PERT 11 *Maintenance & Reliability*

- Arti Penting *Maintenance & Reliability*
- *Reliability*
- *Maintenance*

Orlando Utilities Commission

- ☑ Maintenance of power generating plants
- ☑ Every year each plant is taken off-line for 1-3 weeks maintenance
- ☑ Every three years each plant is taken off-line for 6-8 weeks for complete overhaul and turbine inspection
- ☑ Each overhaul has 1,800 tasks and requires 72,000 labor hours
- ☑ OUC performs over 12,000 maintenance tasks each year

Orlando Utilities Commission

- ☑ *Every day a plant is down costs OUC $100,000*
- ☑ *Unexpected outages cost between $350,000 and $600,000 per day*
- ☑ *Preventive maintenance discovered a cracked rotor blade which could have destroyed a $27 million piece of equipment*

Strategic Importance of Maintenance and Reliability

- ☑ *Failure has far reaching effects on a firm's*
  - ☑ *Operation*
  - ☑ *Reputation*
  - ☑ *Profitability*
  - ☑ *Dissatisfied customers*
  - ☑ *Idle employees*
  - ☑ *Profits becoming losses*
  - ☑ *Reduced value of investment in plant and equipment*

Maintenance and Reliability

- ☑ The objective of maintenance and reliability is to maintain the capability of the system while controlling costs
  - ☑ Maintenance is all activities involved in keeping a system's equipment in working order
  - ☑ Reliability is the probability that a machine will function properly for a specified time

Important Tactics

- ☑ **Reliability**
  1. Improving individual components
  2. Providing redundancy
- ☑ **Maintenance**
  1. Implementing or improving preventive maintenance
  2. Increasing repair capability or speed

Strategy and Results

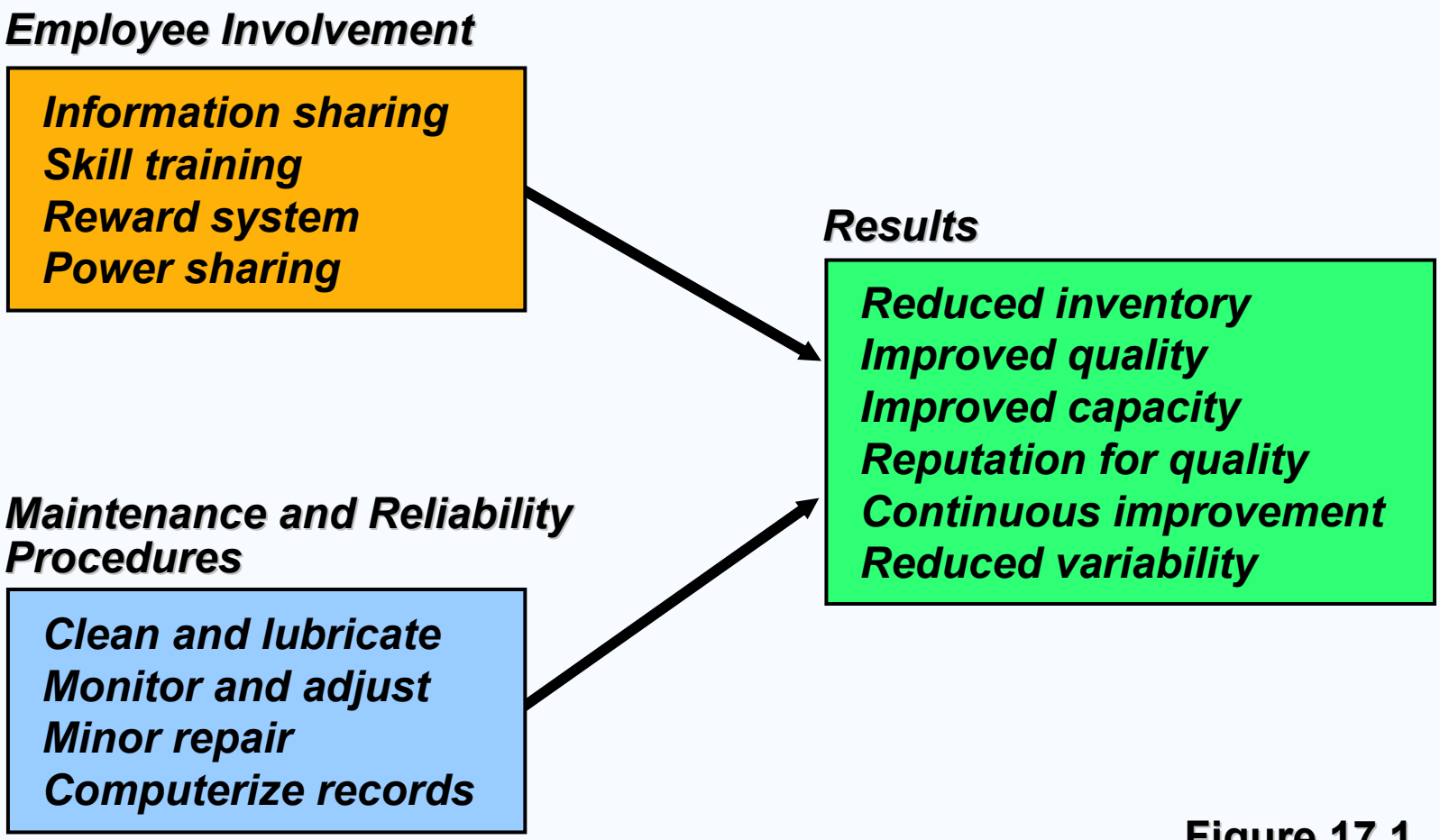


Figure 17.1

Reliability

Improving individual components

$$R_s = R_1 \times R_2 \times R_3 \times \ldots \times R_n$$

where R_1 = reliability of component 1
R_2 = reliability of component 2
and so on

Overall System Reliability

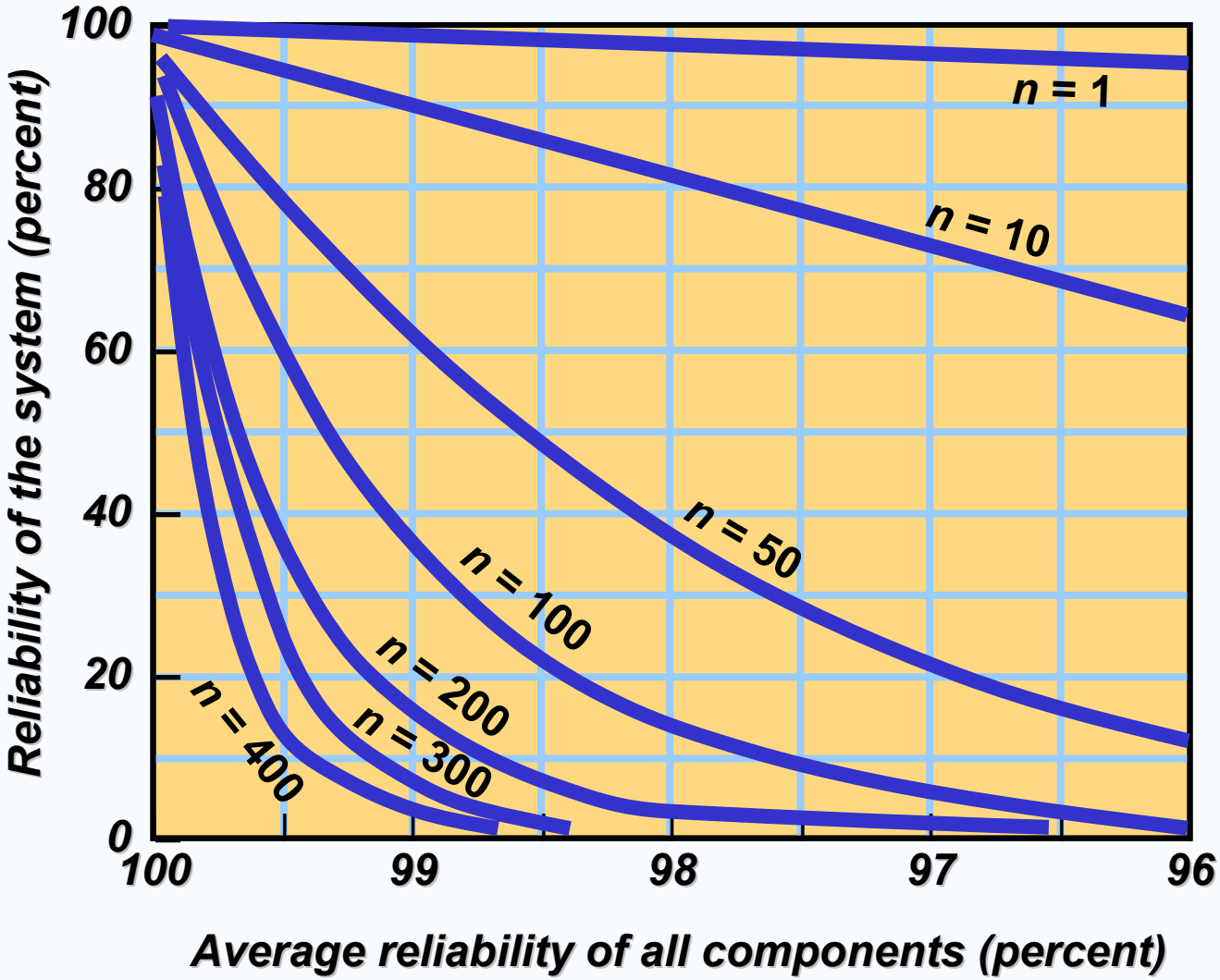
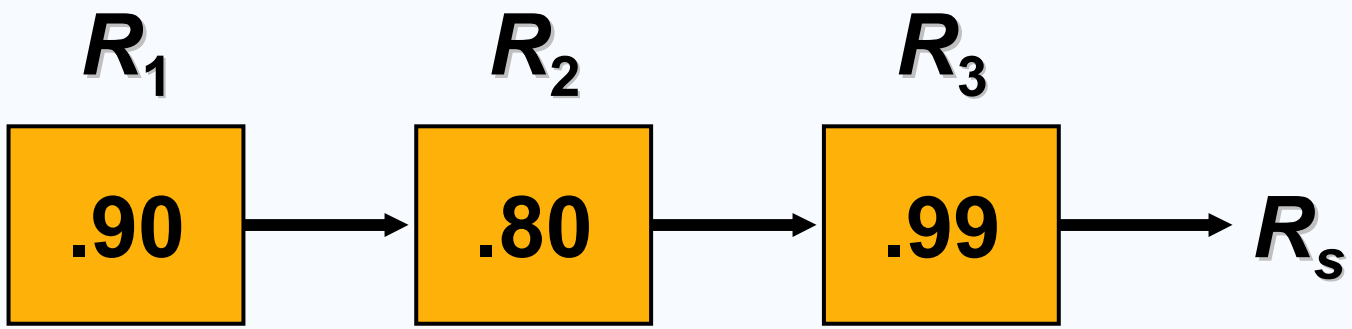


Figure 17.2

Reliability Example



Reliability of the process is

$$R_s = R_1 \times R_2 \times R_3 = .90 \times .80 \times .99 = .713 \text{ or } 71.3\%$$

Product Failure Rate (FR)

Basic unit of measure for reliability

$$FR(\%) = \frac{\text{Number of failures}}{\text{Number of units tested}} \times 100\%$$

$$FR(N) = \frac{\text{Number of failures}}{\text{Number of unit-hours of operating time}}$$

Mean time between failures

$$MTBF = \frac{1}{FR(N)}$$

Failure Rate Example

20 air conditioning units designed for use in NASA space shuttles operated for 1,000 hours
One failed after 200 hours and one after 600 hours

$$FR(\%) = \frac{2}{20}(100\%) = 10\%$$

$$FR(N) = \frac{2}{20{,}000 - 1{,}200} = .000106 \text{ failure/unit hr}$$

$$MTBF = \frac{1}{.000106} = 9{,}434 \text{ hrs}$$

Failure Rate Example

20 *air conditioning units designed for use in NASA space shuttles operated for* 1,000 *hours*

One fai

Failure rate per trip

$$FR = FR(N)(24\ hrs)(60\ days/trip)$$
$$FR = (.000106)(24)(60)$$
$$FR = .152\ failures\ per\ trip$$

$FR(N) =$

$MTBF =$ $= 9{,}434\ hr$

.000106

Providing Redundancy

Provide backup components to increase reliability

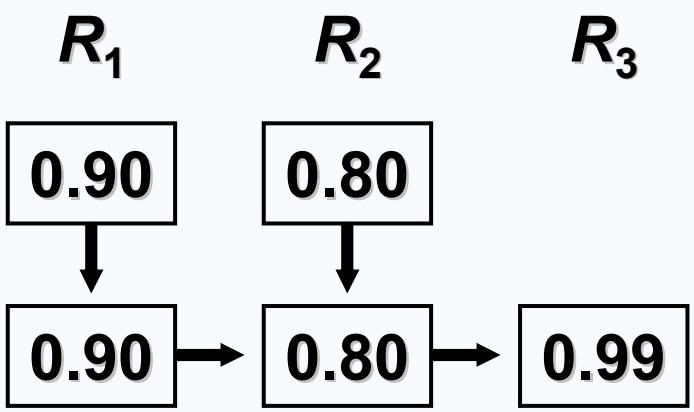
$$\left(\begin{array}{c}\textit{Probability}\\ \textit{of first}\\ \textit{component}\\ \textit{working}\end{array}\right) + \left[\left(\begin{array}{c}\textit{Probability}\\ \textit{of second}\\ \textit{component}\\ \textit{working}\end{array}\right) x \left(\begin{array}{c}\textit{Probability}\\ \textit{of needing}\\ \textit{second}\\ \textit{component}\end{array}\right)\right]$$

$$(.8) + \left[(.8) \; x \; (1 - .8)\right]$$

$$= .8 + .16 = .96$$

Redundancy Example

A redundant process is installed to support the earlier example where R_s = .713



Reliability has increased from .713 to .94

$$= [.9 + .9(1 - .9)] \times [.8 + .8(1 - .8)] \times .99$$

$$= [.9 + (.9)(.1)] \times [.8 + (.8)(.2)] \times .99$$

$$= .99 \times .96 \times .99 = .94$$

Maintenance

- ☑ *Two types of maintenance*
  - ☑ *Preventive maintenance – routine inspection and servicing to keep facilities in good repair*
  - ☑ *Breakdown maintenance – emergency or priority repairs on failed equipment*

Implementing Preventive Maintenance

- ☑ Need to know when a system requires service or is likely to fail
- ☑ High initial failure rates are known as infant mortality
- ☑ Once a product settles in, MTBF generally follows a normal distribution
- ☑ Good reporting and record keeping can aid the decision on when preventive maintenance should be performed

Computerized Maintenance System

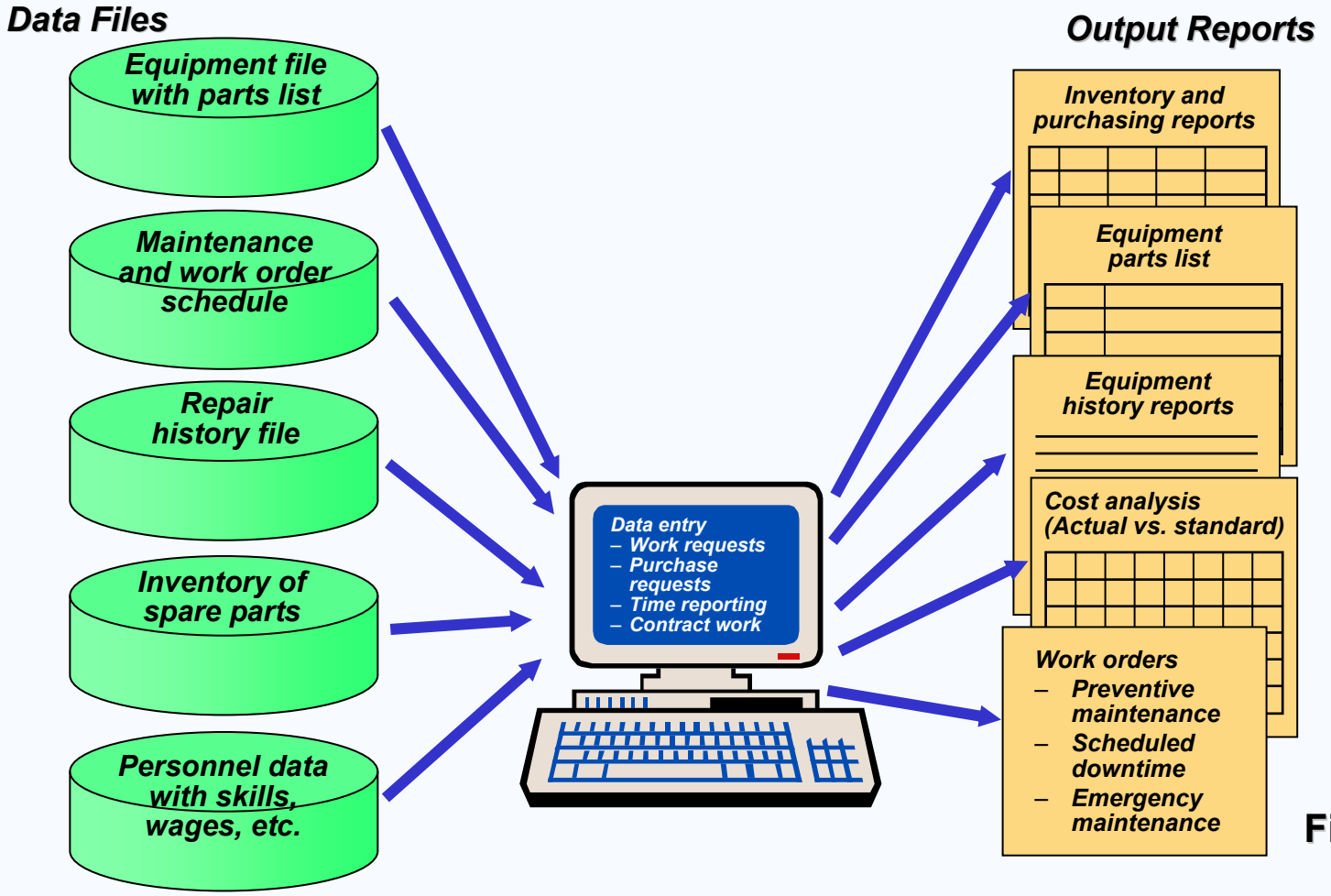
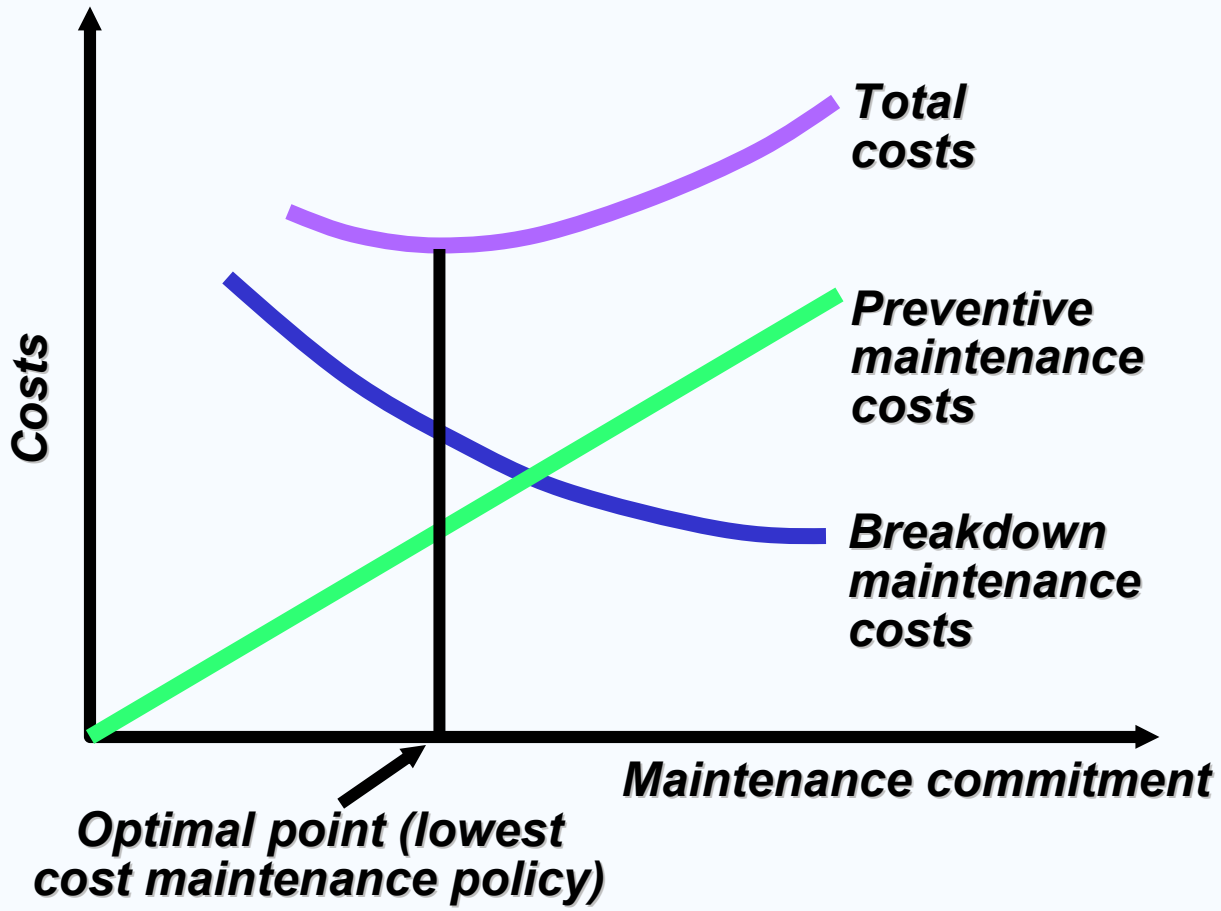


Figure 17.3

Maintenance Costs

- ☑ The traditional view attempted to balance preventive and breakdown maintenance costs
- ☑ Typically this approach failed to consider the true total cost of breakdowns
  - ☑ Inventory
  - ☑ Employee morale
  - ☑ Schedule unreliability

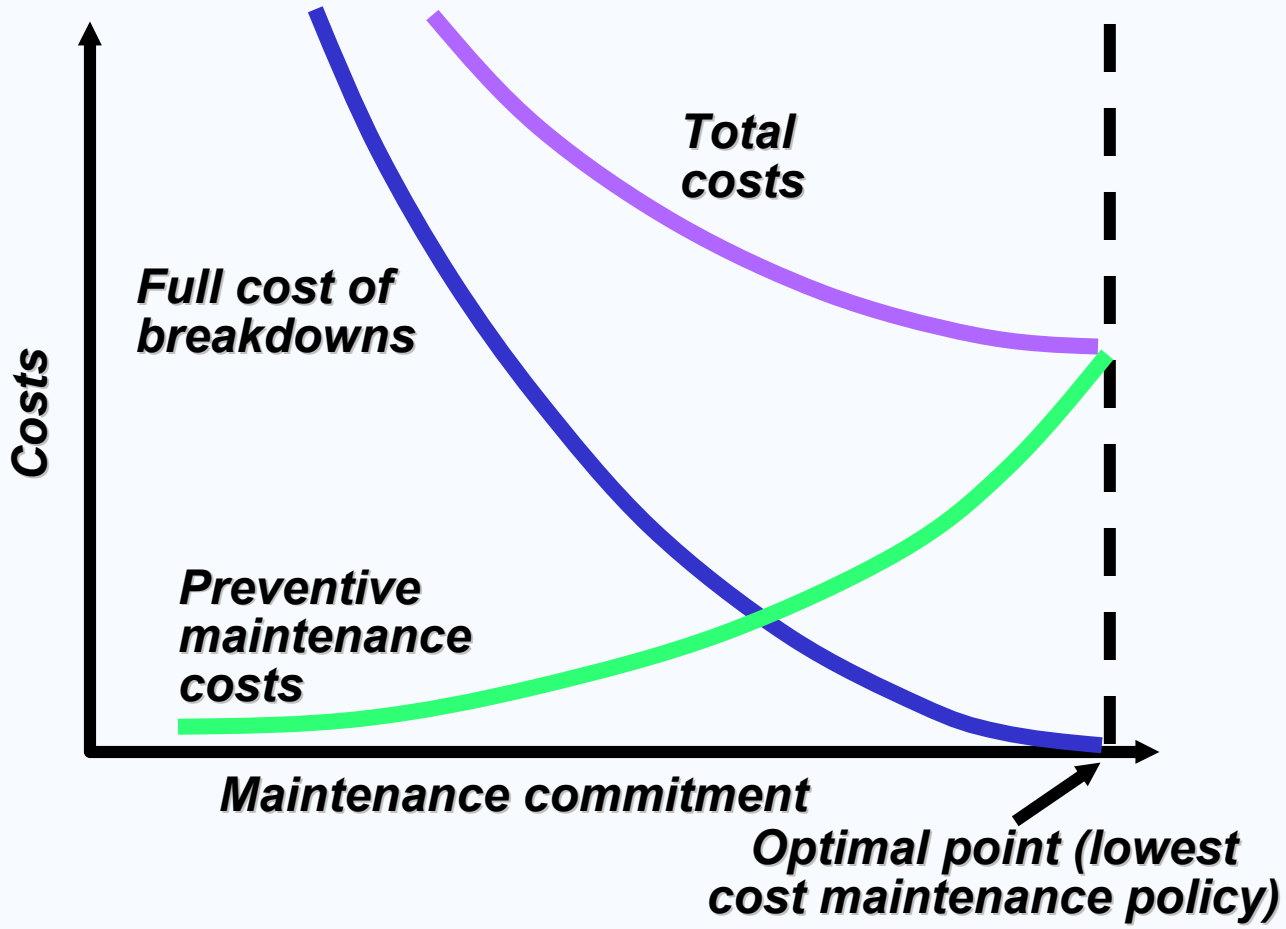
Maintenance Costs



Traditional View

Figure 17.4 (a)

Maintenance Costs



Full Cost View

Figure 17.4 (b)

Maintenance Cost Example

Should the firm contract for maintenance on their printers?

Number of Breakdowns	*Number of Months That Breakdowns Occurred*
0	2
1	8
2	6
3	4
	Total: 20

***Average cost of breakdown* = $300**

Maintenance Cost Example

1. Compute the expected number of breakdowns

Number of Breakdowns	Frequency	Number of Breakdowns	Frequency
0	2/20 = .1	2	6/20 = .3
1	8/20 = .4	3	4/20 = .2

$$\begin{pmatrix}\text{Expected number}\\ \text{of breakdowns}\end{pmatrix} = \sum\left[\begin{pmatrix}\text{Number of}\\ \text{breakdowns}\end{pmatrix} \times \begin{pmatrix}\text{Corresponding}\\ \text{frequency}\end{pmatrix}\right]$$

$$= (0)(.1) + (1)(.4) + (2)(.3) + (3)(.2)$$

$$= 1.6 \text{ breakdowns per month}$$

Maintenance Cost Example

2. Compute the expected breakdown cost per month with no preventive maintenance

$$\begin{pmatrix}\text{Expected}\\ \text{breakdown cost}\end{pmatrix} = \begin{pmatrix}\text{Expected number}\\ \text{of breakdowns}\end{pmatrix} \times \begin{pmatrix}\text{Cost per}\\ \text{breakdown}\end{pmatrix}$$

$$= (1.6)(\$300)$$

$$= \$480 \text{ per month}$$

Maintenance Cost Example

3. Compute the cost of preventive maintenance

$$\begin{pmatrix}\text{Preventive}\\ \text{maintenance cost}\end{pmatrix} = \begin{pmatrix}\text{Cost of expected}\\ \text{breakdowns if service}\\ \text{contract signed}\end{pmatrix} + \begin{pmatrix}\text{Cost of}\\ \text{service contract}\end{pmatrix}$$

= (1 *breakdown/month*)($300) + $150/*month*
= $450 *per month*

Hire the service firm; it is less expensive

Increasing Repair Capabilities

1. Well-trained personnel
2. Adequate resources
3. Ability to establish repair plan and priorities
4. Ability and authority to do material planning
5. Ability to identify the cause of breakdowns
6. Ability to design ways to extend MTBF

How Maintenance is Performed

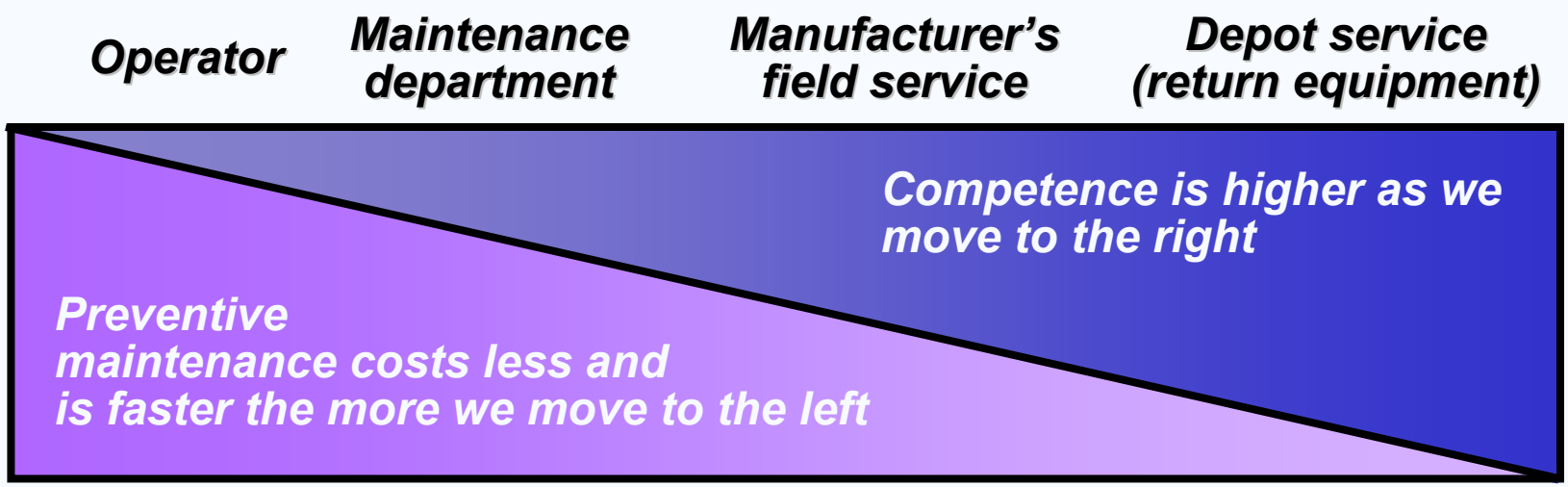


Figure 17.5

Total Productive Maintenance (TPM)

- ☑ Designing machines that are reliable, easy to operate, and easy to maintain
- ☑ Emphasizing total cost of ownership when purchasing machines so that service and maintenance are included in the cost
- ☑ Developing preventive maintenance plans that utilize the best practices of operators, maintenance departments, and depot service
- ☑ Training workers to operate and maintain their own machines

Establishing Maintenance Policies

- ☑ Simulation
  - ☑ Computer analysis of complex situations
  - ☑ Model maintenance programs before they are implemented
- ☑ Expert systems
  - ☑ Computers help users identify problems and select course of action

The objective of maintenance is to:

- ***Ensure that breakdowns do not affect the quality of products.***
- ***Ensure that no breakdowns will ever occur.***
- ***Ensure that preventive maintenance costs are kept as low as possible.***
- ***Maintain the capability of the system while controlling costs.***

The probability that a system will function properly for a specified time under stated conditions is referred to as:

- ***Maintenance.***
- ***Reliability.***
- ***Maintainability.***
- ***Redundancy.***

Which is not *a reliability tactic for improving reliability and maintenance?*

- *Improving individual components.*
- *Providing redundancy.*
- *Increasing repair capabilities and speed.*

Which is not *a maintenance tactic for improving reliability and maintenance?*

- *Improving individual components.*
- *Implementing or improving preventive maintenance.*
- *Increasing repair capabilities and speed.*

MTBF measures the average:

- *Calendar time between failures.*
- *Operating time between failures.*
- *Number of failures per unit time.*
- *Downtime per breakdown.*

Redundancy is achieved by:

- *Improving individual components.*
- *Simplifying the design of components connected in series.*
- *Improving individual components connected in parallel.*
- *Increasing the number of identical units connected in parallel.*

System reliability for components connected in series is computed by:

- Finding the product of individual component probabilities of operating properly.
- Finding the sum of individual component probabilities of operating properly.
- Finding the product of individual component probabilities of failing.
- Finding the sum of individual component probabilities of failing

Redundancy is provided to ensure that:

- ***When a component fails, it can be repaired quickly.***
- ***When a component fails, it can be repaired economically.***
- ***When a component fails, it can be repaired fast and at low cost.***
- ***When one component fails, the system has recourse to another.***

A maintenance system designed to allow the system to perform is referred to as:

- ***Breakdown maintenance.***
- ***Infant Mortality.***
- ***Infant survival.***
- ***Preventive maintenance.***

Which characteristics make a system be a candidate for preventive maintenance?

- ***When the distribution of MTBF exhibits a small standard deviation.***
- ***When the distribution of MTBF exhibits a large standard deviation.***
- ***The system had a high infant mortality rate.***
- ***The system had a low infant mortality rate.***

As a firm's maintenance commitment increases:

- ***The breakdown maintenance costs increase and the preventive maintenance costs decrease.***
- ***Both the breakdown maintenance costs and the preventive maintenance costs increase.***
- ***The breakdown maintenance costs decrease and the preventive maintenance costs increase.***
- ***Both the breakdown maintenance***

TQM concepts combined with maintenance is referred to as:

- ***Preventive maintenance.***
- ***Breakdown maintenance.***
- ***Total productive maintenance.***
- ***Simulation.***
- ***Expert systems.***