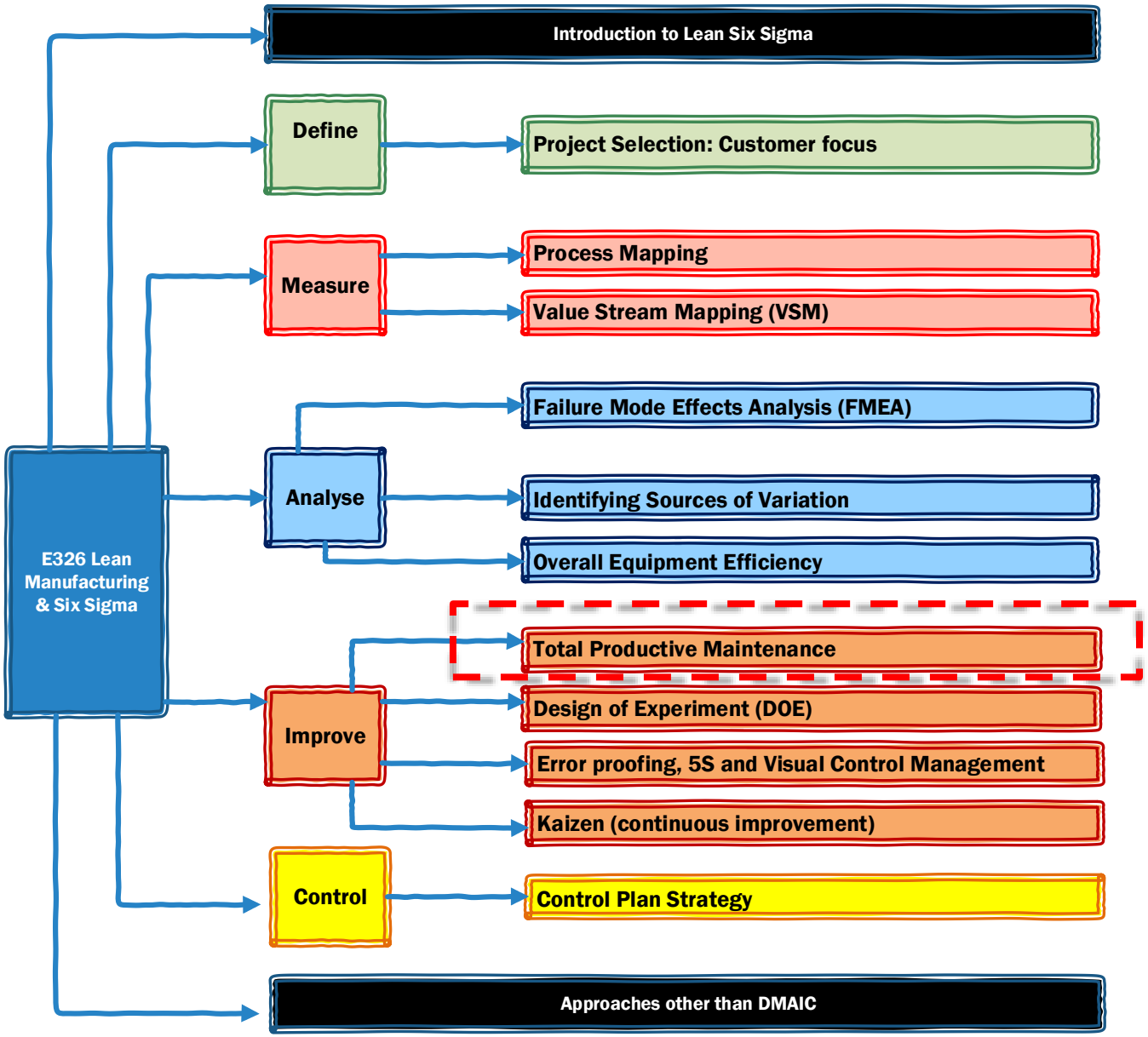
Problem 08
Reliability

E326 – Lean Manufacturing & Six Sigma

SCHOOL OF ENGINEERING

E326 Lean Manufacturing and Six Sigma Topic Tree



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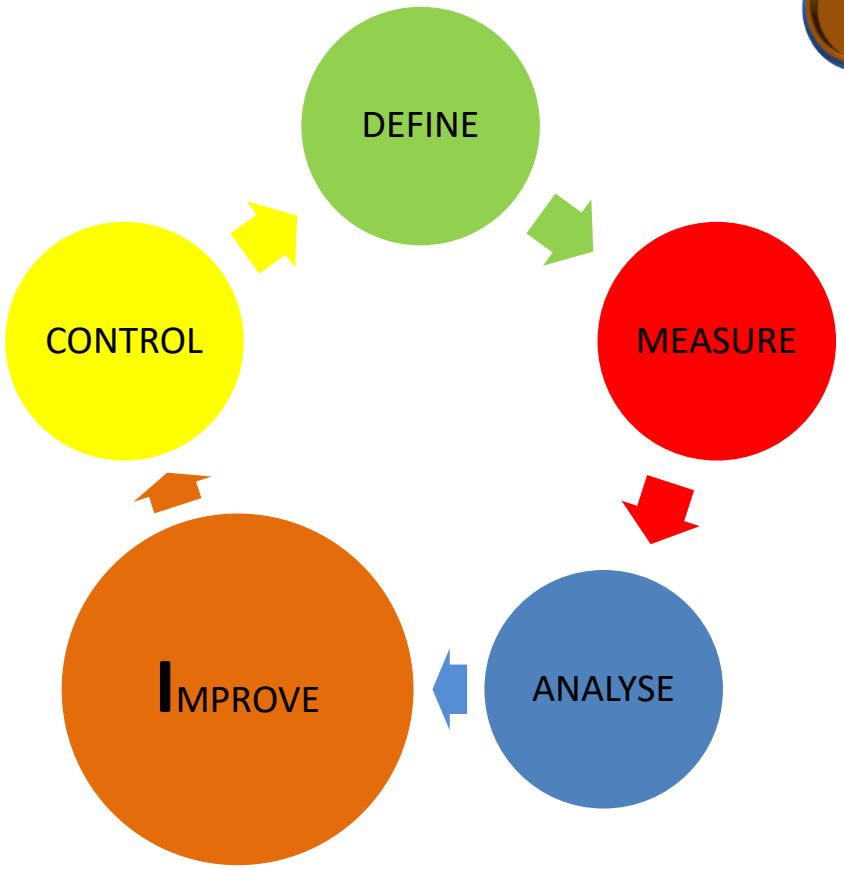


- Total Productive Maintenance

Objective of Improve phase:

- Improve the process by attacking root causes.

History of Total Productive Maintenance

- Total Productive Maintenance (TPM) has been developed from the original PM (preventive maintenance or productive maintenance) concept and methodology introduced from the USA. It has been further developed and implemented in many Japanese companies, and is now established itself as a renowned cultural improvement programme

- In 1971, Nippon Denso Co., Ltd. first introduced and successfully implemented TPM in Japan. They won the Japan Institute of Plant Maintenance (JIPM) PM Excellent Plant Award for their activities. This was the beginning of TPM in Japan.

What is TPM ?

The Japan Institute of Plant Maintenance (JIPM) has defined TPM as :

- **T = Total**. Must involve all employees at all levels of the organisation.
- **P = Productive.** Effective utilisation of all resources.
- **M = Maintenance**. Keeping the Man-Machine-Material system in optimum condition.

It can be considered as the *medical science of machines*.

TPM brings maintenance into focus as a necessary and vitally important part of the business.

Down time for maintenance is scheduled as a part of the manufacturing day and, in some cases, as an integral part of the manufacturing process.

The Importance of TPM

TPM is a critical principle for Lean manufacturing.

1) It guarantees dramatic results
   - Reduce equipment breakdowns
   - Minimize idle time and minor stops
   - Less quality defects and claims
   - Increase productivity
   - Reduce manpower and cost
   - Lower inventory
   - Reduce accidents

2) Visibly transform the workplace
   - Through TPM, a filthy, rusty plant covered in oil and grease, leaking fluids and spilt powders can be reborn as a pleasant and safe working environment
   - Customers and other visitors are impressed by the change
   - Confidence on plant's product increases

The Importance of TPM

3) Raises the level of workers knowledge and skills

As TPM activities begin to yield above concrete results, it helps:

- The workers to become motivated
- Involvement increases
- Improvement suggestions proliferate
- People begin to think of TPM as part of the job

Goals of TPM

- The goal of TMP is the total elimination of all losses, including breakdowns, equipment setup and adjustment losses, idling and minor stoppages, reduced speed, defects and rework, spills and process upset conditions, and start-up and yield losses.
- The ultimate goals of TPM are zero equipment breakdowns and zero product defects, which lead to improved utilization of production assets and plant capacity.

Different Types of Maintenance Strategies

- Maintenance refers to
  - actions performed to keep machine or system functioning or in service.
  - actions necessary for retaining machine or system in or restoring it to a serviceable condition.
- Different Types of Maintenance Strategies
  a) Reactive Maintenance
  b) Preventive Maintenance
  c) Predictive Maintenance
  d) Proactive Maintenance

(a) Reactive Maintenance

- Also known as breakdown maintenance. Based on ‘run it till it breaks’ maintenance mode
- Equipment is expected to run to failure, so a large material inventory of repair parts may be required.
- Usually cannot be planned (must repair when failures occur; failures may sometimes be deferred)
- Suitable for part/subsystem with little failure consequence
- Time taken to return the system to an operating or available status should be considered

(b) Preventive Maintenance

- Periodic activities such as servicing, inspection, lubrication, calibrations, and tuning are carried out to keep equipment at a specified performance level.

- Aim is to postpone the point at which the equipment or any of its components wears out or breaks down

- Time taken to perform the specified maintenance tasks and the interval between servicing needs to be considered

(c) Predictive Maintenance

- Based on condition monitoring
- The equipment is monitored on a scheduled or ongoing basis to discover conditions indicating that a failure is about to occur.
- Usually involves use of diagnostics equipment to generate measurements indicative of the condition of the system, e.g. power output, vibration level
- If the equipment is found to be about to fail, initiate preventive maintenance.

(d) Proactive Maintenance

- Based on failure finding inspections and condition monitoring leading to detection of sources of failures
- If the equipment is found to be failed, initiate corrective maintenance.
- A one-time action may be carried out to reduce consequences of failure or resolve root cause of failure. Examples are:
  - ✓ Item redesign
  - ✓ Change in an operational or maintenance procedure
  - ✓ Training
  - ✓ Improved documentation

Summary of Maintenance Strategies

Maintenance Strategy	Maintenance Approach	Significance
Reactive Maintenance	Fix-it when broken	Comes with failure consequences
Preventive Maintenance	Scheduled Maintenance	Periodic component replacement/servicing
Predictive Maintenance	Condition-based Monitoring	Maintenance decision based on equipment condition
Proactive Maintenance	Detection of Sources of Failures	Monitoring and correcting failing root causes

Failure Rate, Mean Time Between Failures (MTBF)

- A failure rate is the ***average frequency*** with which which an engineered system or component fails, expressed in failures per unit of time.
- It is denoted by the ***Greek letter λ (lambda)***

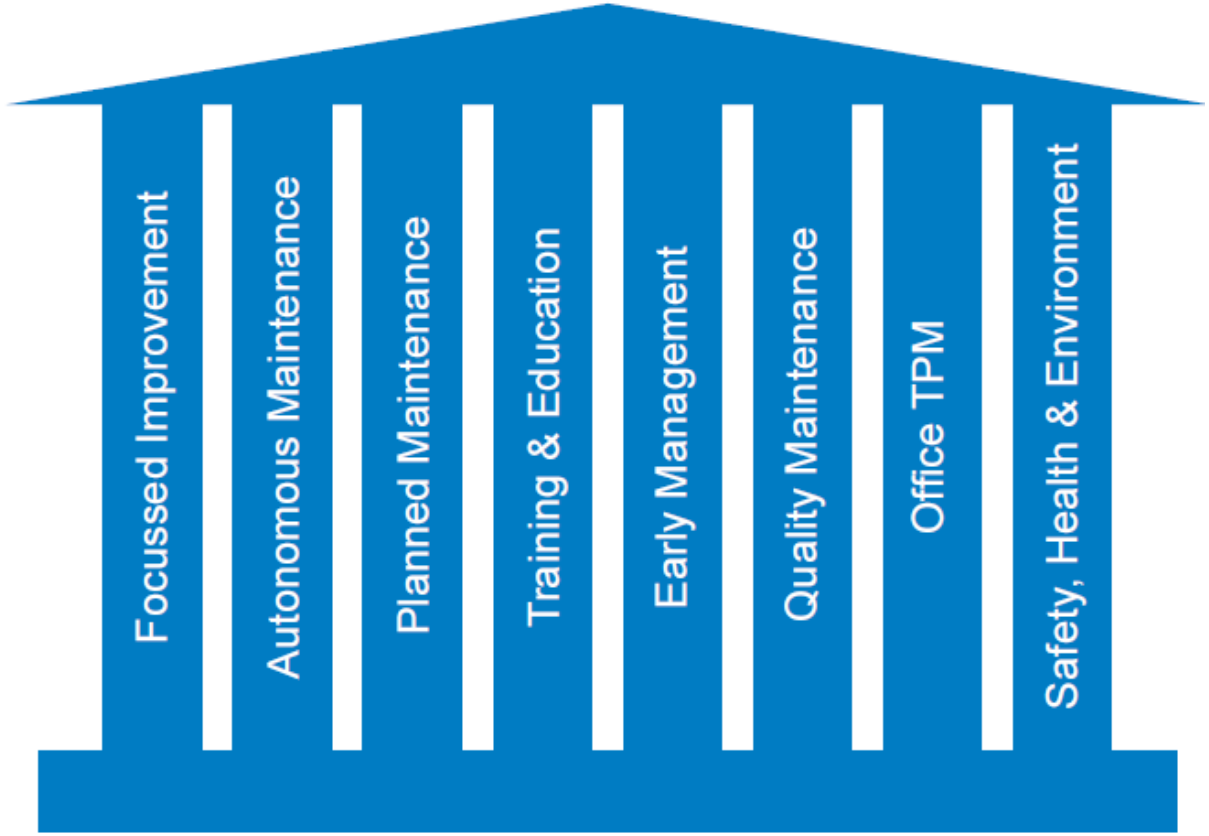
$$\text{Failure rate} = \lambda = \frac{\text{Number of failures, } N_f}{\text{Total unit test hours, T}}$$

- "Mean Time Between Failures" (MTBF) is literally the average time elapsed from one failure to the next during a given scheduled production period. Usually people think of it as the average time that something works until it fails and needs to be repaired (again).
- MTBF = Sum of Uptime Periods / Number of breakdowns
- MTBF is also the reciprocal of the failure rate
- MTBF assumes that a product or system is **repaired** (or **fixed**) after each failure, and then returned to service. ca

Mean Time To Repair (MTTR) and Mean Time To Failure (MTTF)

- "Mean Time To Repair" (MTTR) is the average time that it takes to repair something after a failure.
- MTTR = Sum of Downtime Periods / Number of breakdowns
- Mean Time To Failure (MTTF) is sometimes used instead of MTBF in cases where a product or component is **replaced** (**non-repairable**) after a failure.
- MTTF applies to items that are not repaired, such as bearings and transistors.
- Similar to MTBF, the MTTF is the reciprocal of the failure rate
- The formula MTTF or MTBF = $1/\lambda$ is meaningful for situations where failure rate is constant

Eight Pillars Approach to TPM



The eight pillars approach to TPM focused on achieving:

- Zero Break-downs
- Zero Defects
- Zero Accidents

Eight Pillars Approach to TPM

TPM Pillars	Description
Focused Improvement	Use of cross-functional teams for improvement activities
Autonomous Maintenance	Hands operators of equipment responsibility to carry out basic maintenance of equipment
Planned Maintenance	Maintenance scheduled using the historic failure rate of equipment
Training & Education	Bridging of the skills and knowledge gap through training of all workers
Early Management	Design of new equipment using lesson learnt from previous TPM activities
Quality Maintenance	Quality ingrained in the equipment so as to reduce defects
Office TPM	Spread of the principles to administrative functions within an organization
Safety, Health & Environment	Providing of an ideal working environment devoid of accidents and injuries

TPM Implementation Program

Stage	Steps	Essentials
Preparation	1. Declartion by top management to introduce TPM	The declaration is made in an internal TPM lecture meeting, and should be printed in an internal bulletin or newsletter.
	2. TPM introduction education and campaign	- Managerial staff: Staff of the same echelon are scheduled together for training - General employees: Slide-show meetings
	3. Establishing TPM promotion organsiation and pilot organisation model	Committees, specialized subcommittees, promotion secretariat, Formal organization models Model machine for "Jishu-Hozen" training by group leaders
	4. Setting of basic TPM principles and targets	Benchmarks and targets; prediction of effects
	5. Preparation of a master plan for implementing TPM	From preparation for introduction to undergoing examinations / PM awards.
Kickoff	6. TPM Kickoff	Customers, affiliated companies, and cooperative companies are invited
Implementation	7. Establishment of a system for improving the efficiency of the production department	Pursuit of improvement of efficiency in the production department
	7.1 Kobetsu-Kaizen (Focused improvement)	Project-team activities and workshop small-group activities to maximise the overall effectiveness of equipment and processes
	7.2 Jishu-Hozen (Autonomous Maintenance)	To empower the employee to make a daily conscious effort to maintain the performance of equipment and processes. Step up these methods and the diagnosis
	7.3 Planned maintenance	Corrective maintenance, periodic maintenance, predictive maintenance
	7.4 Operation/maintenance skill development	Collective education of leaders & education concerning transmission of education to members
	8. Establishment of initial phase management systems for new products & new equipment	Development of easy-setup-to-manufacture products and easy-to-use equipment
	9. Establishment of Quality Maintenance systems	Creation of conditions in which defects do not occur, and the maintenance/management of those conditions.
	10. Estabishment of system to realise operation efficiency in the administrative departments	Production support, improvement of the efficiency of related sectors, and improvement of efficiency of equipment.
	11. Creation of systems for the control of safety, health, and the environment	Creation of systems for zero accidents and zero pollution cases
Steady Application	12. Full application of TPM and raising its level	Undergoing examinations for the receipt of PM awards; Setting sights on higher targets

Critical Success Factors for TPM implementation

The following five critical success factors are essential for delivering benefits from TPM:

- Maximize equipment effectiveness
- Develop a system of productive maintenance for the life of the equipment
- Involve all department that plan, design, use or maintain equipment in implementing TPM
- Actively involve all employees from top management to shopfloor workers
- Promote TPM through motivation management; autonomous small group activities

Problem 08
Suggested Solution

Overview of today's problem

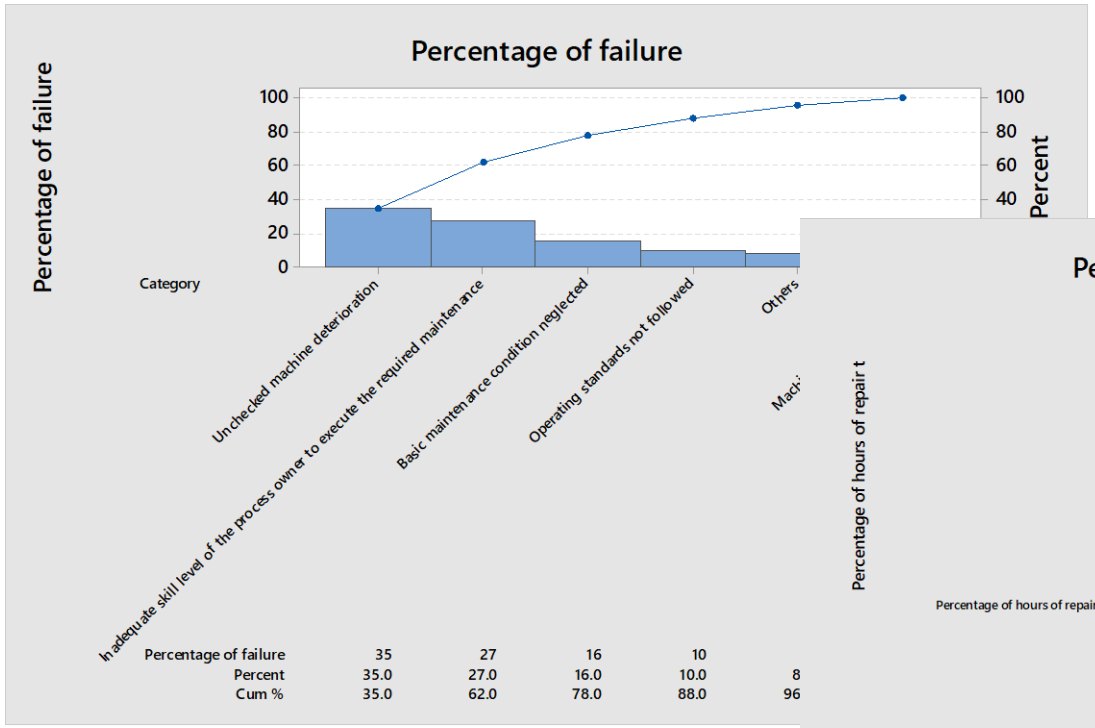
- Operators would just wait for the maintenance team to arrive
- The operators have the mentality that "fix-it only when broken"
- "Basic maintenance condition neglect
- Unchecked machine deterioration"
- Most of operators do not go through any formal maintenance training
- "As the operators are not trained in maintenance of the machines, the machines are not running in full potential. Machines and equipment have broken down more frequently and emergency repairs were more frequent than before"
- Some machines will produce defective parts that may ship to customers
- Support functions have minimum knowledge on maintenance
- The operators are also not sensitive to the safety and health when operating the machines

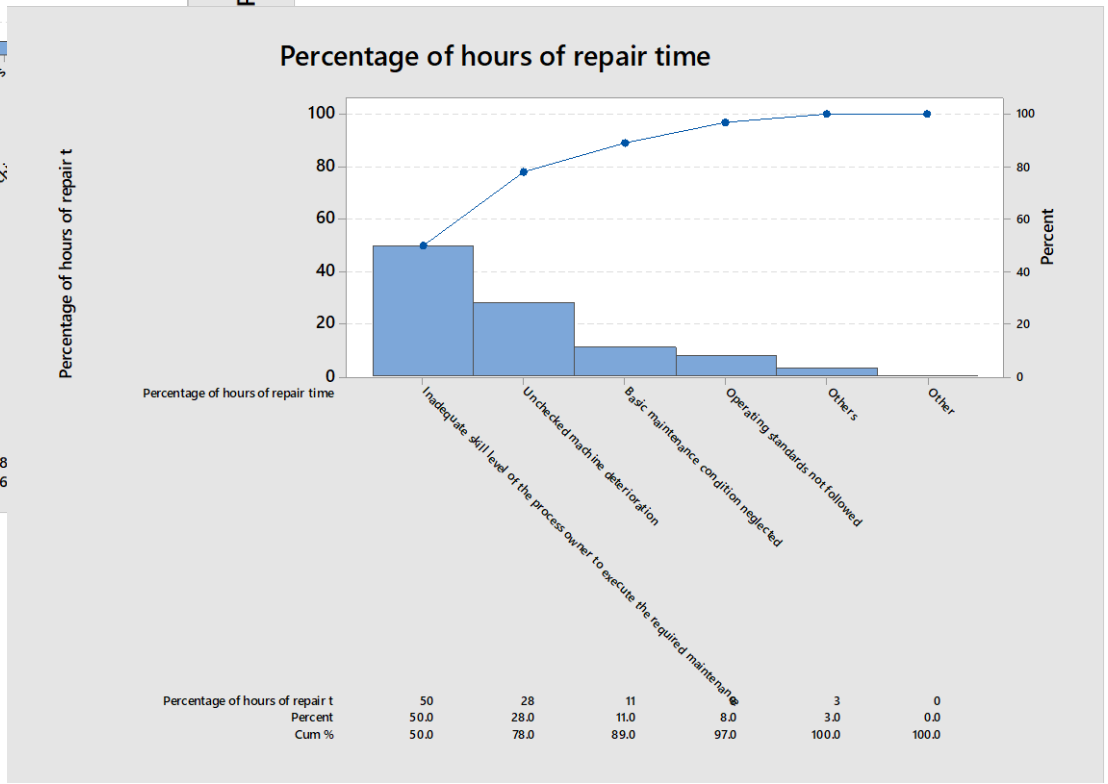
→ **This results in high maintenance costs!**

Selecting the right blend of maintenance strategies

- The company is currently adopting “Reactive maintenance” strategy as they have the mentality of “fixing-it only when broken”.
- There is **no one maintenance strategy that fits for all situations and all companies**! Rather, Keegan can consider using a blend of maintenance management strategies that are right for the operation and for the age of the equipment.
- There will always require an amount of preventative maintenance with predictive maintenance when equipment ages, along with root cause analysis to eliminate non-random failures. On top of this, there should be occasional overhaul shutdowns, replacement of old technologies with new, and so on.

Pareto charts to identify the categories of failure and the repair time





- The two main causes of failure: “Inadequate skill level” and “Unchecked machine deterioration” constitute to 62% of the repair time that prompted the urgent needs to have a TPM program in place to reduce this percentage.

Mean Time To Repair (MTTR) and Mean Time To Failure (MTTF)

Based on the given info:

- Each machine is running at 20 hours per day, 5-day per week and 20-day per month
- For the past month, on an average for a machine, there are altogether 80 failures and 250 hours of repair time
- Total production time per month = 21 * 20 = 420 hours
- Mean Time Between Failures, MTBF = Sum of Uptime Periods / Number of breakdowns = (21 * 20 – 250) / 80 = 2.125 hours
- Mean Time To Repair, MTTR = Sum of Downtime Periods / Number of breakdowns = 250 / 80 = 3.125 hours

MTBF happens once every 2.125 hours and this will take around 3.125 hours to repair! If the operators can be better trained to take up the basic maintenance check and daily check for the machine conditions, this can further improve the MTBF and MTTR.

Eight Pillars Approach to TPM

TPM Pillars	Description	Rationale
Focused Improvement	Use of cross-functional teams for improvement activities	Improves problem solving capabilities of the workers
Autonomous Maintenance	Hands operators of equipment responsibility to carry out basic maintenance of equipment	Operators feel responsible for their machines, equipment becomes more reliable
Planned Maintenance	Maintenance scheduled using the historic failure rate of equipment	Maintenance can be scheduled when production activities are few
Training & Education	Bridging of the skills and knowledge gap through training of all workers	Employees gain the necessary skills to enable them solve problems within the organization
Early Management	Design of new equipment using lesson learnt from previous TPM activities	New equipment achieves full potential in a shorter period of time
Quality Maintenance	Quality ingrained in the equipment so as to reduce defects	Defect reduction & consequent profit improvement
Office TPM	Spread of the principles to administrative functions within an organization	Support functions understand the benefits of these improvements
Safety, Health & Environment	Providing of an ideal working environment devoid of accidents and injuries	Elimination of harmful conditions & healthy workforce

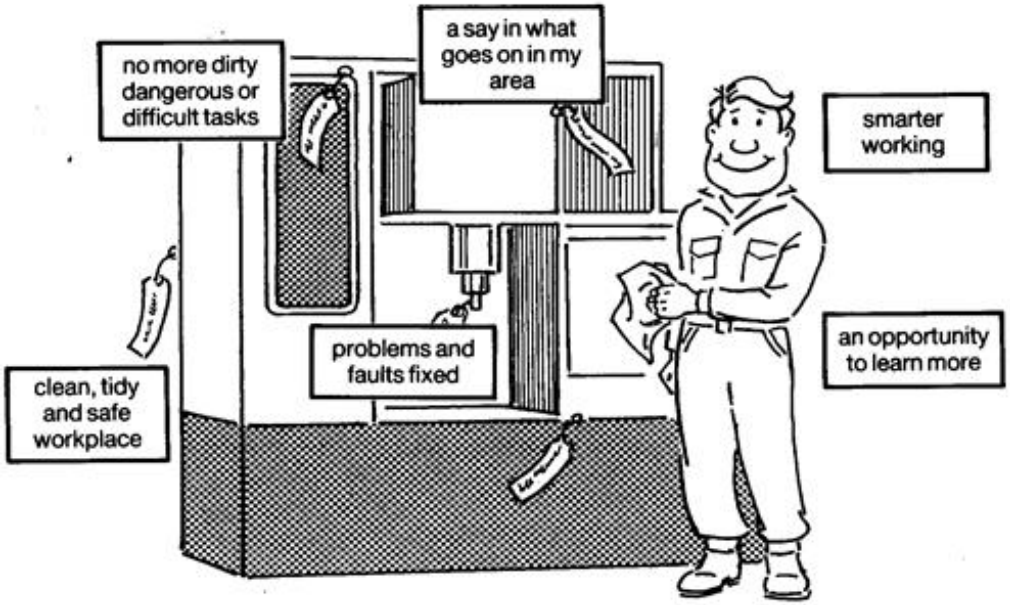
12 Steps of TPM Implementation Program

Stage	Preparation					Kickoff
Steps	1. Declartion by top management to introduce TPM	2. TPM introduction education and campaign	3. Establishing TPM promotion organsiation and pilot organisation model	4. Setting of basic TPM principles and targets	5. Preparation of a master plan for implementing TPM	6. TPM Kickoff

Stage	Implementation									Steady Application
Steps	7. Establishment of a system for improving the efficiency of the production department	7.1 Kobetsu-Kaizen (Focused improvement)	7.2 Jishu-Hozen (Autonomous Maintenance)	7.3 Planned maintenance	7.4 Operation/maintenance skill development	8. Establishment of initial phase management systems for new products & new equipment	9. Establishment of Quality Maintenance systems	10. Estabishment of system to realise operation efficiency in the administrative departments	11. Creation of systems for the control of safety, health, and the environment	12. Full application of TPM and raising its level

Discussion

- From a management point of view, TPM involves all members of the company, TPM may be the thing that stands between success and total failure for some companies.
- Employees must be educated and Bill needs to convince them that TPM is not just another "program of maintaining machines" it is a program to help the company survive and develop.



Learning Objectives

- Introduction to Total Productive Maintenance (TPM)
- Differentiate Different Types of Maintenance Strategies in TPM
- Discuss the difference between Mean Time Between Failures(MTBF) and Mean Time To Repair (MTTR)
- Explain the 8 Pillars of TPM
- Develop and Plan a Maintenance Strategy
- Identify Critical Success Factors for TPM implementation

Overview of E326 Lean Manufacturing and Six Sigma