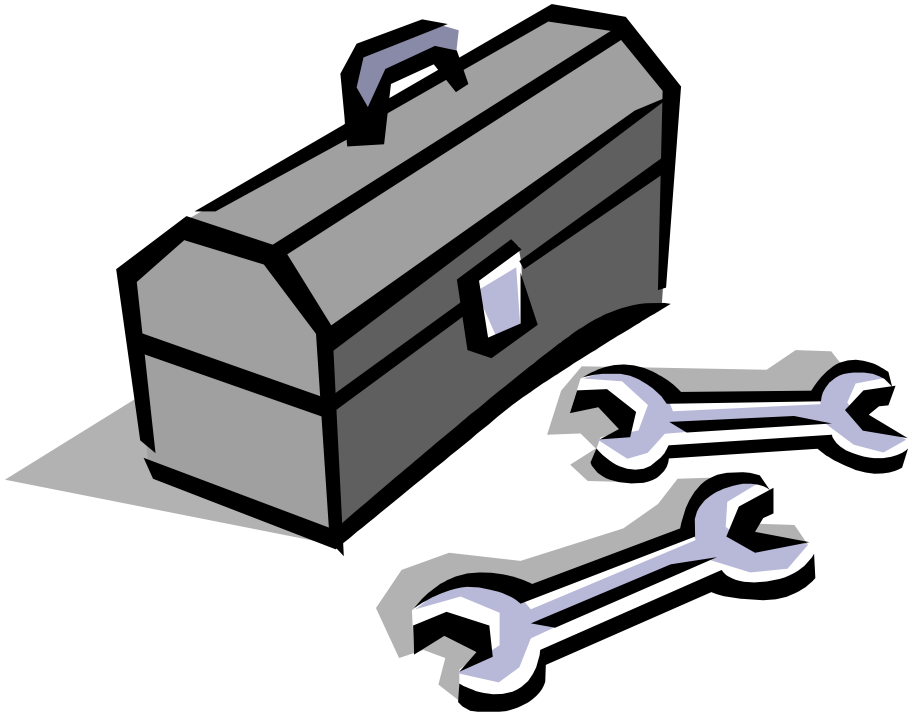
Maintenance Management



Overview

- Introduction
- Repair Programs
- Preventive Maintenance (PM) Programs
- Machine Reliability
- Secondary Maintenance Department Responsibilities
- Trends in Maintenance
- Maintenance Issues in Service Organizations
- Wrap-Up: What World-Class Companies Do

Equipment Malfunctions

- Equipment malfunctions have a direct impact on:
  - Production capacity
  - Production costs
  - Product and service quality
  - Employee or customer safety
  - Customer satisfaction

Maintenance Departments

- A maintenance manager typically is a plant engineer who reports to a plant or manufacturing manager
- Maintenance departments are usually split into two groups:
  - Buildings and Grounds
  - Equipment

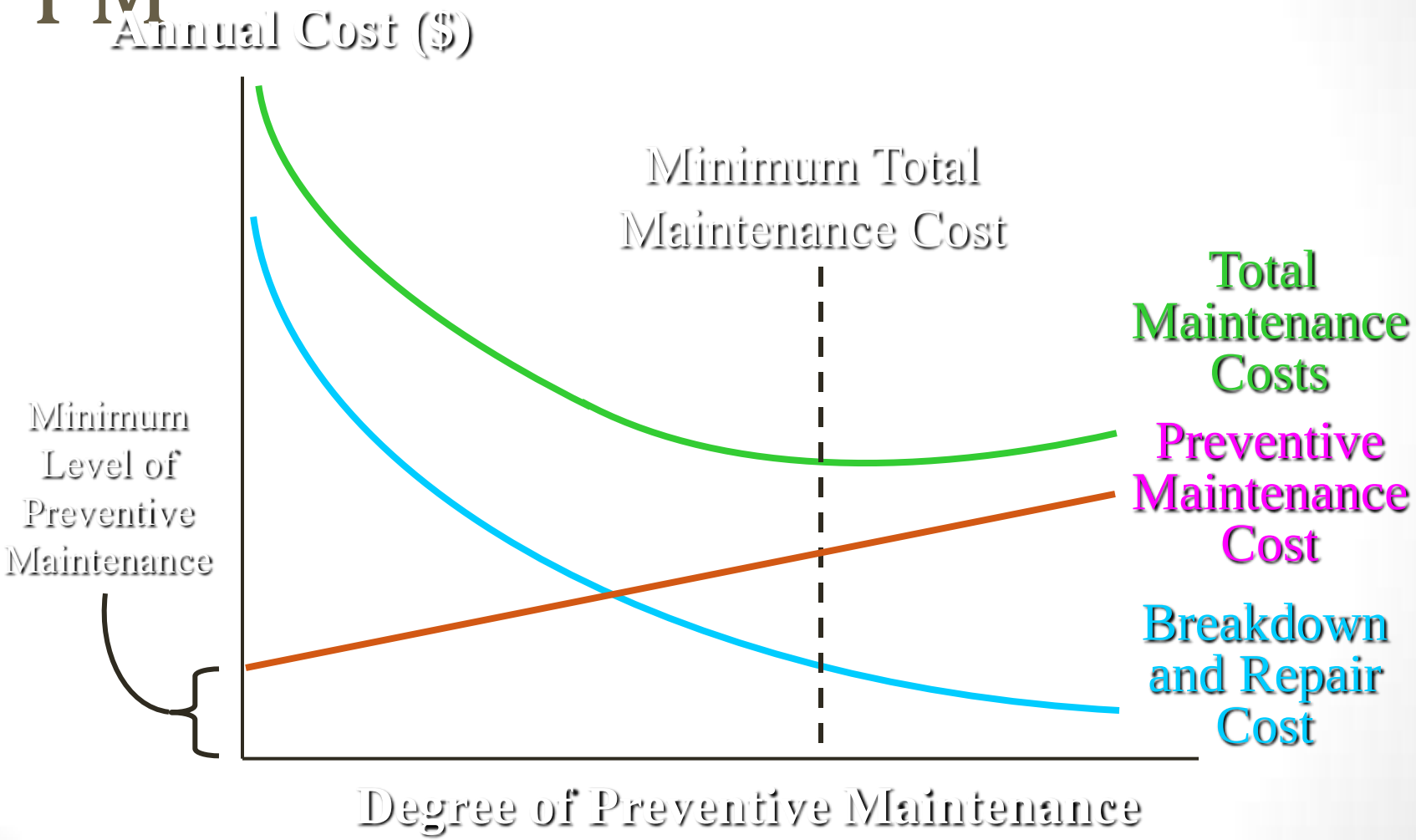
Maintenance Activities

- Repairs
  - Repair activities are reactive.
  - Breakdowns and malfunctions typically occur when equipment is in use.
  - Standby machines and parts can speed repairs.
- Preventive Maintenance (PM)
  - Regularly scheduled inspections are performed.
  - PM activities are performed before equipment fails.
  - PM is usually performed during idle periods.

Tradeoff Between Repairs and PM

- At minimum level of PM, it is a remedial policy
  - fix machines only when they break
  - the cost of breakdowns, interruptions to production, and repairs is high
- As the PM effort is increased, breakdown and repair cost is reduced
- At some point, the total maintenance cost (PM, breakdown, and repair) reach a minimum

Tradeoff Between Repairs and PM



Maintenance Policies that Reduce Frequency and Severity of Malfunctions

Maintenance Policy	Reduces Frequency	Reduces Severity
Emphasize preventive maintenance	X	X
Provide extra machines	X	
Replace machine parts early	X	
Involve operators in maintenance	X	X
Overdesign machines	X	
Design machines for maintainability		X
Enhance maint. dept.'s capability	X	X
Increase spare parts supply		X
Increase standby machines		X
Increase in-process inventories		X

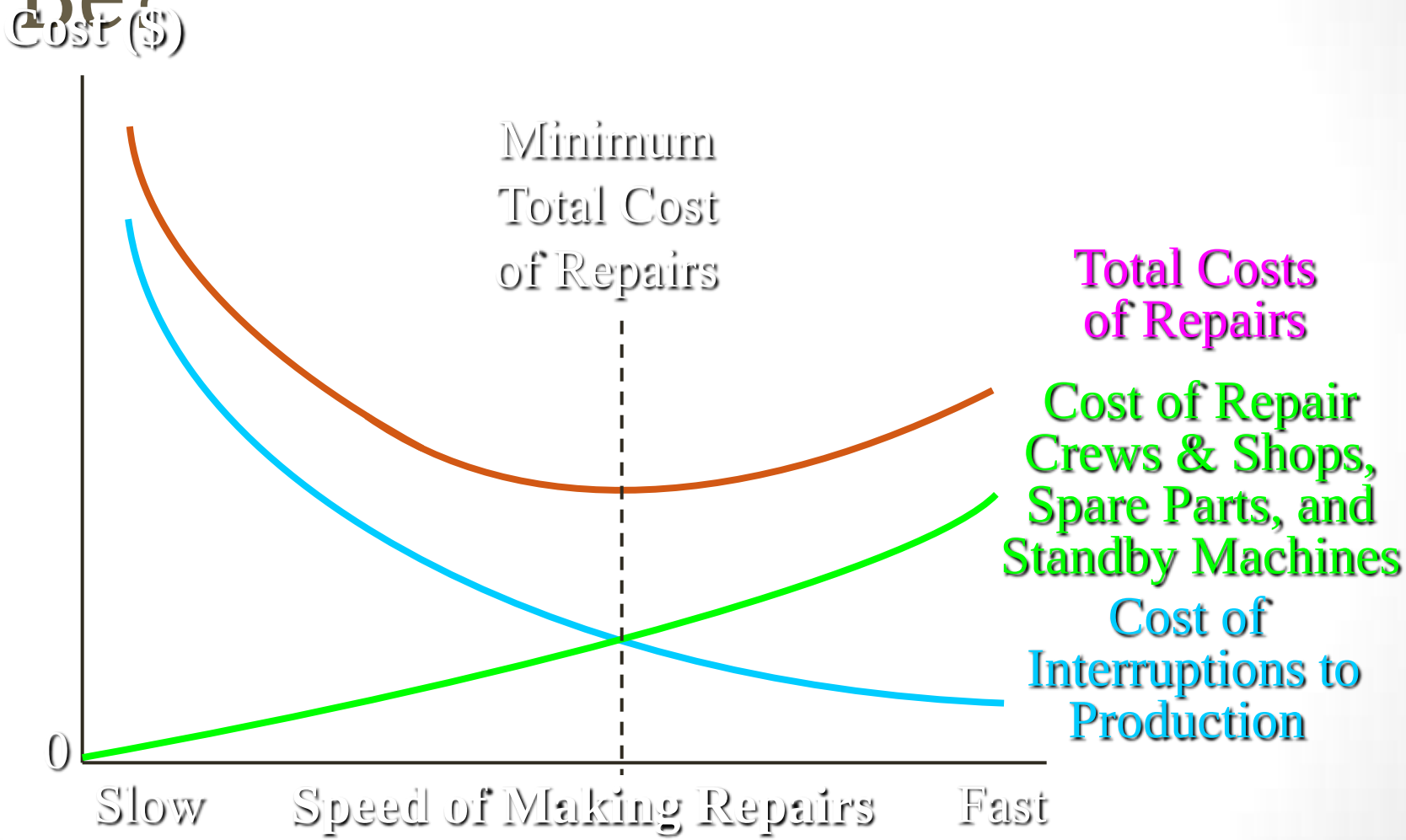
Repair Programs

- Objectives
  - Get equipment back into operation as quickly as possible.
  - Control cost of repairs crews.
  - Control cost of the operation of repair shops.
  - Control the investment in replacement spare parts.
  - Control the investment in standby or backup machines.
  - Perform the appropriate amount of repairs at each malfunction.

Repair Crews and Standby Machines

- Repairs often performed on an emergency basis to:
  - Minimize interruptions to production
  - Correct unsafe working conditions
  - Improve product/service quality
- In emergency situations:
  - Specialists may work overtime
  - Supervisor/engineers are nearby to collaborate
  - Standby machines may be quickly put in operation

How Speedy Should Repairs Be?



Breakdowns Trigger Repairs and Corrective Actions

An equipment breakdown should trigger two actions:

- Fast repair of the malfunction equipment
- Development of a program to eliminate cause of the malfunction and need for such repairs in the future
  - Modification/redesign of malfunctioning machine
  - Modification/redesign of part or product being processed
  - Training of operators to improve machine care
  - More frequent preventive maintenance/inspection

Extent of Repairs

- Do just enough repairs to get equipment running again.
- Repair the malfunction and replace some parts that are worn.
- Perform a major overhaul of the equipment.
- Replace the old equipment with new.

Decision Analysis in Repair Programs

- Determining the size of repair crews
  - This is one repair-capacity decision
  - Queuing analysis (Chapter 9) is often used
  - Computer simulation (Chapter 9) is used when the assumptions of queuing formulas do not apply
- Determining the number of standby machines to have
  - Trade-off between cost of lost production time and cost of machine storage, handling, ….

Example: The Shirt Factory

- Determining the Size of Repair Crews

Example: The Shirt Factory

- Determining the Size of Repair Crews

$$\overline{t_s} = 1/(u - \lambda)$$

Example: The Shirt Factory

- Determining the Size of Repair Crews

Example: Accounting Unlimited

- Determining the Number of Standby Machines

Example: Accounting Unlimited

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Example: Accounting Unlimited

- Determining the Number of Standby Machines
  - Payoff Table (C_{ij} values in box)

Standby Computers Stocked (S_j) \ SN_i	Standby Computers Needed 5	10	15	20	EC= $\Sigma[P(SN_i)(C_{ij})]$
5	0	1500	3000	4500	$2,643.00
10	900	0	1500	3000	$1,486.20
15	1800	900	0	1500	$ 900.60
20	2700	1800	900	0	$1,114.20
$P(SN_i)$	.143	.238	.333	.286	

Advantages of Letting Workers Repair Their Own Machines

- Greater variety may make job more satisfying
- May be more sensitive to potential malfunctions
- Increase flexibility
- Can make minor repairs faster
- Can avoid minor repairs by cleaning, lubricating, adjusting and servicing machines
- Operate machines more carefully

Reasons for a PM Program

- Reduce the frequency and severity of interruptions due to malfunctions
- Extend the useful life of equipment
- Reduce the total cost of maintenance by substituting PM costs for repair costs
- Provide a safe working environment
- Improve product quality by keeping equipment in proper adjustment

PM and Operations Strategies

- PM program is essential to the success of a product-focused positioning strategy
- On production lines, there are little if any in-process inventories between adjacent operations
- If a machine breaks down, all downstream operations will soon run out of parts to work on

Automation and the Prominence of PM

- Many operations are slowly moving toward workerless production
- We are seeing a shift from large to smaller production workforces
- Along with this, we are seeing a shift from small to larger PM workforces
- Production workers displaced by automation will need to be retrained to become PM workers

Scheduling PM Activities

- PM and production are increasingly viewed as being equally important
- In some plants, two 8-hour shifts are devoted to production and one 4-hour minishift is devoted to PM
- In other plants, three shifts are used for production, but time allowances are factored into production schedules for PM activities

PM Database Requirements

- Detailed records, or an ongoing history, must be maintained on each machine
  - Dates and frequency of breakdowns
  - Descriptions of malfunctions
  - Costs of repairs
- Machine specifications/checklists for PM inspection
- Computers generally used to maintain a database
- Also, data can be kept in plastic pocket on a machine

Modern Approaches to PM

- PM at the source - workers have the fundamental responsibility for preventing machine breakdowns by conducting PM on their own machines
- Workers listen for indications of potential equipment malfunction
- Maintenance-related records maintained by workers
- Use of quality circles

Decision Analysis in PM

- Three decisions in particular
  - Determining the number of spare parts to carry
  - Determining how often to perform PM on a group of machines
  - Planning and controlling a large-scale PM project

Determining the Number of Spare Parts to Carry for PM Inspections

Two types of parts demand arise from PM inspection:

- Parts that we routinely plan to replace at the time of each inspection (demand that is certain)
  - This demand can be satisfied by applying Material Requirements Planning (MRP) logic (Chapter 15)
- Parts, discovered during an inspection, in need of replacement (demand that is uncertain)
  - This inventory problem is similar to the number-of-standby-machines problem covered earlier in this chapter (payoff table analysis was used)

Determining the Frequency of Performing PM

- First, compute the expected number of breakdowns for each PM policy.
- Next, compute the expected breakdown cost, preventive maintenance cost, and total cost for each PM policy.
- Finally, identify the policy that minimizes the total cost per unit of time (say, per week).

Expected Number of Breakdowns

$$B_n = N\left(\sum_{1}^{n} p_n\right) + B_{(n-1)}p_1 + B_{(n-2)}p_2 + \ldots + B_1 p_{(n-1)}$$

where:

B_n = expected number of breakdowns for each of the PM policies

p_n = probability that a breakdown will occur between PM inspections when PM is performed every *n* periods

N = number of machines in group

Example: PM Frequency

It costs $6,000 to perform PM on a group of four machines. The cost of down time and repairs, if a machine malfunctions between PM inspections, is $8,000.

How often should PM be performed to minimize the expected cost of malfunction and the cost of PM?

(The machines' breakdown history is on the next slide.)

Example: PM Frequency

- Machine Breakdown History

Weeks Between PM	Probability That a Machine Will Malfunction
1	0.2
2	0.3
3	0.5

Example: PM Frequency

$B_1 = 4(0.2) = 0.800$

$B_2 = 4(0.2 + 0.3) + 0.8(0.2) = 2.160$

$B_3 = 4(0.2 + 0.3 + 0.5) + 2.16(0.2) + 0.8(0.3) = 4.672$

Example: PM Frequency

PM Every *n* Wks.	Exp. Number Of BDs	Exp. Number of BDs per Wk.	Exp. Cost of BDs	Weekly Exp. Cost of PM	Total Weekly Cost
1	0.800	0.800	$6,400	$6,000	$12,400
2	2.160	1.080	8,640	3,000	
3	4.672	1.557	12,456	2,000	14,456

The policy that minimizes total weekly cost is: perform PM every 2 weeks.

Large-Scale PM Projects

- Large-scale projects occur commonly in maintenance departments.
- Banks of machines, whole production departments, and even entire factories are shut down periodically to perform PM.
- The number and diversity of the PM tasks that must be performed can be great.
- CPM (in Chapter 10) is a useful way to plan and control large-scale maintenance projects.

Approaches to Improving Machine Reliability

- Overdesign - enhancing the machine design to avoid a particular type of failure
- Design simplification - reducing the number of interacting parts in a machine
- Redundant components - building backup components right into the machine so that if one part fails, it's automatically substituted

Secondary Maintenance Responsibilities

- Housekeeping, groundskeeping, janitorial
- New construction, remodeling
- Painting
- Security, loss prevention
- Pollution control
- Waste recycling
- Safety equipment maintenance
- Public hazard control

Trends in Maintenance

- Production machinery is becoming more and more complex and maintenance personnel must keep pace
- Special training programs to maintain worker skill level
- Subcontracting service companies
- Production workers maintain own equipment
- Computer assistance in maintenance

Computer Assistance in Maintenance

- Scheduling maintenance projects
- Maintenance cost reports by production department, cost category, and other classifications
- Inventory status reports for maintenance parts and supplies
- Parts failure data
- Operations analysis studies

Maintenance Issues in Service Organizations

- Maintenance issues are not limited to manufacturing
- Transportation firms (airlines, trucking companies, package delivery services, railroads) must keep their vehicles in top operating condition
- Highway departments must maintain roadways
- Office personnel are reliant on copiers, printers, computers, and fax machines working properly
- As services become increasingly automated, service firms face more and more maintenance issues

Wrap-Up: World-Class Practice

- Empower workers so they “own” their machines
- Implement JIT to help reduce inventories and cycle time
- Invest in factory and service automation projects
- Utilize automated process sensing and control systems
- Use computers in maintenance management

End of Chapter 19