To achieve zero breakdowns, hidden defects in the machine need to be expected and corrected before they have deteriorated to the extent that they will cause the machine to break down.

To do this:
- Maintain equipment in good operating condition through proper cleaning and effective lubrication
- Restore the condition of deteriorated parts
- Enhance the operation, setup, inspection and maintenance skills of operators

Traditionally, these duties fall outside the responsibility of machine operator, whose role is nothing else but operate the machine.

When it breaks down, the operator's duty is to request maintenance to fix.

Thus, TPM involves a restructuring of work relating to equipment maintenance.

Machine operator are empowered to perform routine maintenance, servicing, and minor repairs.

This concept of operator involvement is enhancing equipment wellness is known as autonomous maintenance**.**

It is cultivated through 5S and CLAIR.

5S is a tool for starting the journey towards world class competitiveness.

It is a team effort that involved everyone in the organization to create a productive workplace by keeping it safe, clean, and orderly.

5S stands for:
- Sorting
  - Separate the needed from not needed.
  - Identify items that you use frequently. Sort, tag, and dispose of the unneeded items.
- Simplifying
  - A place for everything and everything in its place.
  - Once you have determined what you need, organize it and standardize its use to increase your effectiveness.
- Systematic Cleaning:
  - Making things ready for inspection.
  - Regular cleaning helps to solve problems before they become too serious by identifying sources and root cause of potential problems.
- Standardizing:
  - Create common methods to achieve consistency.
- Sustaining:
  - Constant maintenance, improvement, and communication.

5S has become a continuous improvement process.

CLAIR – clean, lubricate, adjust, inspect, (minor) repair

- Have operators work with maintenance toward the common goals of stabilizing equipment conditions, and halting accelerated deterioration.

- The operators are empowered to perform the basic tasks of cleaning, checking lubrication, simple adjustments, inspections, and replacement of parts, minor repairs, and other simple maintenance tasks.

By providing them with training on equipment functions and functional failures, the operations will also prevent failure through early detection and treatment of abnormal conditions.

Being relieved of the routine tasks of maintenance, the experts in maintenance unit can be deployed to focus on more specialized work, such as major repairs, overhauls, tracking and improving equipment performance, and replacement or acquisition of physical assets.

<u>Reliability by Design</u>
Reliability Centered Maintenance (RCM)

TPM is people focused. Its emphasis is on the early detection of wear out to prevent in-service failures.

RCM is an alternative approach to enhancing asset reliability by focusing on designs.

It asks questions such as: Do we have to do maintenance at all?

Will a design chance eliminate the root cause of failure?

What kind of maintenance is most likely to meet the organizations business objectives?

RCM is a structured methodology for determining the maintenance requirement of a physical asset in its operating context.

The primary objective of RCM is to preserve system function rather than to keep on asset in service.

Application of the RCM requires a full understanding of the functions of physical assets and the nature of the functions of physical assets and the nature of failures related to those functions.

Some failures can not be prevented by overhaul or preventative maintenance.

Thus, maintenance actions that are not cost effective in preserving system functions will not be performed.

Benefits of RCM:
- Improved understanding of the equipment. How it fails and consequences of failure.
- Clarify the roles that operators and maintenance play in making equipment more reliable and less costly to operate.
- Make the equipment safer, more environmentally friendly, more productive, more maintainable, and more economical to operate.

Results of RCM applications reported in various industry sectors have been published:
- Manufacturing
- Utility
- Mining
- Military

The RCM Methodology developed the appropriate maintenance tactics using a thorough and rigorous decision process in several steps.

Step 1: Select and Prioritize Equipment

- Production and supporting processes are examined to identify key physical assets.
- These key physical assets are then prioritized according to how critical they are to operations, cost of downtime, and cost of repair.

Step 2: Define functions and performance standards

- The functions of each system selected for risk analysis need to be defined.
- The functions of equipment are what it does.
- Some systems are dormant until some other event occurs, as in safety systems.
- Each function also has a set of operating limits.
- The parameters define the normal operation of the function under a specialized operating environment.

Step 3: Define function failures

- When the system operates outside its normal parameters, it is considered to have failed.
- Failures can be total, partial, and intermittent.

Step 4: Identify failure modes / root causes

- A failure mode is how the system fails to perform its functions.
- A cylinder may be stuck in one position because of a lack of lubrication.
- The functional failure in this case is the failure to provide linear motion, but the failure mode is the loss of lubricant properties of the hydraulic fluid.
- A failure may have more than one possible root cause.
- This step identifies the chain of events when a failure occurs.
- What conditions need to exist? What event was necessary to trigger the failure?

Step 5: Determine failure effects and consequences

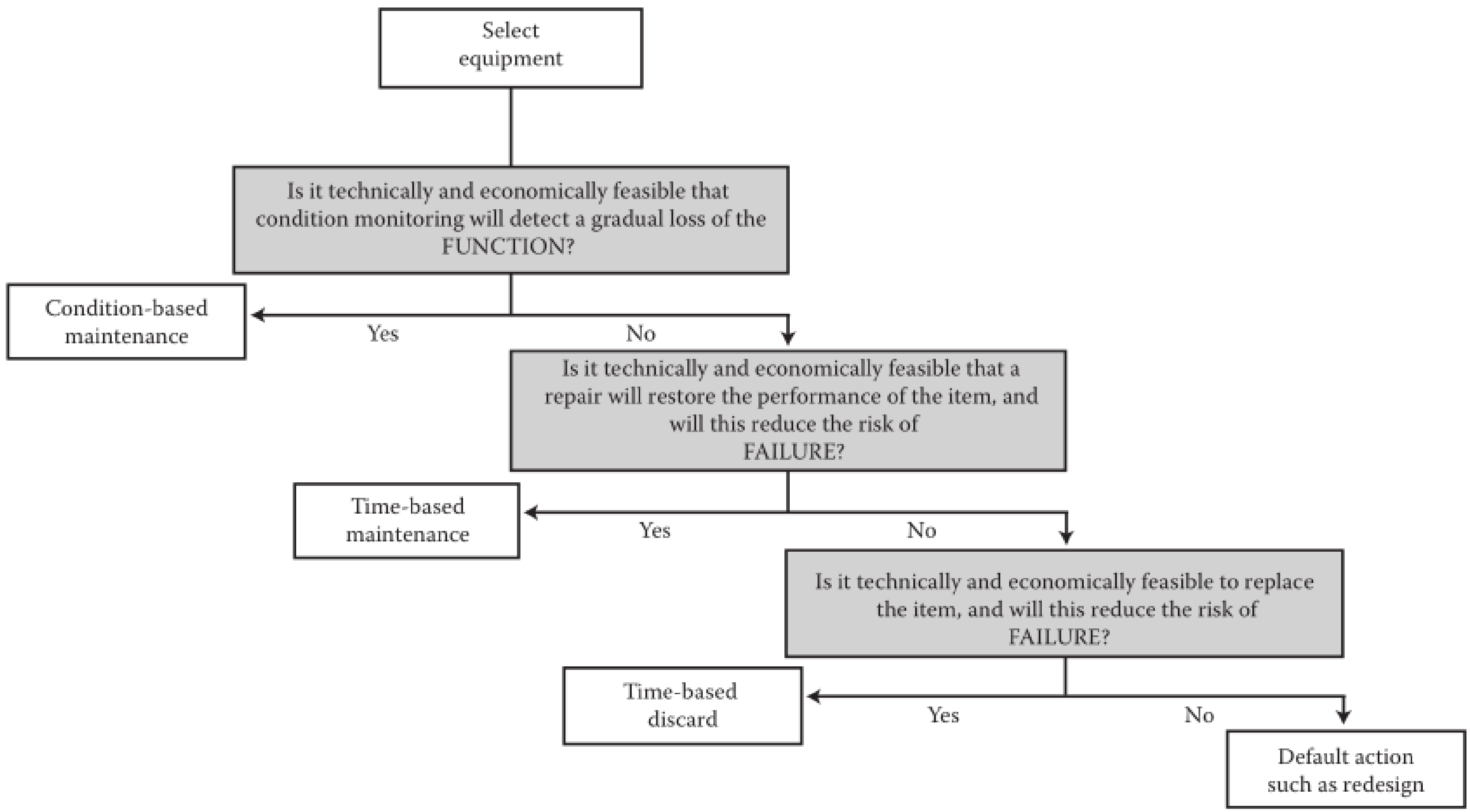
- What will happen when a functional failure occurs?
- The severity of the failures effect on safety, the environment, operation, and maintenance is assessed.

The results of analysis made in steps 2 to 5 are documented in a failure mode, effect, and criticality analysis worksheet.

Step 6: Select Maintenance Tactics

- A decision logic tree is used to select the approximate maintenance tactics for the various functional failures.

RCM Methodology Logic



If time-based maintenance, intervention or periodic inspection has been selected, the frequency of such a task needs to be determined to achieve optimal results.

Step 7: Implement and refine the maintenance plan

- Need multidisciplinary team with members knowledgeable in the day-to-day operations of the plant and equipment as well as in the details of equipment itself.

Optimizing maintenance and replacement decisions:

RCM determines the type of maintenance tactics to be applied to an asset, while it answers the question of “what type of maintenance actions need to be taken?”

The issue of when to perform the recommended maintenance actions that will produce the best results possible remain to be addressed.

The optimization of these tactical decisions is the important issues addressed

The optimization of these tactical decisions is the important issue addressed in the top of the “continuous improvement” layer of the maintenance excellence pyramid.

Traditionally, maintenance practitioners in industry were expected to cope with maintenance problems without seeking to operate in optimal manner.

Many preventative maintenance schemes are put into operation with only a slight, if any, qualitative approach to the scheme.

Asset managers who wish to optimize the life cycle value of the organizations human and physical assets must consider four key decision areas.

1. Component Replacement
2. Inspection Procedures
3. Capital Equipment Replacement
4. Resource Requirement

The course will be looking at several models for these items.

Chapter 2: Component Replacement Decisions

Two types of situations:

1. Deterministic
2. Probabilistic

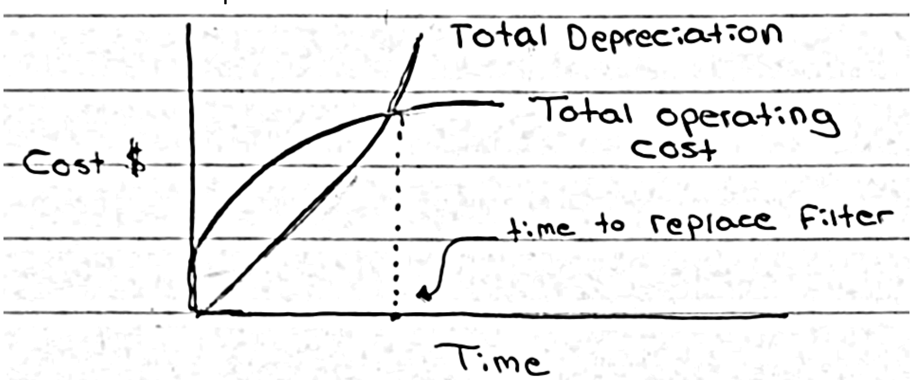
Optimal Replacement times for equipment whose operating cost increases with use:

Some equipment operates with excellent efficiency when it is new, but as it ages, its performance deteriorates.

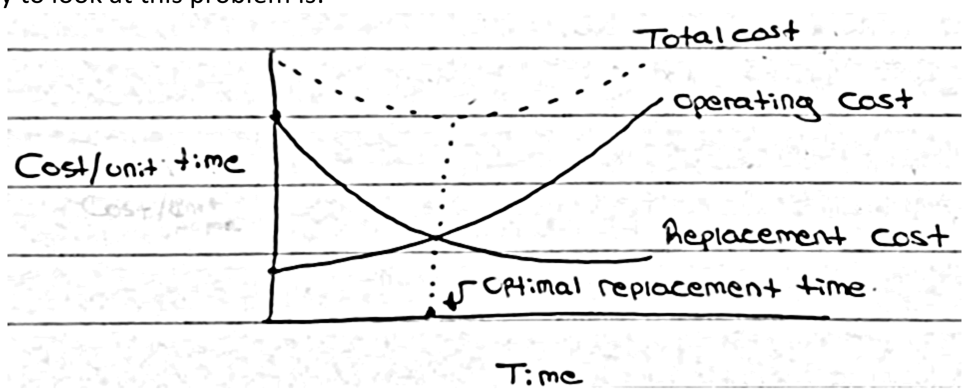
It has some resale value that keeps on decreasing with time.

The decreasing resale value results in increasing depreciation, which is the difference between the purchase price and the resale value.

The optimal replacement policy for such items is to replace the equipment at a point where the total cost curve intersects the total depreciation curve.

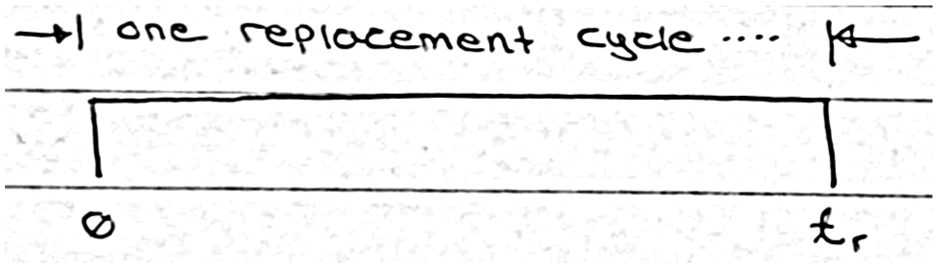


Another way to look at this problem is:



This class of problem can be called a short-term deterministic problem, for a long-term situation time value of money becomes very important and complicated.

Construction of the model:
$c(t)$ is the operating cost per unit time at time t after replacement cycle
C_r is the total cost of a replacement
The replacement policy is to perform replacements at intervals of length t_r



The objective is to determine the optimal interval between replacements to minimize the total cost of operation and replacement per unit time.

$$C(t_r) = \frac{total\ cost\ in\ interval\ (0, t_r)}{length\ of\ interval}$$

Total cost in interval $((0, t_r) = cost\ of\ operating + cost\ of\ replacement$

$$= \int_0^{t_r} c(t)dt + C_r$$

So,

$$C(t_r) = \frac{1}{t_r}\left[\int_0^{t_r} c(t)dt + C_r\right]$$

The optimal replacement time is determined from calculus.

$$\frac{d}{dt_r}C(t_r) = 0 \text{ for determining minimum}$$

$$= -\frac{C_r}{t_r^2} - \frac{1}{t_r^2}\int_0^{t_r} c(t)dt + \frac{1}{t_r}c(t_r)$$

$$c(t_r) = \frac{C_r}{t_r} + \frac{1}{t_r}\int_0^{t_r} c(t)dt$$

$$= \frac{1}{t_r}\left[\int_0^{t_r} c(t)dt + C_r)\right]$$

$$= C(t_r) \text{ The total cost per unit time.}$$

So, the optimal replacement time is when current operating cost rate is equal to the average total cost per unit time.