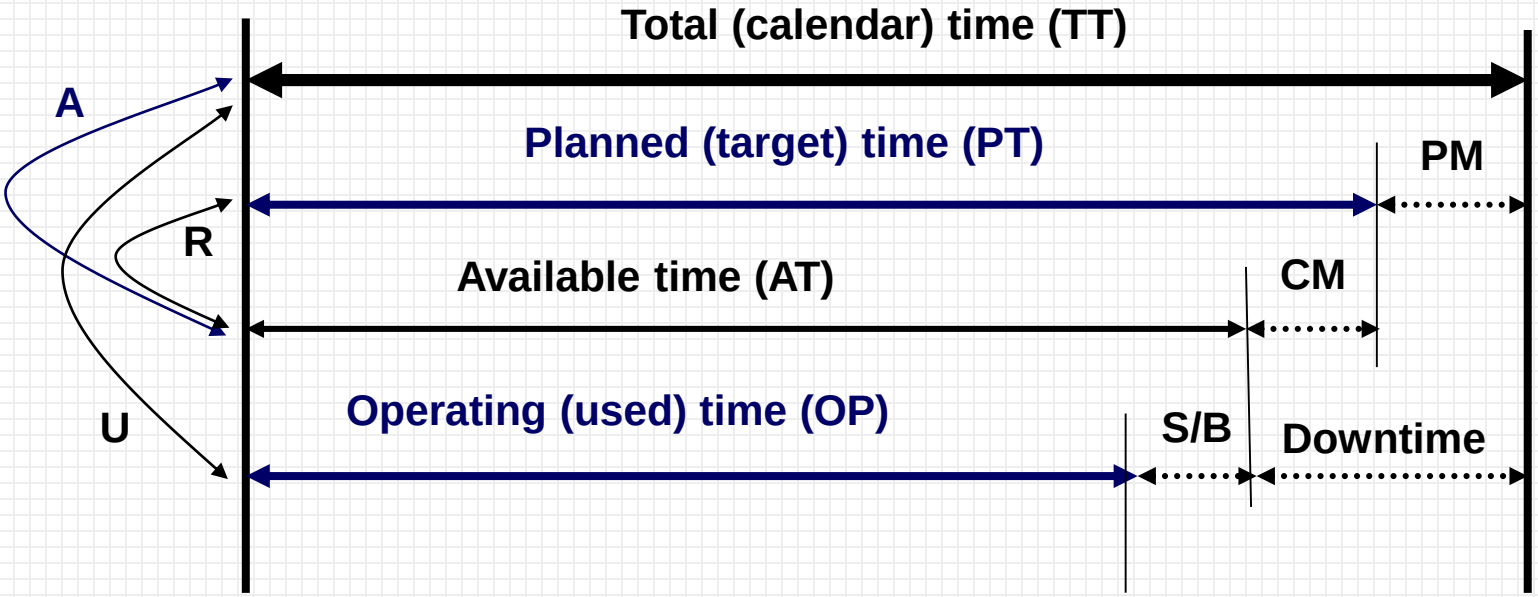
	Boiler A	Boiler B	Boiler C	Std. Hrs
Jan-14	744	744	744	744
Feb-14	668	672	666	672
Mar-14	740	744	715	744
Apr-14	702	713	709.5	720
May-14	744	742	740	744
Jun-14	720	720	720	720
Jul-14	370	744	591	744
Aug-14	665	420	744	744
Sep-14	720	720	720	720
Oct-14	744	744	744	744
Nov-14	618.5	621	720	720
Dec-14	744	720	744	744
Jan-15	744	744	741	744
Total	8923.5	9048	9298.5	9504
Acc. Availability	93.89%	95.20%	97.84%	100.00%



KPIs - Level II

KPIs Report

Accumulative Boiler Availability



Total Hours	Planned downtime	Unplanned downtime	Total downtime	Available time	Standby time	Operating time
9504	400	180.5	580.5	8923.5	0	8923.5

Availability %	Reliability %	Utilization %
93.89	98	93.89

KPIs - Level II

KPIs Report

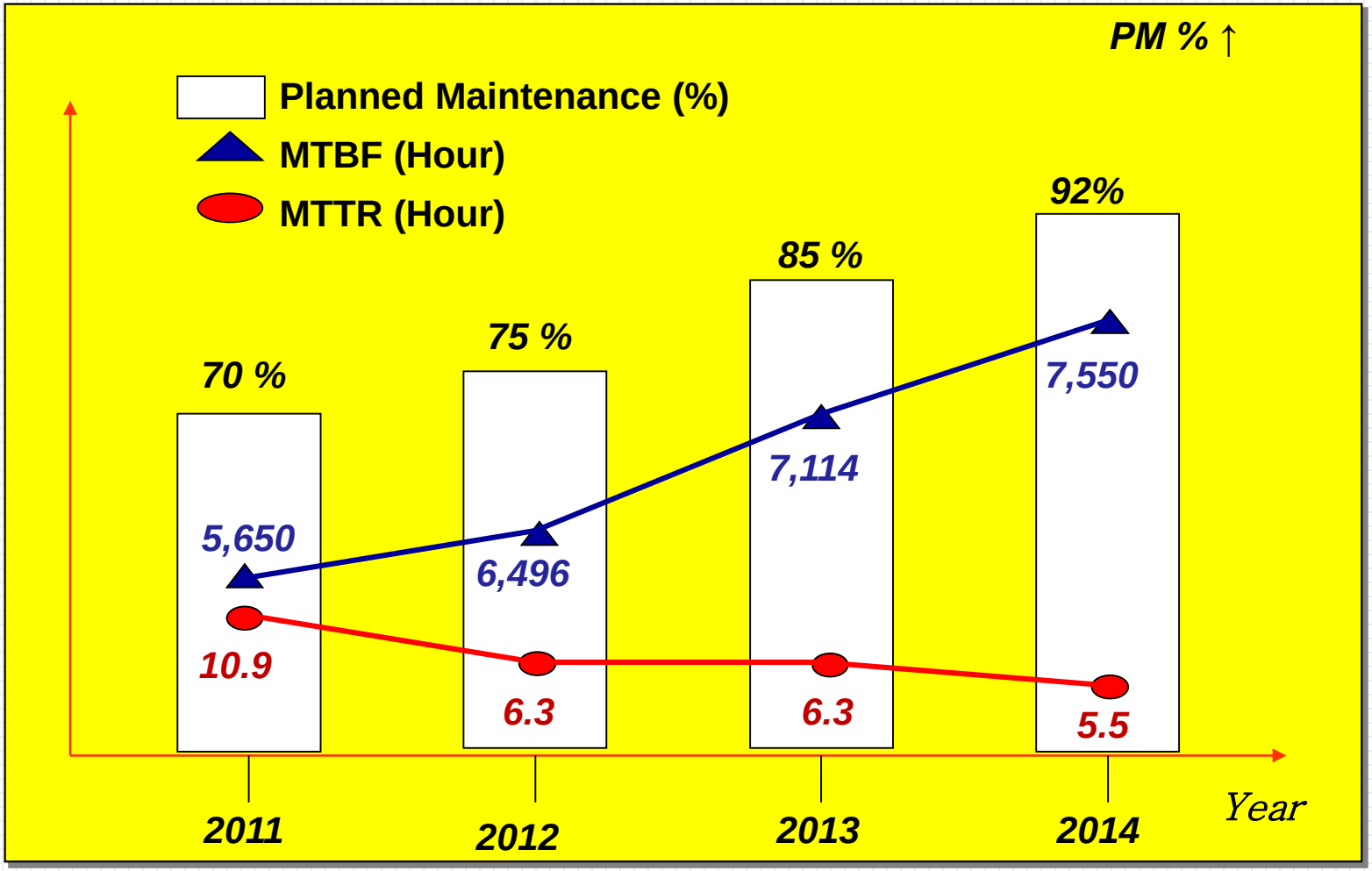
Top Critical Equipment (Accumulative Down Time)

Unit	Equipment	Total
UNIT 400	GA-402B	1548
UNIT 1000	GA-1001A	1209
UNIT 1000	GA-1009A	1093.5
UNIT 400	GA-402A	747
UNIT 6000	GB-302A	321

KPIs - Level III

KPIs Report

Reliability Analysis for Boilers



Page 6/6

Total Productive Maintenance (TPM):

TPM is a systematic approach to maximize the equipment effectiveness through operators involvement.

Management + Operators + Maintenance

Autonomous Maintenance (AM):

Case Study

Process: Excavation **Equipment: Excavator**

Item	Day #1
Total working hours	12
Planned Performance Rate, m3/hr	30
Net Quantity, m3	**210**

Capacity Analysis:

Maximum Quantity = 12 * 30 = 360 m3 **(Optimal ??)**

Net Quantity = 210 m3

Capacity Utilization = 210 / 360 = 58% **Losses= 42%**

Time Analysis:

Total Working Time = 12 hours **Net Quantity = 210 m3**

Productive time = 210/30 = 7 hours

Capacity Utilization = 7 / 12 = 58% **Losses= 42%**

Case Study

Process: xxx **Equipment: Compressor xxx**

Item	2017
Total working hours	8760
Planned Performance Rate, ton/hour	15
Net Quantity, ton	**100,000**

Capacity Analysis:

Maximum Quantity = 8760 * 15 = 131400 ton (Optimal ??)

Net Quantity = 100,000

Capacity Utilization = 76% **Losses= 24%**

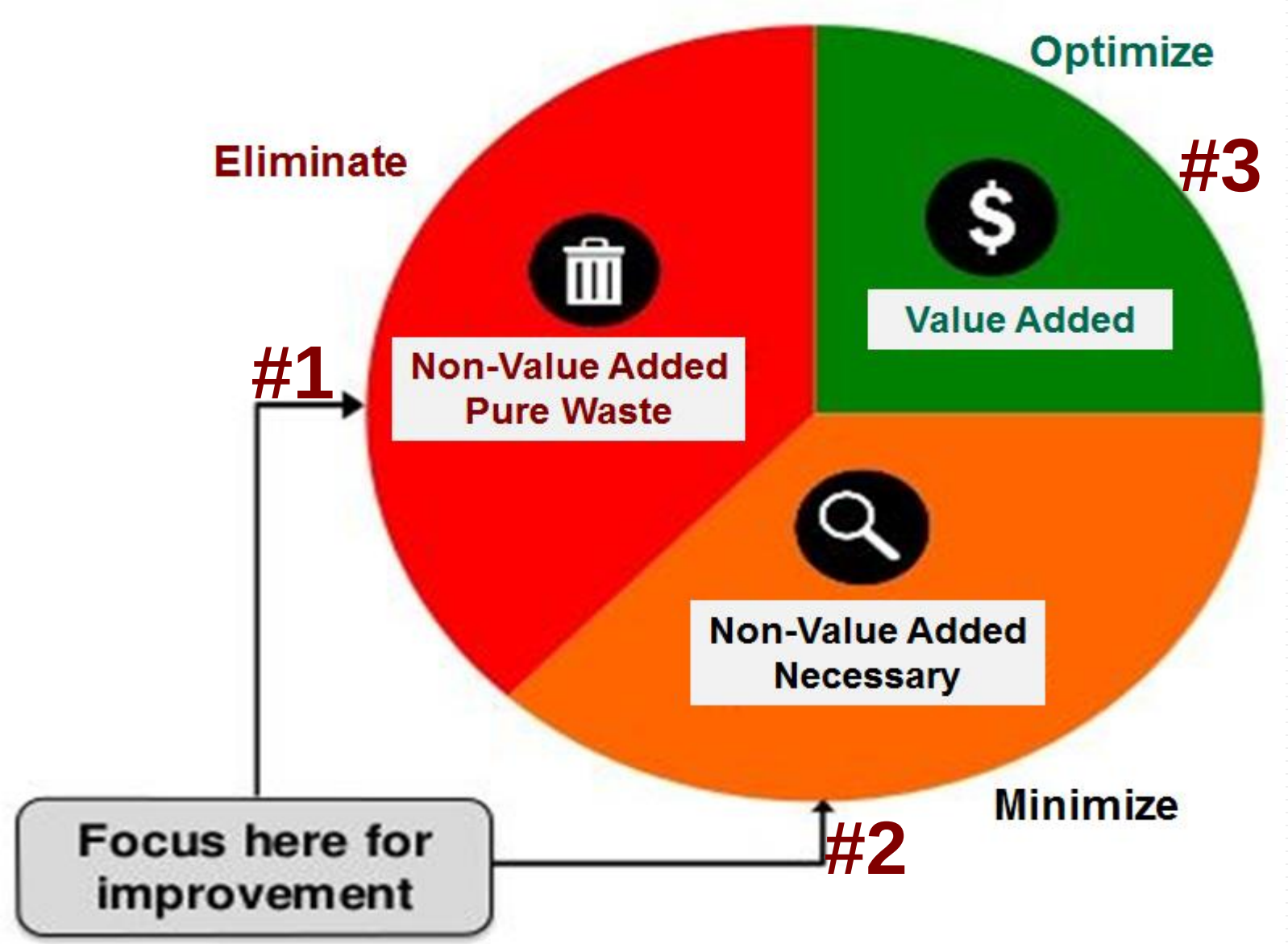
Time Analysis:

Total Working Time = 8760 **Net Quantity = 100,000**

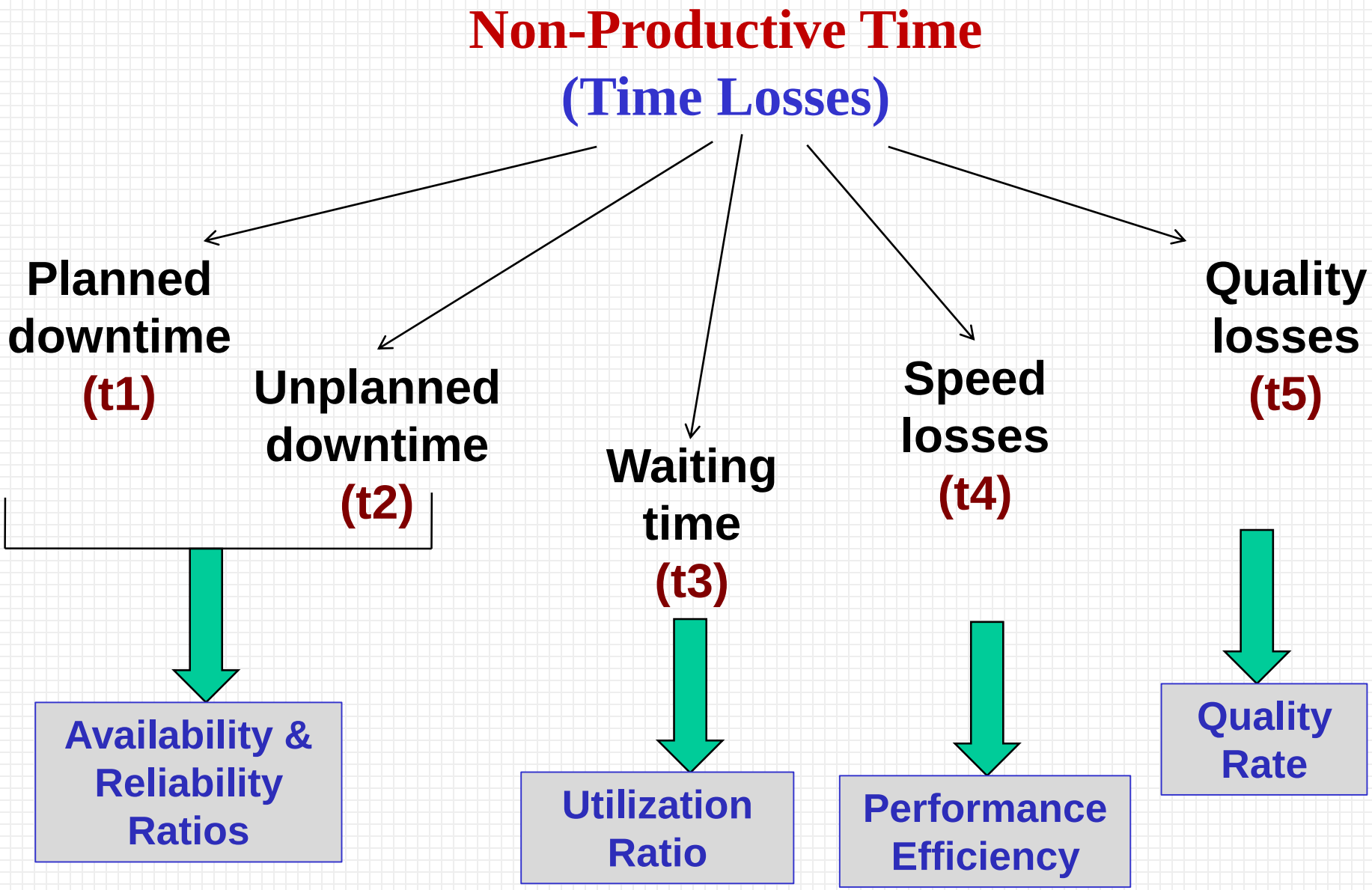
Productive time = 100,000/15 = 6667

Capacity Utilization = 76% **Losses= 24%**

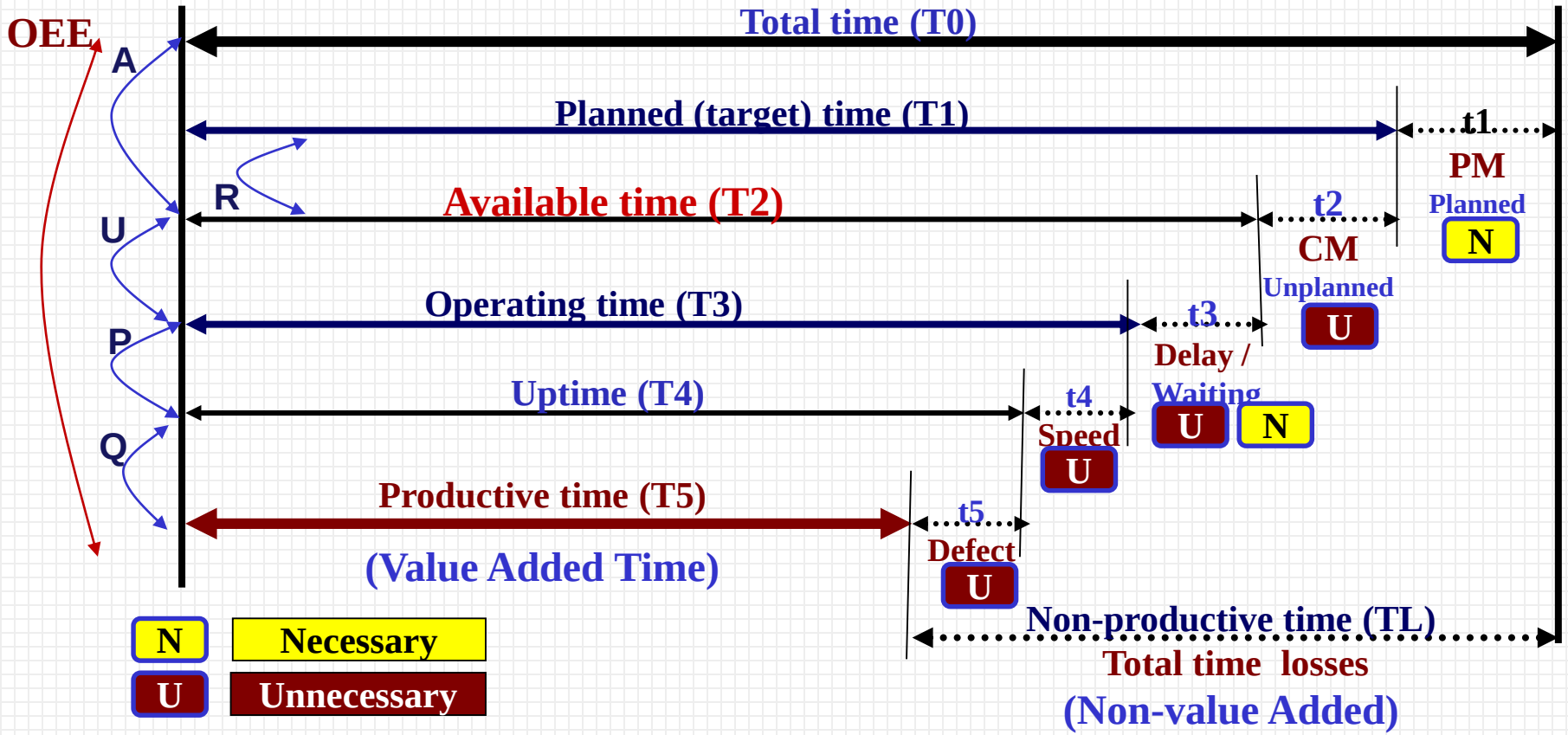
Lean Approach – Value Added Flow Analysis



Process Time Analysis:



Process Time Analysis



A = Availability	= (Total Time – Down Time) / Total Time	=
R = Reliability	= Available Time / Planned Time	=
U = Utilization	= Operating Time / Available Time	=
P = Performance	= Actual Production / Target Production	=
Q = Quality yield	= Net Production / Total Production	=

OEE = Availability * Performance * Quality yield =

OEE = Availability * Utilization * Performance * Quality yield =

Overall Equipment Effectiveness (OEE)

= Availability * Performance * Quality yield

Availability = (Total Time – Down Time) / Total Time ➔ **Downtime loss**

Performance = Actual Production / Target Production ➔ **Speed loss**

Quality Yield = Net Production / Total Production ➔ **Quality loss**

(Target ➔ Zero Losses)

Case Study:

Annual KPIs

Company: Petrochemical Industry **Product:** XXX

Case Study: KPIs

The operation information 2017 for a petrochemical industry is as follows:

Total Working Hours	**8760**	**hours**
Performance Standard Rate	**15**	**units/hour**
Net Production Quantity	**100,000**	**units**

Based on this information, discuss briefly KPIs.

Main KPIs:

Operation Efficiency = (100,000/15)/8760 = 76%

Operation Efficiency = 100,000/(15*8760) = 76%

Unused Capacity = 100 - 76% = 24%

(Non-Value Added)

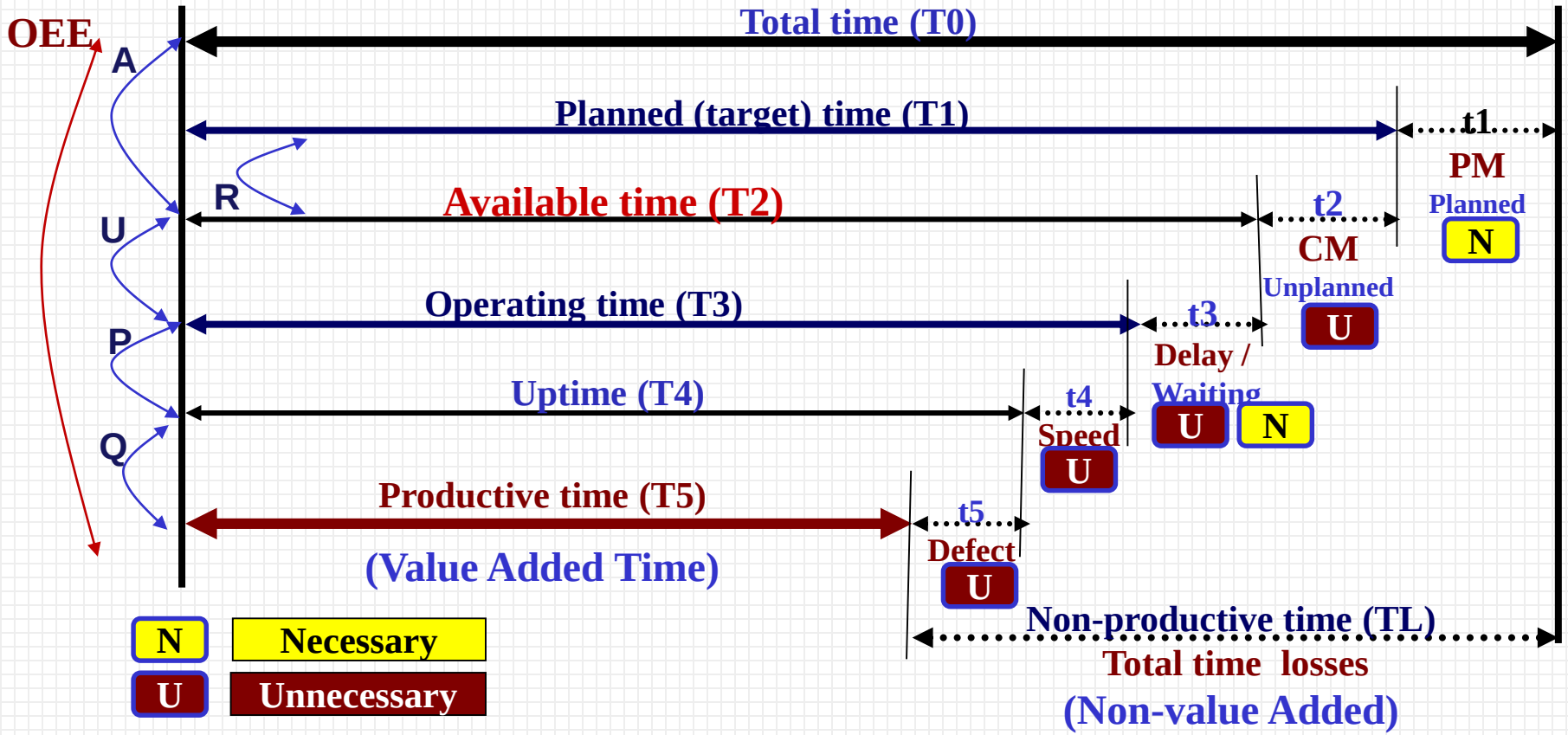
Case Study: KPIs

The operation information 2017 for a petrochemical industry is as follows:

Daily Working Hours	24	hour/day
Annual Working Days	365	days
Planned Downtime (PM)	72	hours
Unplanned Downtime (CM)	48	hours
Performance Standard Rate	15	units/hour
Actual Operating Time	8,000	hours
Total Production Quantity	105,000	units
Reject/Scrap Quantity	5,000	units

Based on this information, discuss briefly KPIs.

Process Time Analysis / Productivity Analysis / OEE Analysis:

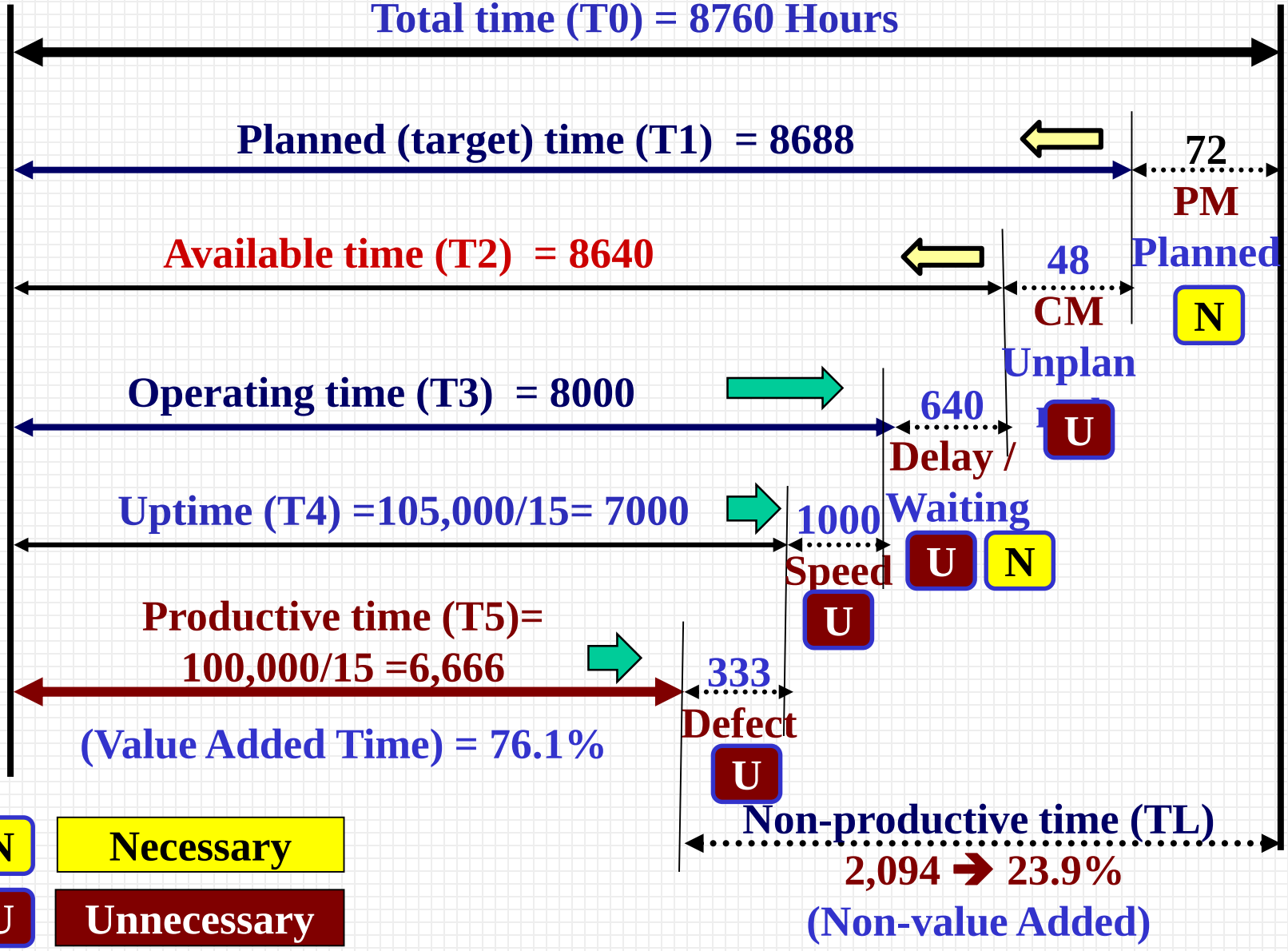


A = Availability	= (Total Time – Down Time) / Total Time	=
R = Reliability	= Available Time / Planned Time	=
U = Utilization	= Operating Time / Available Time	=
P = Performance	= Actual Production / Target Production	=
Q = Quality yield	= Net Production / Total Production	=

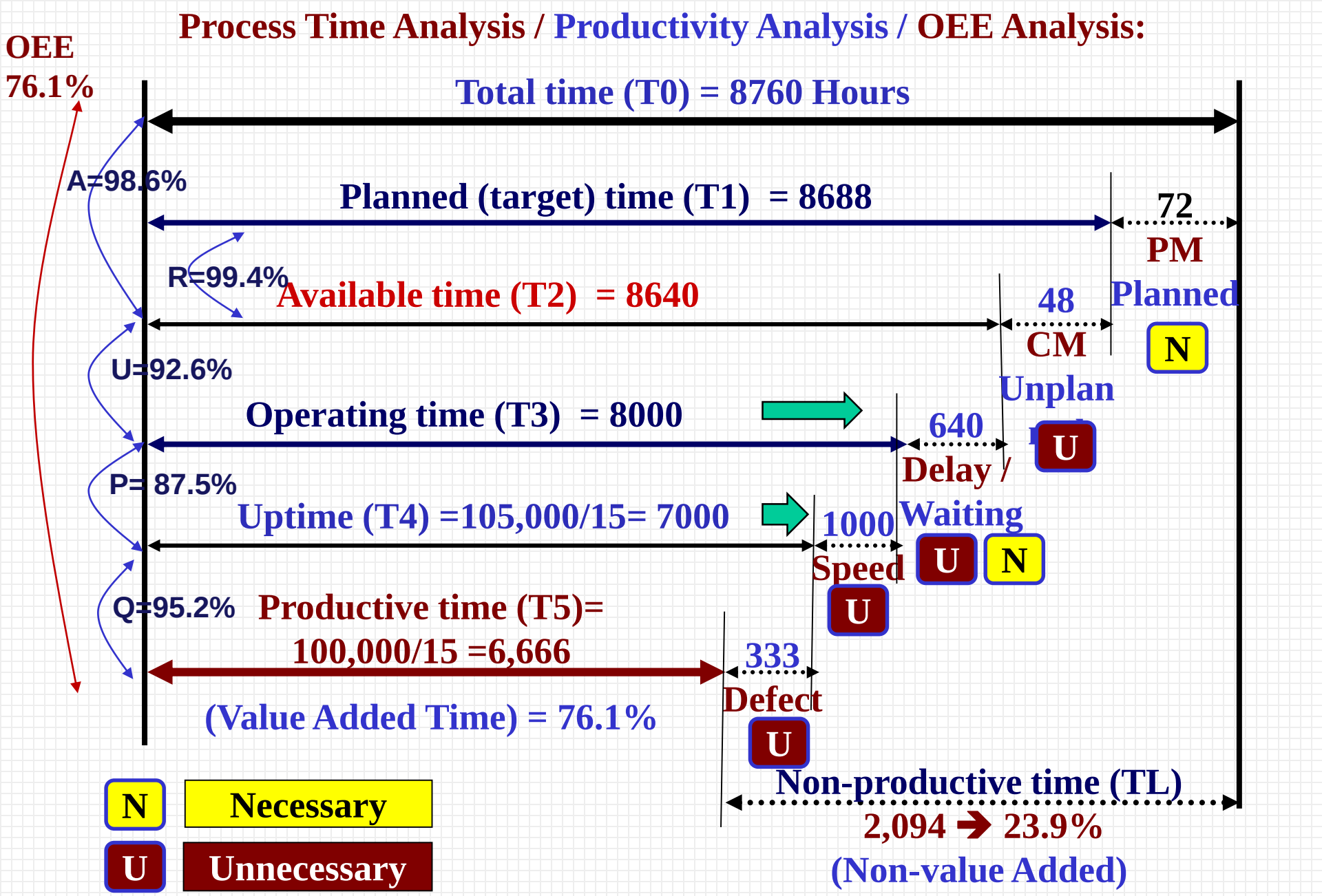
OEE = Availability * Performance * Quality yield =

OEE = Availability * Utilization * Performance * Quality yield =

Process Time Analysis / Productivity Analysis / OEE Analysis:

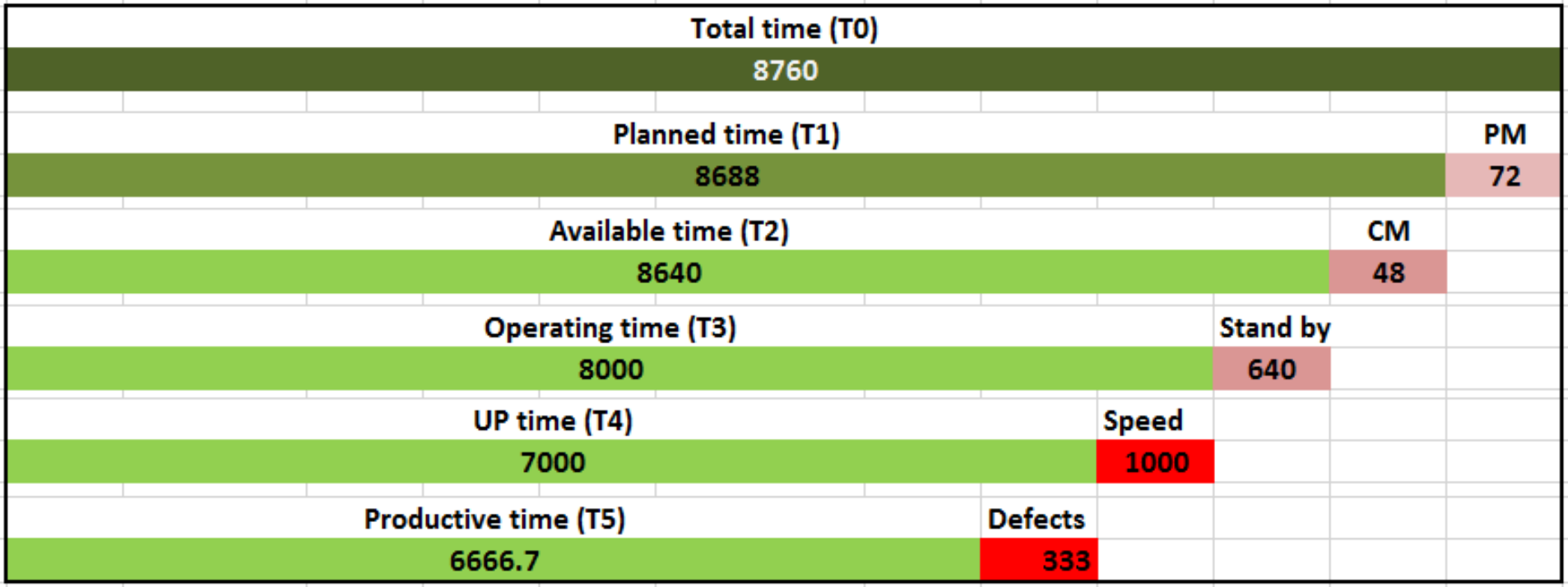


Process Time Analysis / Productivity Analysis / OEE Analysis:



OEE Analysis:

Working hours	24		Planned down time	72	hr		
Workinh days	365		unplanned downtime	48	hr		
Standard rate	15	unit /hr	Total production quantity	105000	unit	7000	hr
Actual operating time	8000	hr	Reject scrap quantity	5000	unit	333.333	hr



Availability (A)	98.6%
Reliability (R)	99.4%
Utilization (U)	92.6%
Performance (P)	87.5%
Quality (Q)	95.2%

	A*P*U*Q	T5/T0
OEE	76.1%	76.1%

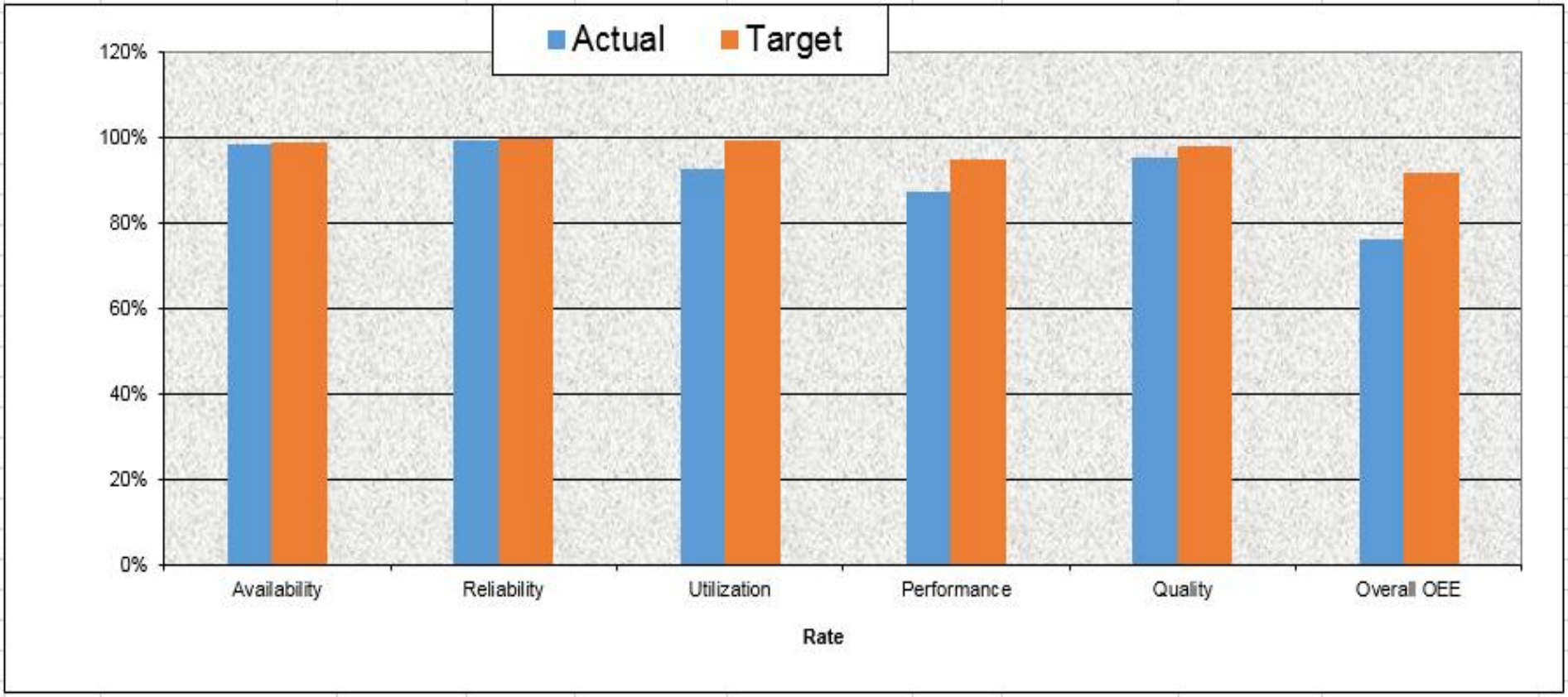
Overall Equipment Effectiveness (OEE)

Company:	xxx	Process:	xxx

	1	Total Time	8760	Hours	
	2	Planned Downtime	72	Hours	
	3	Unplanned Downtime	48	Hours	
	4	Available Time (1-2-3)	8640	Hours	
Availability Rate = (4/1)			98.63%		Maintenance
Reliability = (4/(1-2))			99.45%		
	5	Actual Operating Time	8000	Hours	
Utilization Rate = (5/4)			92.59%		Logistic
	6	Total Production Quantity	105000	Units	
	7	Standard Production Rate	15	Units per hour	
	8	Uptime	7000.0	Hours	
Performance Rate = (8/5)			87.50%		Operation
	9	Reject/Scrap Quantity	5000	Units	
Quality Rate = ((6-9)/6)			95.24%		Quality

KPIs Report (2017):

KPIs	Actual	Target	Gap%	Resposiblity
Availability	98.6%	99.0%	0.4%	Maintenance
Reliability	99.4%	99.6%	0.2%	Maintenance
Utilization	92.6%	99.5%	6.9%	Logistic
Performance	87.5%	95.0%	7.5%	Operation
Quality	95.2%	98.0%	2.8%	Quality
Overall OEE	76.1%	91.7%	15.6%	Business



KPIs Report (2017):

KPIs	Actual	Target	Gap%	Resposiblity
Availability	98.6%	99.0%	0.4%	Maintenance
Reliability	99.4%	99.6%	0.2%	Maintenance
Utilization	92.6%	99.5%	6.9%	Logistic
Performance	87.5%	95.0%	7.5%	Operation
Quality	95.2%	98.0%	2.8%	Quality
Overall OEE	76.1%	91.7%	15.6%	Business

Recommendations (2018):

Improve OEE% (76.1 to ≥ 91.7%)

- **Improve A% (98.6 to ≥ 99%):**
  (Min. Downtime losses)
  1. Standard RCFA
  2. Advanced Training
  3. Motivation Program
- **Improve U% (92.6 to ≥ 99.5%):**
  (Min. waiting / delay)
  1. Raw Material Availability
  2. Commination Plan
  3. Motivation Program
- **Improve P% (87.5 to ≥ 95%):**
  (Min. Speed losses)
  1. Monthly Test Run (full)
  2. Advanced Training
  3. Motivation Program
- **Improve Q% (95.2 to ≥ 98%):**
  (Min. Defect Ratio)
  1. Sample Analysis
  2. Labor Rotation
  3. Motivation Program

Case Study: KPIs

The operation information for a petrochemical industry is as follows:

Item	Units	2017	2018
Daily Working Hours	hour/day		
Annual Working Days	days		
Planned Downtime (PM)	hours		
Unplanned Downtime (CM)	hours		
Standard Performance Rate	units/hour		
Actual Operating Time	hours		
Total Production Quantity	units		
Reject/Scrap Quantity	units		

Based on this information, discuss briefly KPIs.

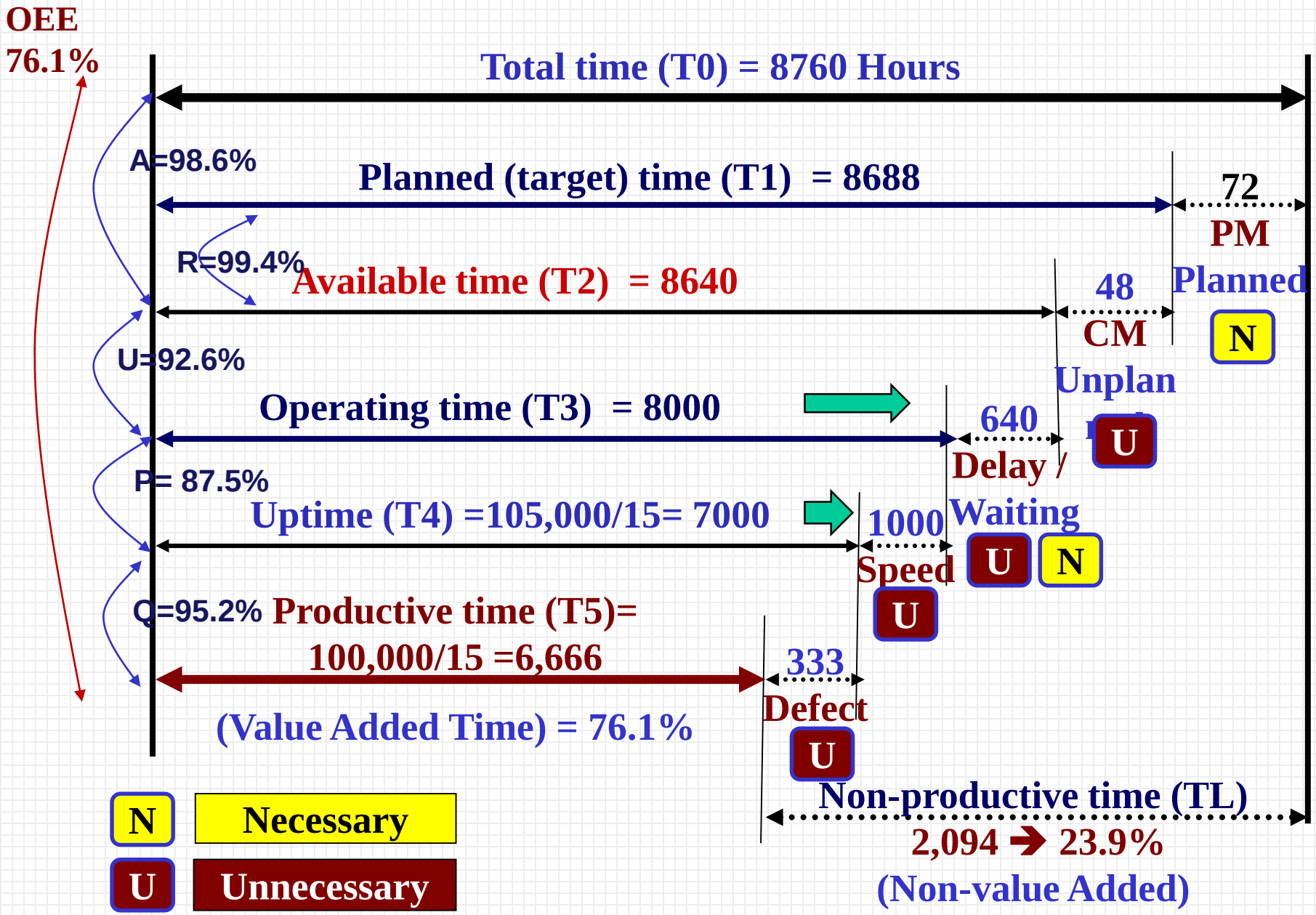
Case Study: KPIs

The operation information for a petrochemical industry is as follows:

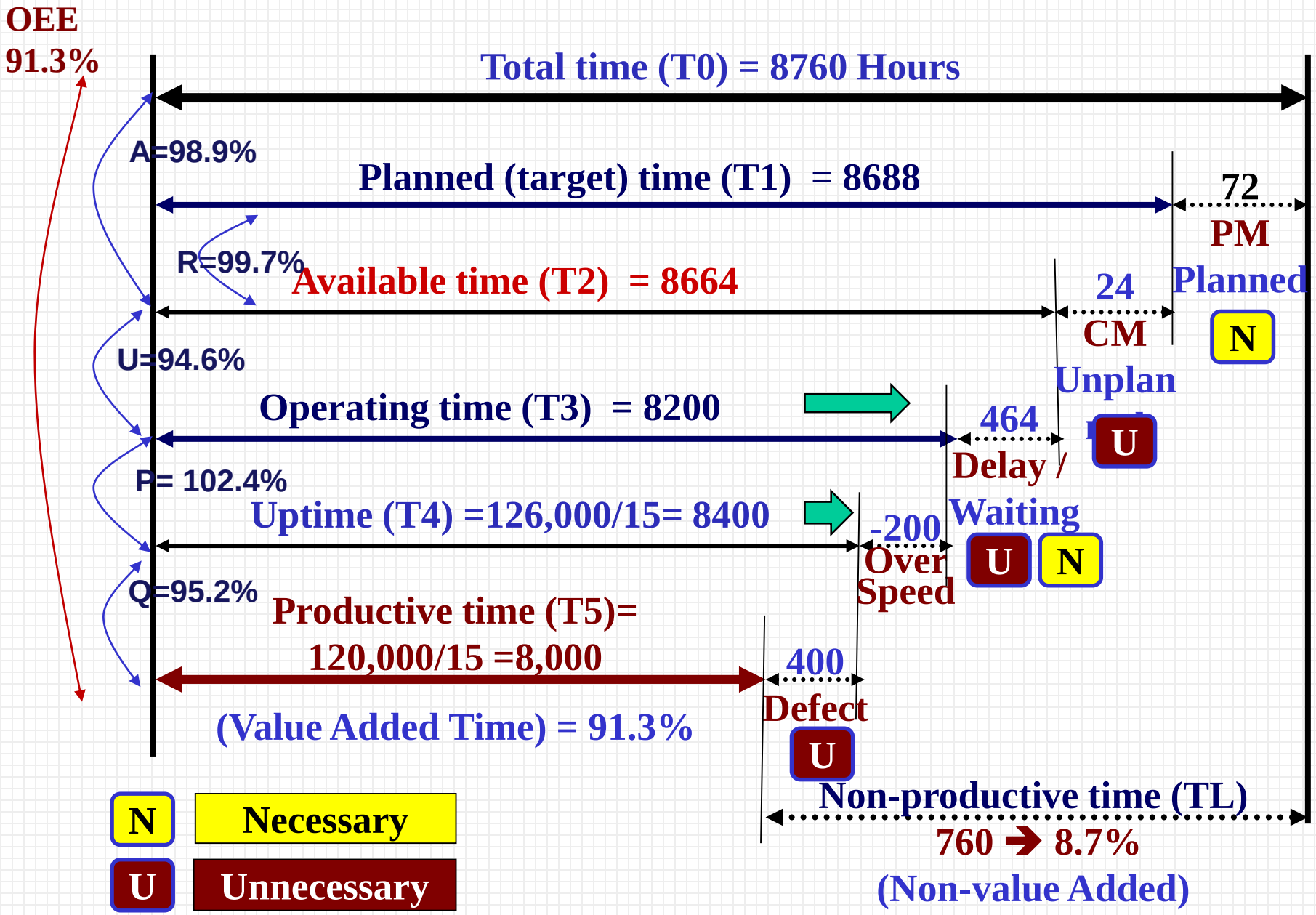
Dept.	Item	Units	2017	2018
Maintenance	Daily Working Hours	hour/day	24	24
	Annual Working Days	days	365	365
	Planned Downtime (PM)	hours	72	72
	Unplanned Downtime (CM)	hours	48	24
Operation	Standard Performance Rate	units/hour	15	15
	Actual Operating Time	hours	8,000	8,200
	Total Production Quantity	units	105,000	126,000
	Reject/Scrap Quantity	units	5,000	6,000

Based on this information, discuss briefly KPIs.

2017


OEE
76.1%
Total time (T0) = 8760 Hours
A=98.6%
Planned (target) time (T1) = 8688
72
PM
Planned
N
R=99.4%
Available time (T2) = 8640
48
CM
Unplan
U=92.6%
Operating time (T3) = 8000
640
Delay /
U
P= 87.5%
Uptime (T4) =105,000/15= 7000
1000
Speed
Waiting
U
N
U
Q=95.2%
Productive time (T5)=
100,000/15 =6,666
333
Defect
U
(Value Added Time) = 76.1%
Non-productive time (TL)
2,094 → 23.9%
(Non-value Added)
N
Necessary
U
Unnecessary

2018


OEE
91.3%
Total time (T0) = 8760 Hours
A=98.9%
Planned (target) time (T1) = 8688
72
PM
Planned
N
R=99.7%
Available time (T2) = 8664
24
CM
Unplan
U=94.6%
Operating time (T3) = 8200
464
Delay /
Waiting
U
P= 102.4%
Uptime (T4) =126,000/15= 8400
-200
Over
Speed
U
N
Q=95.2%
Productive time (T5)=
120,000/15 =8,000
400
Defect
U
(Value Added Time) = 91.3%
Non-productive time (TL)
760 ➔ 8.7%
(Non-value Added)
N
Necessary
U
Unnecessary

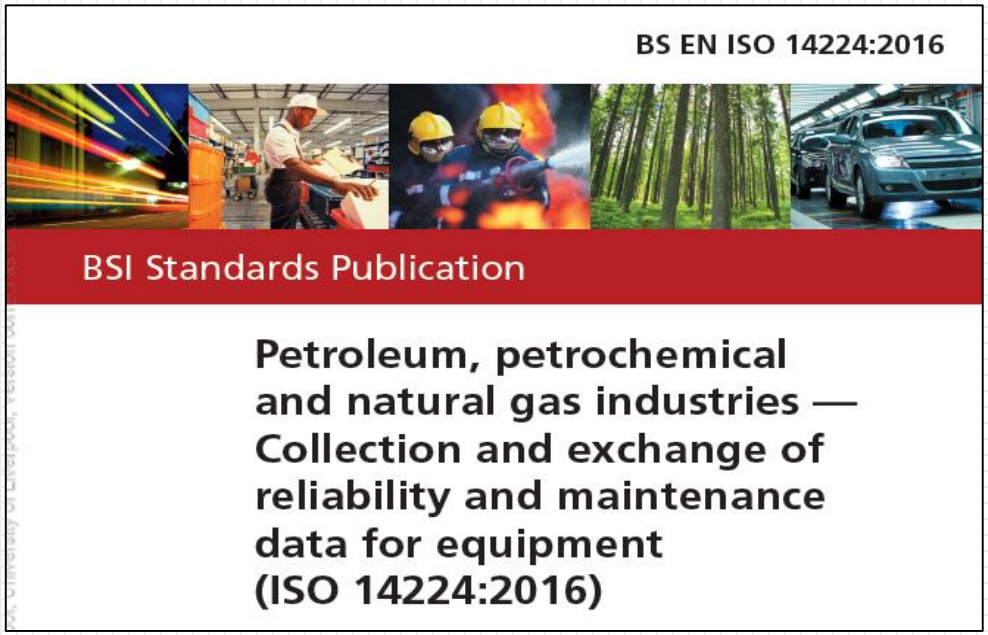
KPIs Report

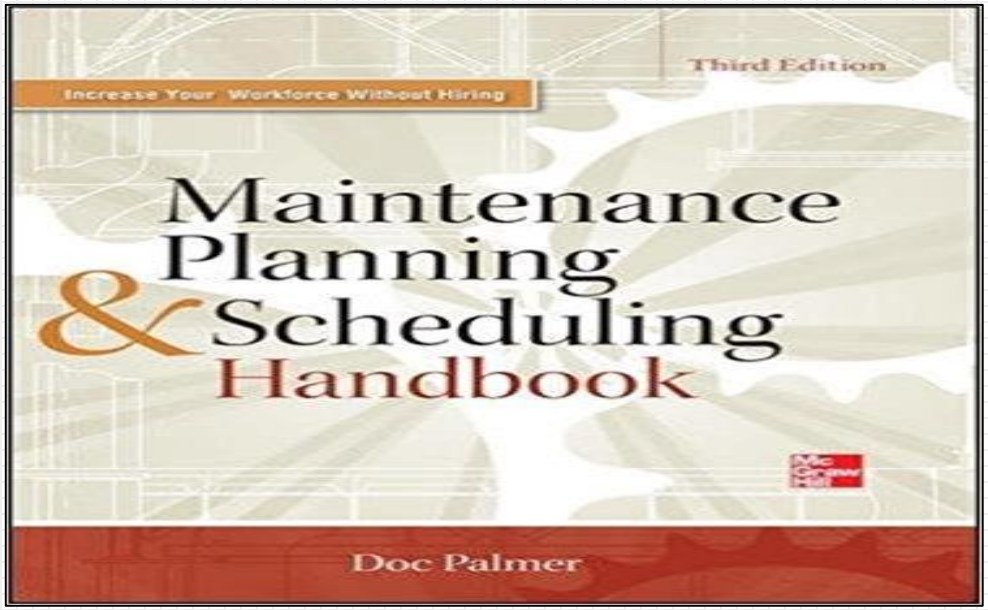
KPIs	2017	2018	Evaluation 2018 / 2017	Target 2019	Responsibility
OEE %	76.1	91.3	+ 15.2%	93%	Facility
Availability %	98.6	98.9	+ 0.3%	99.5	Maintenance
Reliability %	99.4	99.7	+ 0.3%	99.99	
Utilization %	92.6	94.6	+ 2.0%	96%	Logistics
Performance %	87.5	102.4	+ 14.9%	100%	Operation
Quality %	95.2	95.2	-	97%	Quality

Comments & Recommendations for the next period 2019:

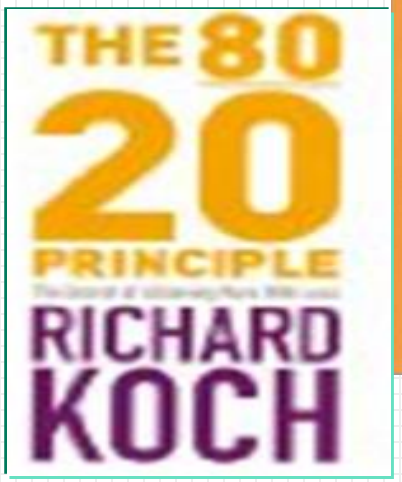
1- Advanced Training Program
2- Performance Motivation Program
3- Standard Documentation System
4- Update Maintenance Program
5- Root Cause Failure Analysis (RCFA)

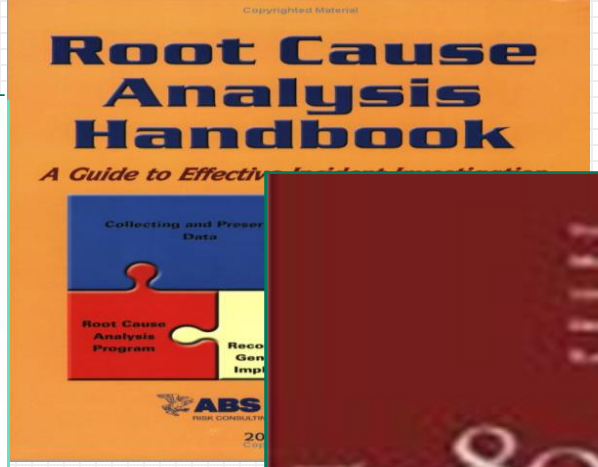
Main References:

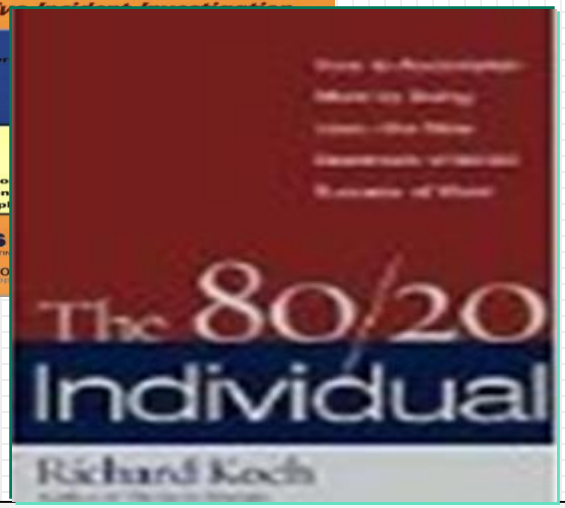




References:







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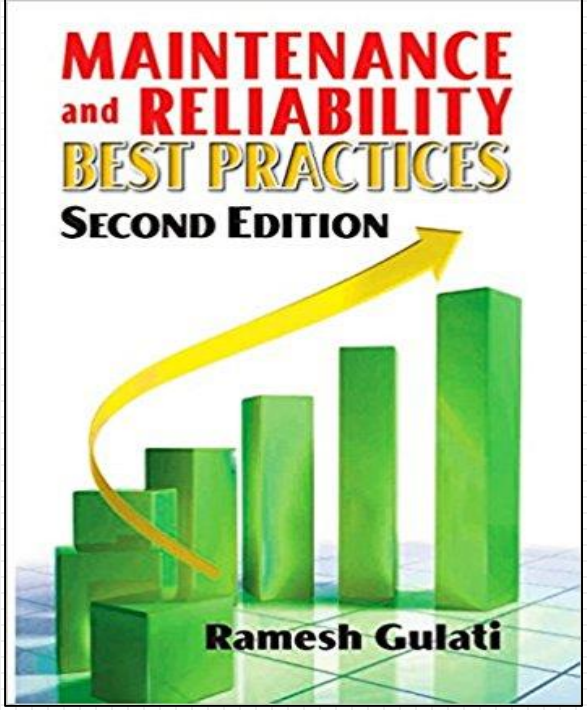
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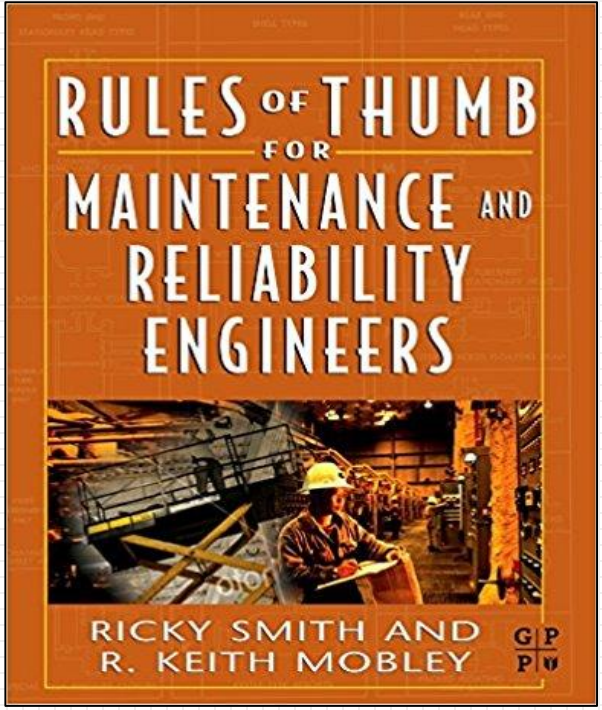
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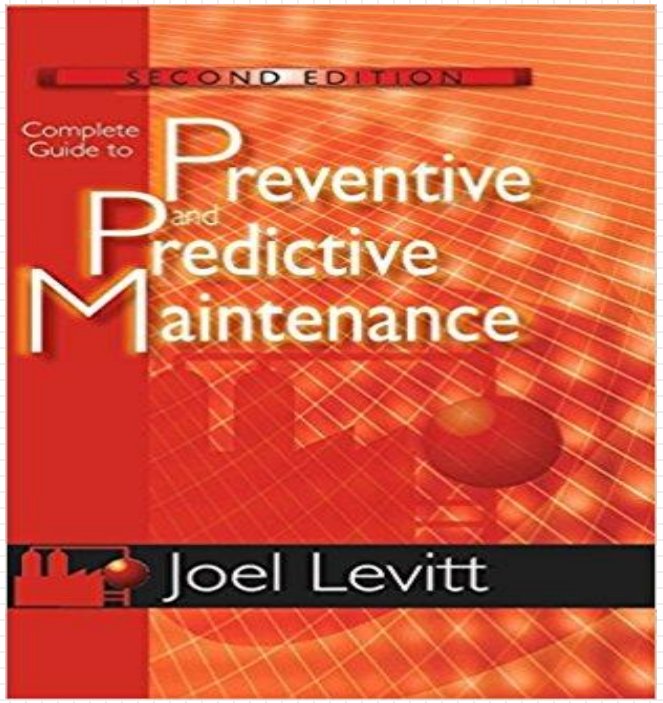
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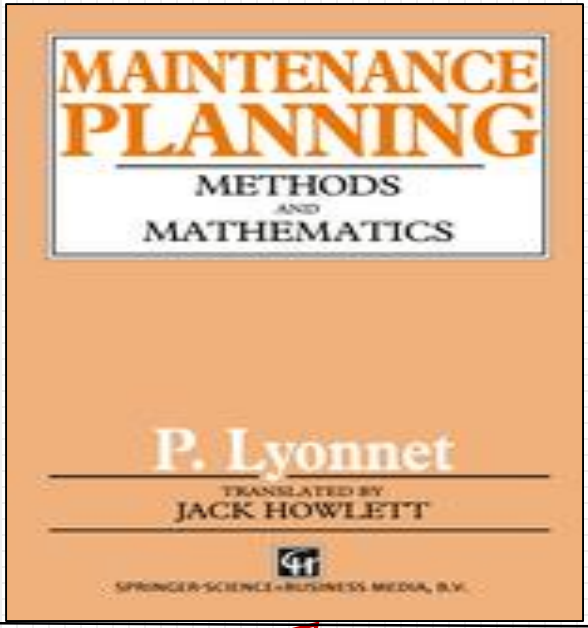
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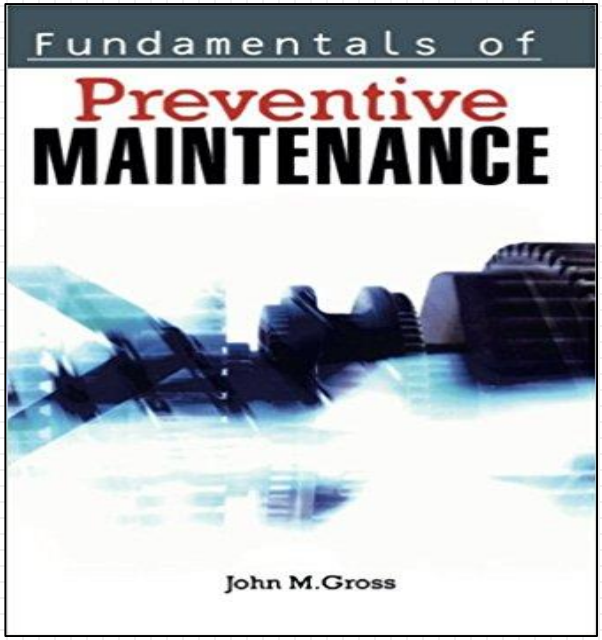
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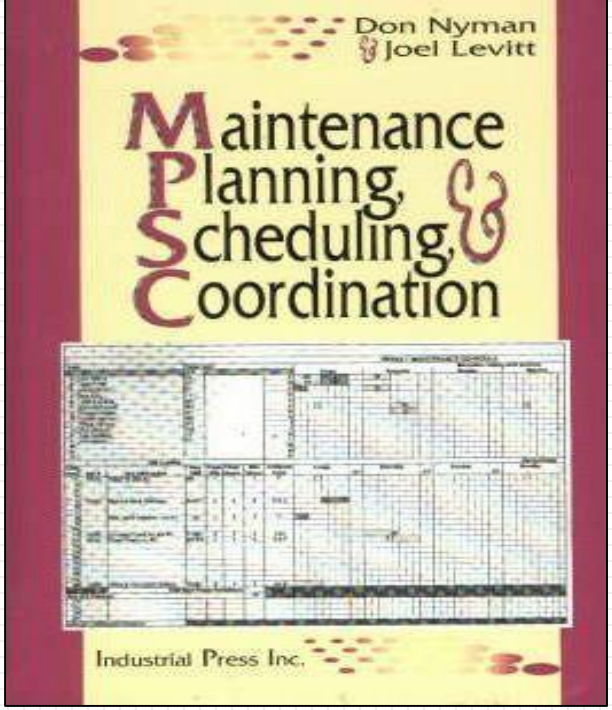
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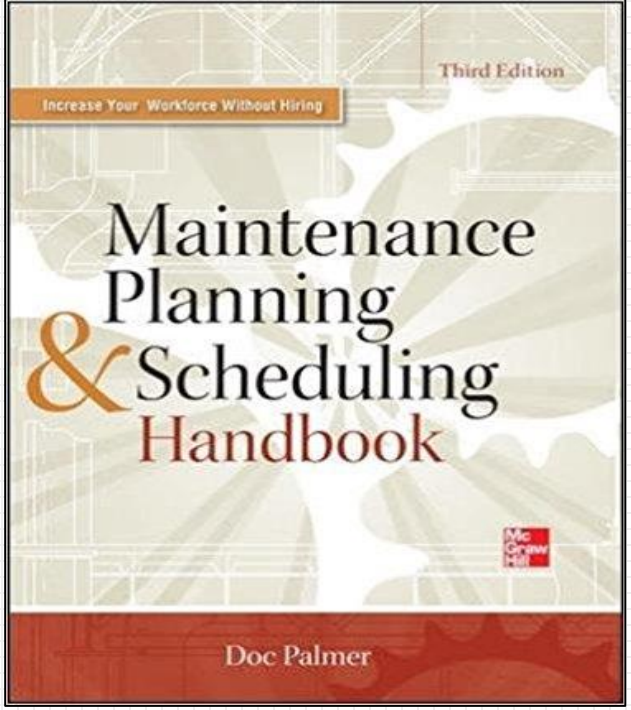
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Increase Your Workforce Without Hiring
Maintenance Planning & Scheduling Handbook
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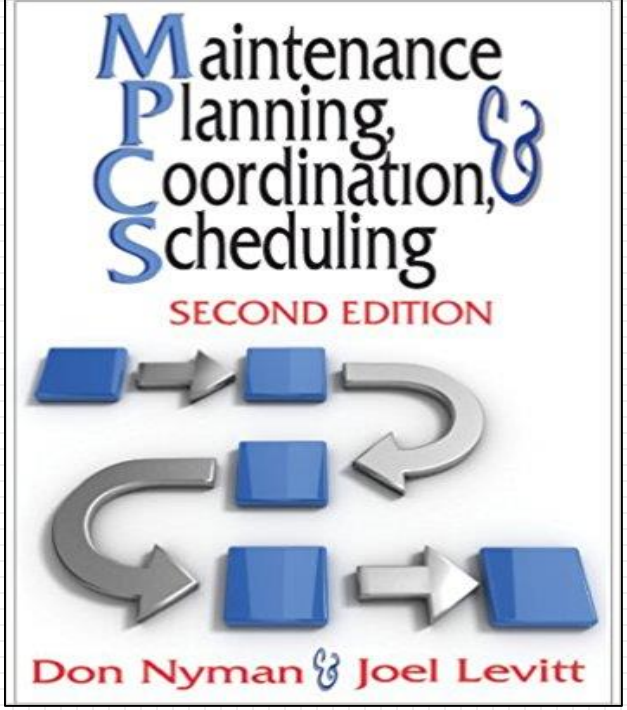
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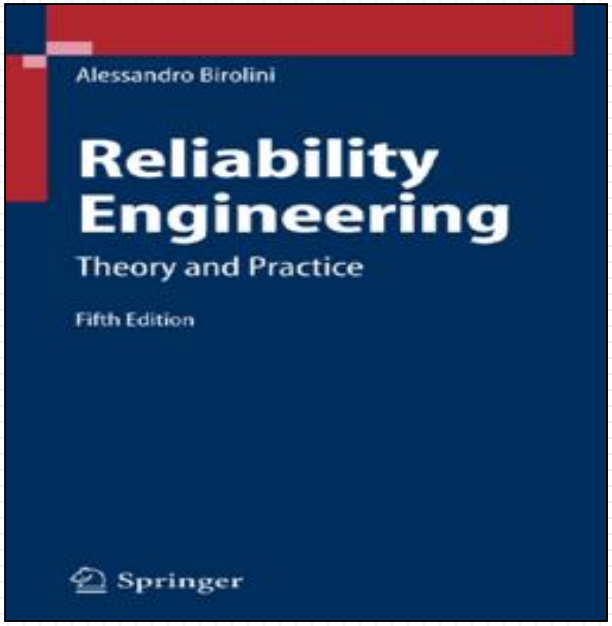
Alessandro Birolini
Reliability Engineering
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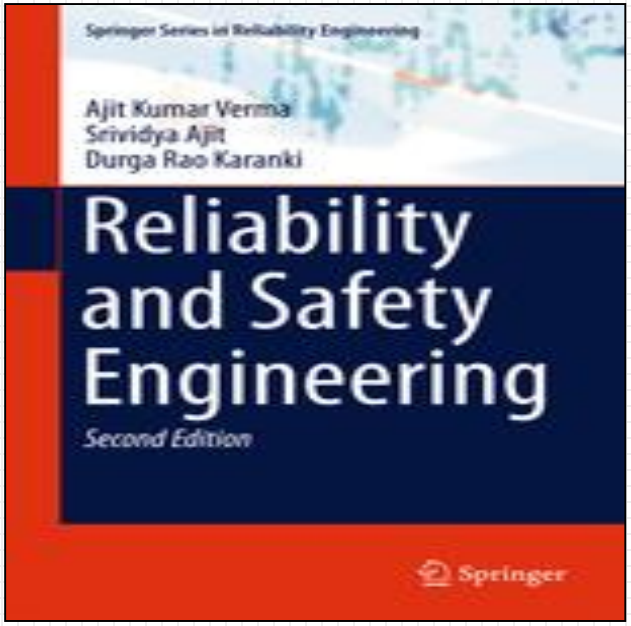
Springer Series in Reliability Engineering
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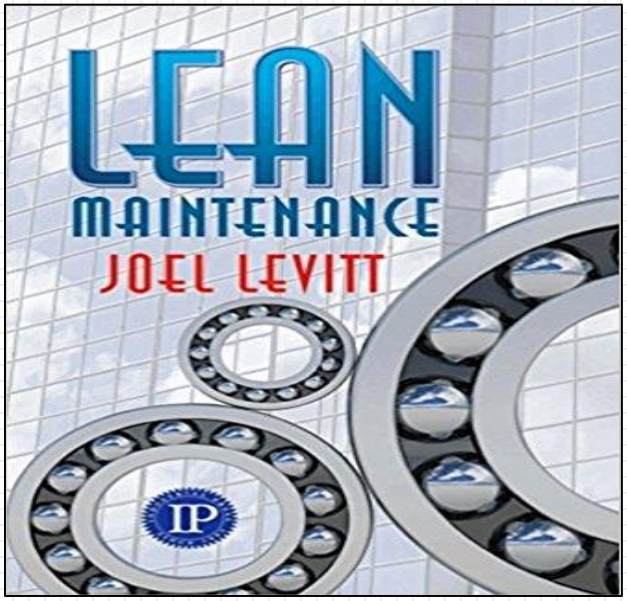
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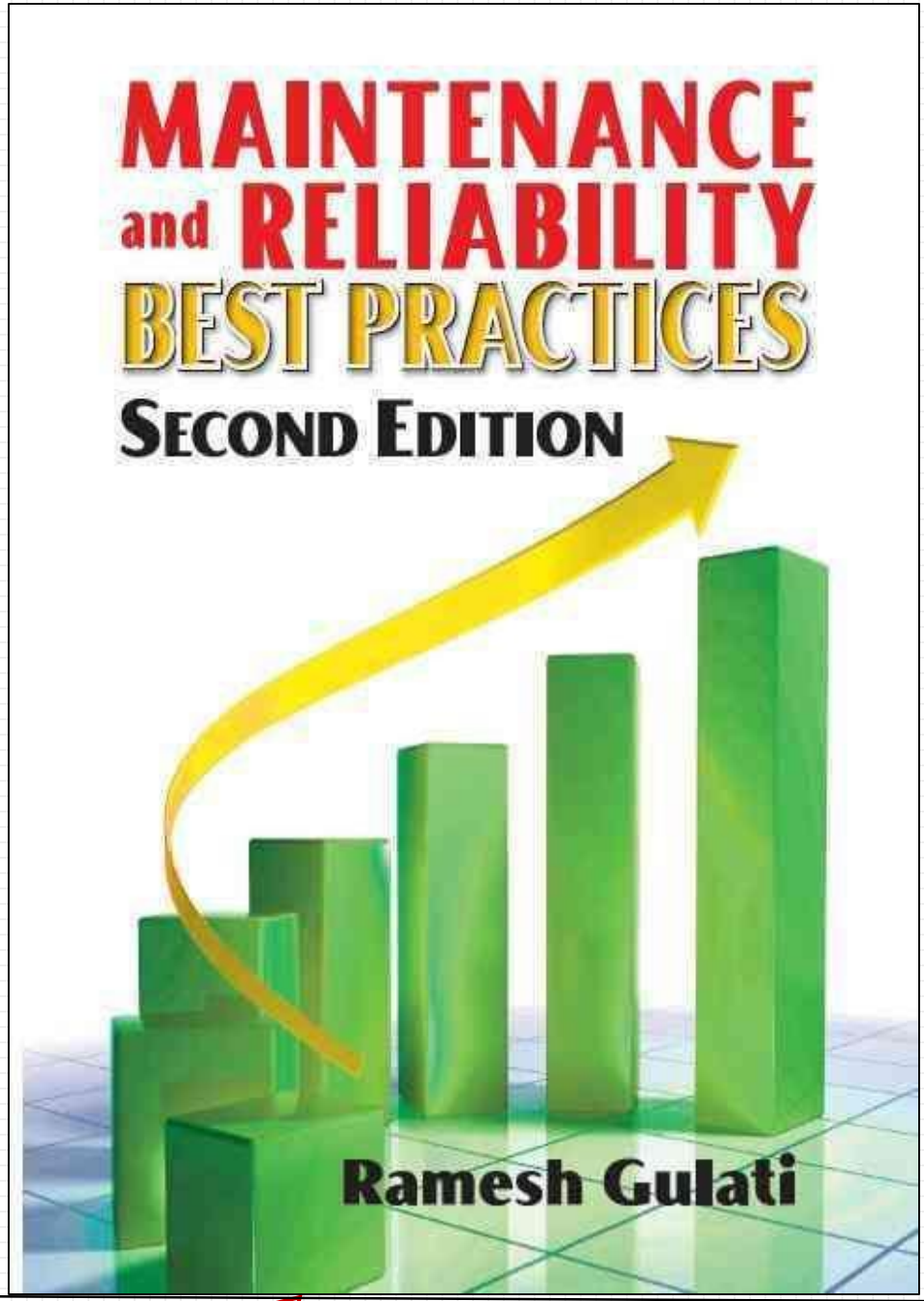
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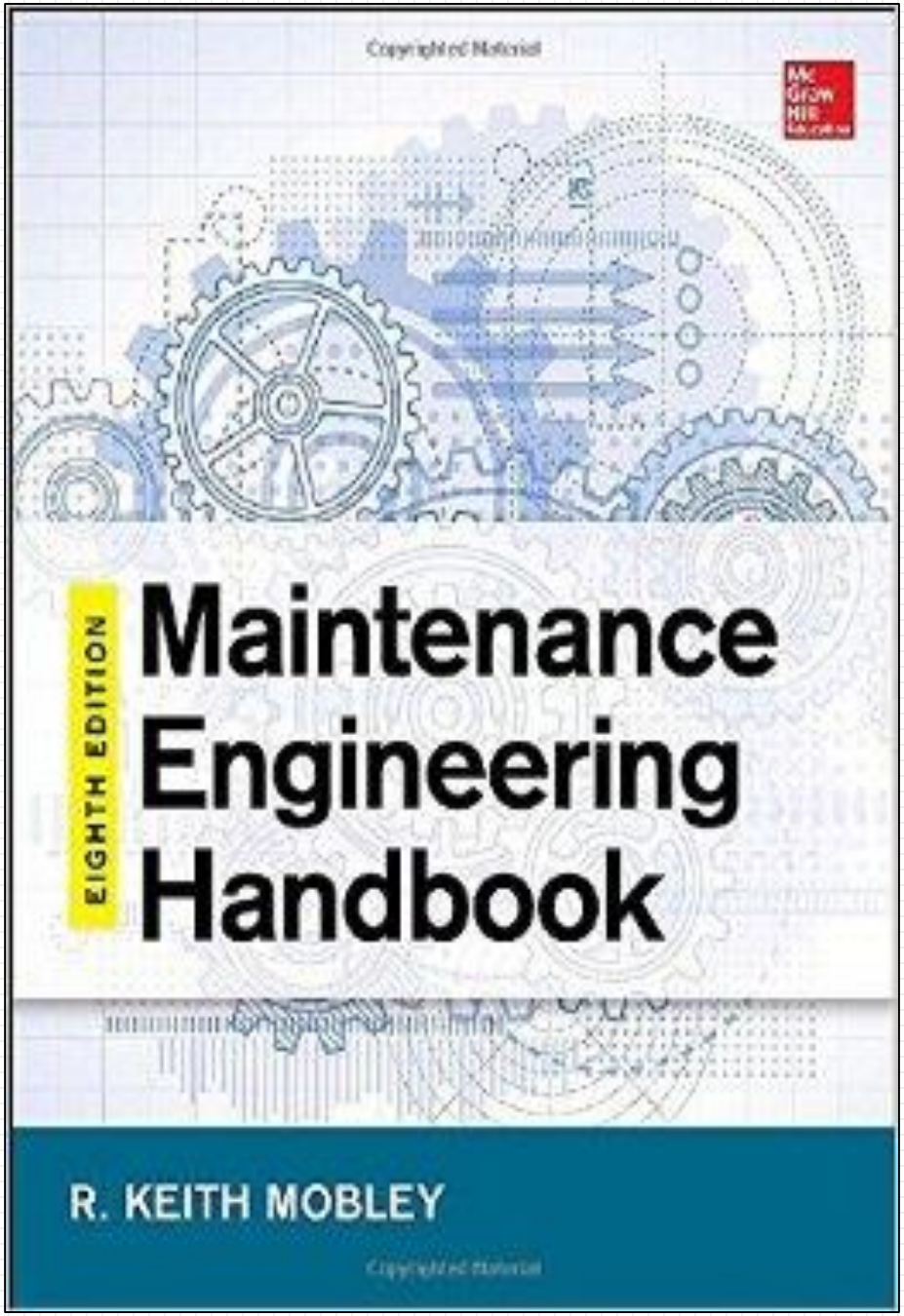
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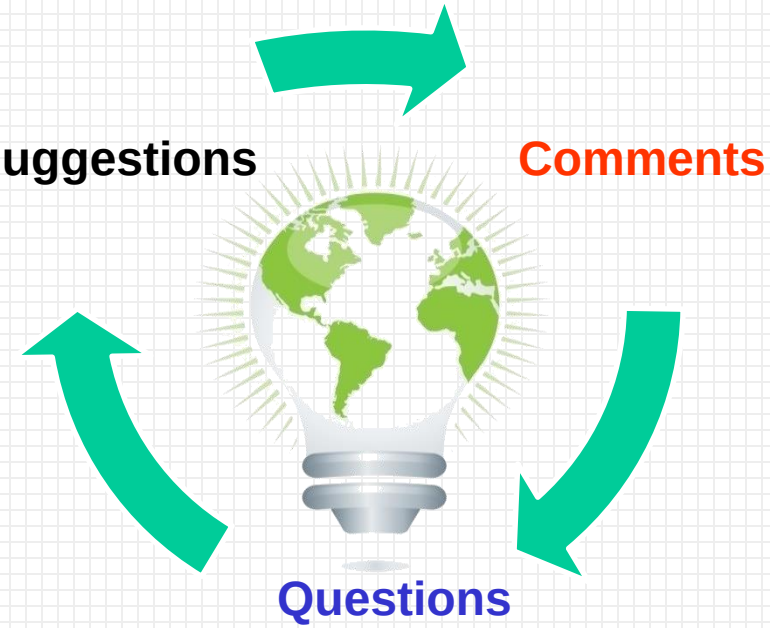
في
القلب

Thank you for your attention!



Useful Science For the Sake of Allah

اللهم تقبل هذا العلم

قالوا سُبْحَانَكَ لا عِلْمَ لَنَا إلا مَا
عَلَّمْتَنَا إِنَّكَ أَنتَ العَلِيمُ الحَكِيمُ"
(سورة البقرة آية 32)

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