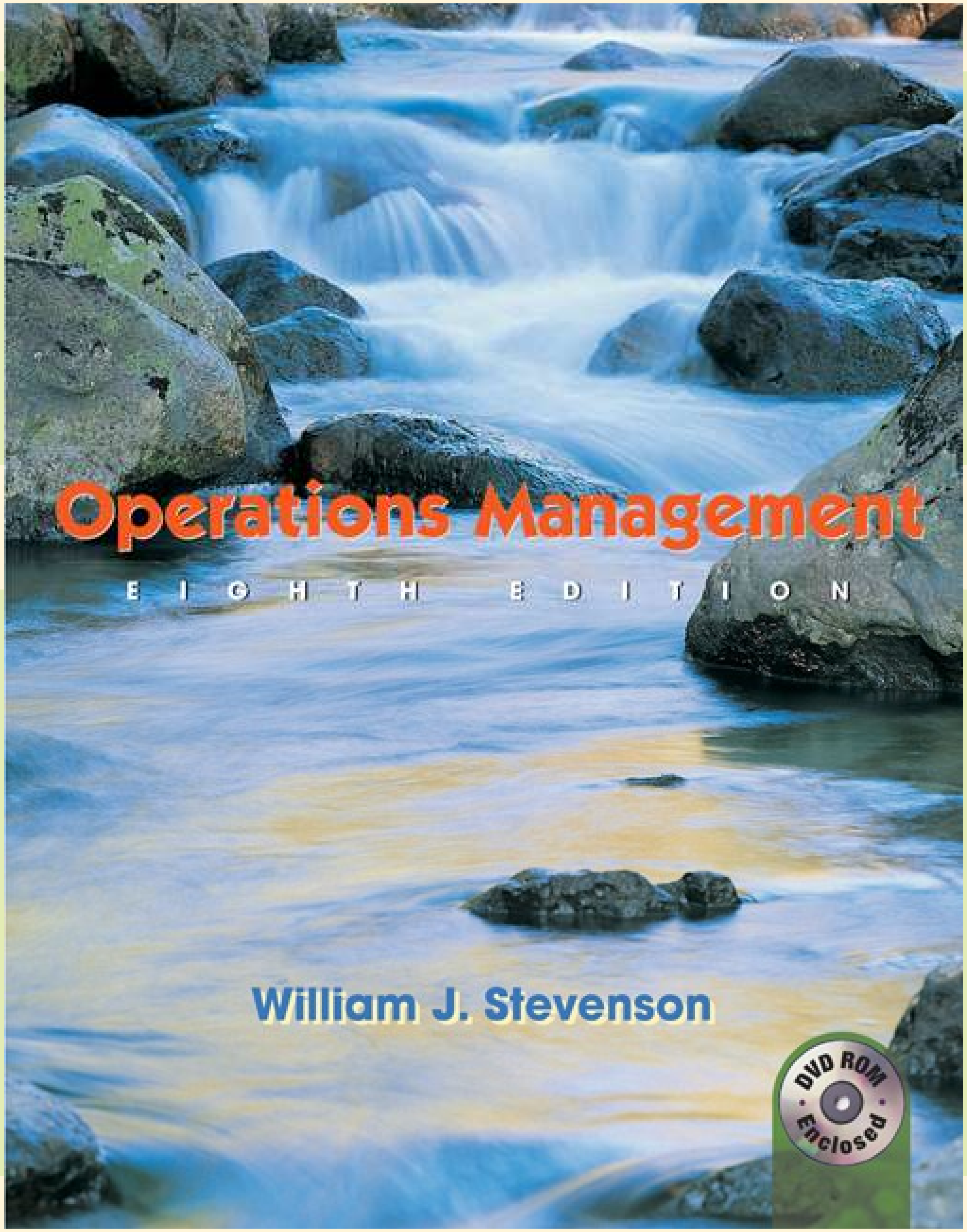

Operations Management
EIGHTH EDITION
William J. Stevenson
DVD ROM Enclosed

CHAPTER
1

Scheduling

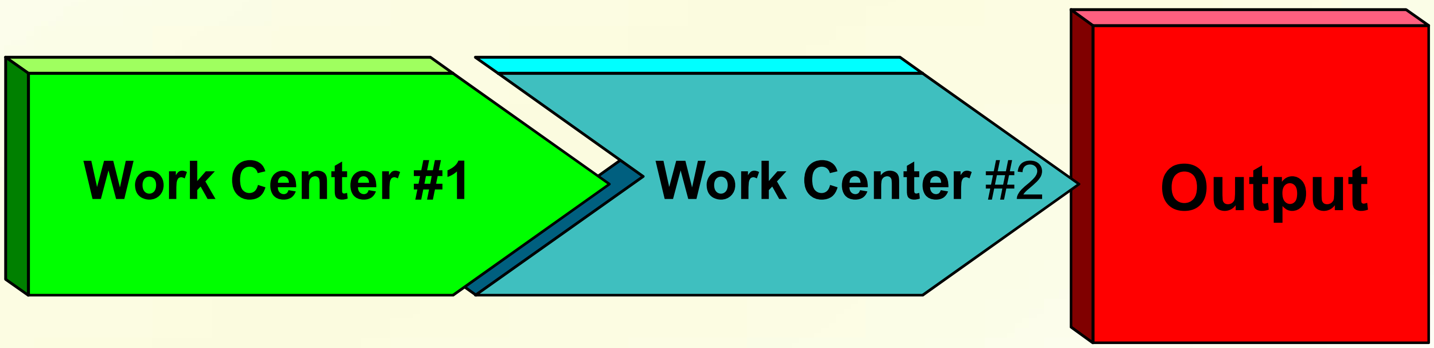
McGraw-Hill/Irwin

Scheduling

- Scheduling: Establishing the timing of the use of equipment, facilities and human activities in an organization
- Effective scheduling can yield
  - Cost savings
  - Increases in productivity

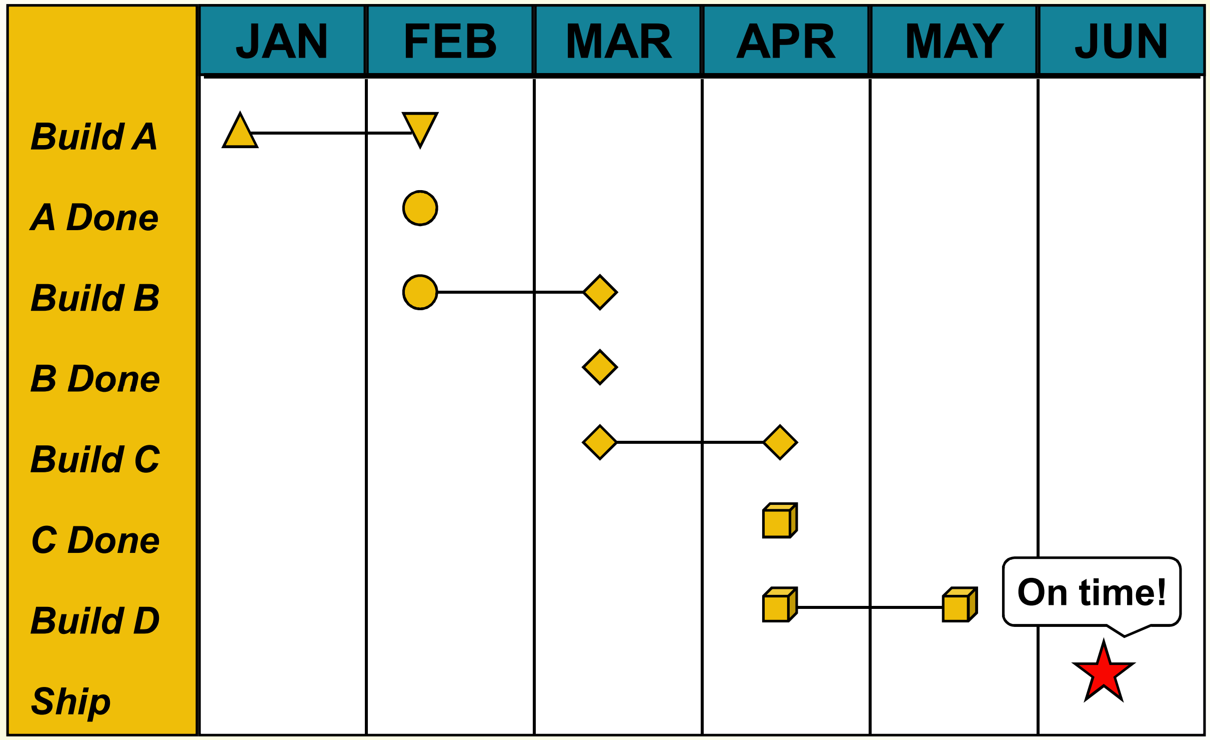
High-Volume Systems

- *Flow system*: High-volume system with Standardized equipment and activities
- *Flow-shop scheduling*: Scheduling for high-volume flow system



Scheduling Manufacturing Operations

- High-volume
- Intermediate-volume
- Low-volume
- Service operations



High-Volume Success Factors

- Process and product design
- Preventive maintenance
- Rapid repair when breakdown occurs
- Optimal product mixes
- Minimization of quality problems
- Reliability and timing of supplies

Intermediate-Volume Systems

- Outputs are between standardized high-volume systems and made-to-order job shops
  - Run size, timing, and sequence of jobs
- Economic run size:

$$Q_0 = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-u}}$$

Scheduling Low-Volume Systems

- *Loading* - assignment of jobs to process centers
- *Sequencing* - determining the order in which jobs will be processed
- Job-shop scheduling
  - Scheduling for low-volume systems with many variations in requirements

Job Shops

Gantt Load Chart

Figure 15.2

- *Gantt chart* - used as a visual aid for loading and scheduling

Work Center	Mon.	Tues.	Wed.	Thurs.	Fri.
1	Job 3			Job 4	
2		Job 3	Job 7		
3	Job 1			Job 6	Job 7
4	Job 10				

Loading

- Infinite loading
- Finite loading
- Vertical loading
- Horizontal loading
- Forward scheduling
- Backward scheduling
- Schedule chart

Sequencing

- *Sequencing*: Determine the order in which jobs at a work center will be processed.

- *Workstation*: An area where one person works, usually with special equipment, on a specialized job.

Sequencing

- *Priority rules*: Simple heuristics used to select the order in which jobs will be processed.
- *Job time*: Time needed for setup and processing of a job.

Priority Rules

Table 15.2

- FCFS - first come, first served
- SPT - shortest processing time
- EDD - earliest due date
- CR - critical ratio
- S/O - slack per operation
- Rush - emergency

Example 2

Table 15.4

Rule	Average Flow Time (days)	Average Tardiness (days)	Average Number of Jobs at the Work Center
FCFS	20.00	9.00	2.93
SPT	18.00	6.67	2.63
EDD	18.33	6.33	2.68
CR	22.17	9.67	3.24

Scheduling Difficulties

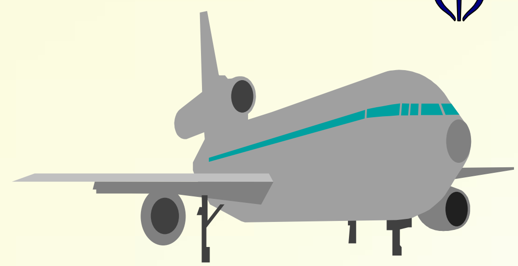
- Variability in
  - Setup times
  - Processing times
  - Interruptions
  - Changes in the set of jobs
- No method for identifying optimal schedule
- Scheduling is not an exact science
- Ongoing task for a manager

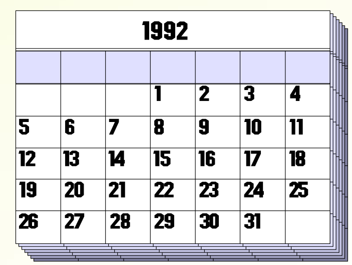
Minimizing Scheduling Difficulties

- Set realistic due dates
- Focus on bottleneck operations
- Consider lot splitting of large jobs

Scheduling Service Operations

- Appointment systems
  - Controls customer arrivals for service
- Reservation systems
  - Estimates demand for service
- Scheduling the workforce
  - Manages capacity for service
- Scheduling multiple resources
  - Coordinates use of more than one resource





Cyclical Scheduling

- Hospitals, police/fire departments, restaurants, supermarkets
- Rotating schedules
  - Set a scheduling horizon
  - Identify the work pattern
  - Develop a basic employee schedule
  - Assign employees to the schedule

Service Operation Problems

- Cannot store or inventory services
- Customer service requests are random
- Scheduling service involves
  - Customers
  - Workforce
  - Equipment

Chapter 2

Aggregate Planning

PowerPoint presentation to accompany
Heizer/Render
Principles of Operations Management, 7e
Operations Management, 9e

PEARSON
Prentice Hall

Outline

- ☑ Global Company Profile: Anheuser-Busch
- ☑ The Planning Process
- ☑ The Nature of Aggregate Planning
- ☑ Aggregate Planning Strategies
  - ☑ Capacity Options
  - ☑ Demand Options
  - ☑ Mixing Options to Develop a Plan

Outline – Continued

- ☑ Methods for Aggregate Planning
  - ☑ Graphical Methods
  - ☑ Mathematical Approaches
  - ☑ Comparison of Aggregate Planning Methods

Outline – Continued

- ☑ Aggregate Planning in Services
  - ☑ Restaurants
  - ☑ Hospitals
  - ☑ National Chains of Small Service Firms
  - ☑ Miscellaneous Services
  - ☑ Airline Industry
- ☑ Yield Management

Learning Objectives

When you complete this chapter you should be able to:

1. Define aggregate planning
2. Identify optional strategies for developing an aggregate plan
3. Prepare a graphical aggregate plan

Learning Objectives

When you complete this chapter you should be able to:

4. Solve an aggregate plan via the transportation method of linear programming
5. Understand and solve a yield management problem

Anheuser-Busch

- ☑ Anheuser-Busch produces nearly 40% of the beer consumed in the U.S.
- ☑ Matches fluctuating demand by brand to plant, labor, and inventory capacity to achieve high facility utilization
- ☑ High facility utilization requires
  - ☑ Meticulous cleaning between batches
  - ☑ Effective maintenance
  - ☑ Efficient employee and facility scheduling

Anheuser-Busch

- ☑ Product-focused facility with high fixed costs
- ☑ High utilization requires effective aggregate planning of the four basic stages of production
  - ☑ Selection and delivery of raw materials
  - ☑ Brewing process from milling to aging
  - ☑ Packaging
  - ☑ Distribution

Aggregate Planning

Determine the quantity and timing of production for the immediate future

- ☑ Objective is to minimize cost over the planning period by adjusting
  - ☑ Production rates
  - ☑ Labor levels
  - ☑ Inventory levels
  - ☑ Overtime work
  - ☑ Subcontracting rates
  - ☑ Other controllable variables

Aggregate Planning

Required for aggregate planning

- ☑ A logical overall unit for measuring sales and output
- ☑ A forecast of demand for an intermediate planning period in these aggregate terms
- ☑ A method for determining costs
- ☑ A model that combines forecasts and costs so that scheduling decisions can be made for the planning period

The Planning Process

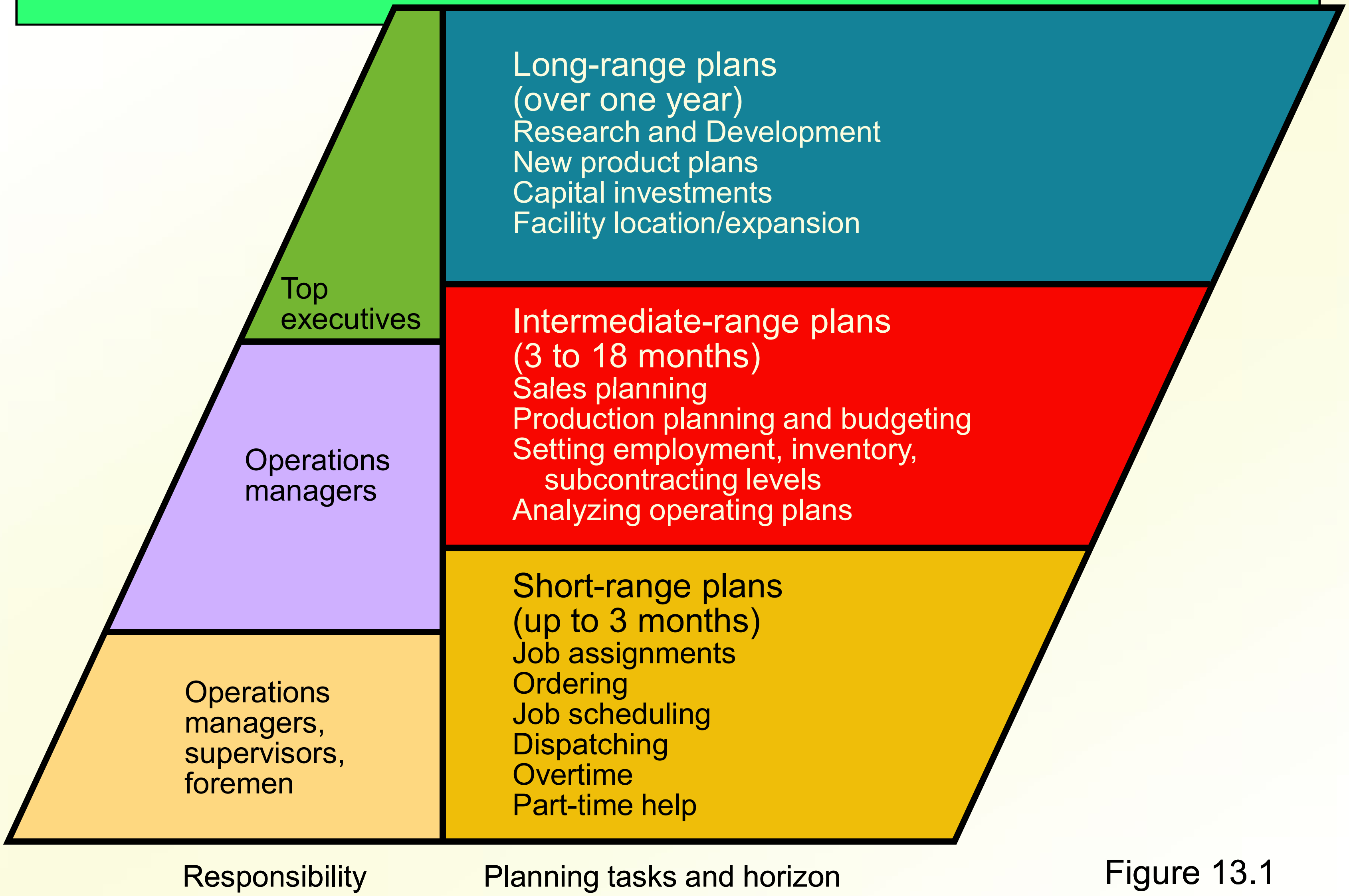


Figure 13.1

Aggregate Planning

Quarter 1		
Jan	Feb	Mar
150,000	120,000	110,000

Quarter 2		
Apr	May	Jun
100,000	130,000	150,000

Quarter 3		
Jul	Aug	Sep
180,000	150,000	140,000

Aggregate Planning

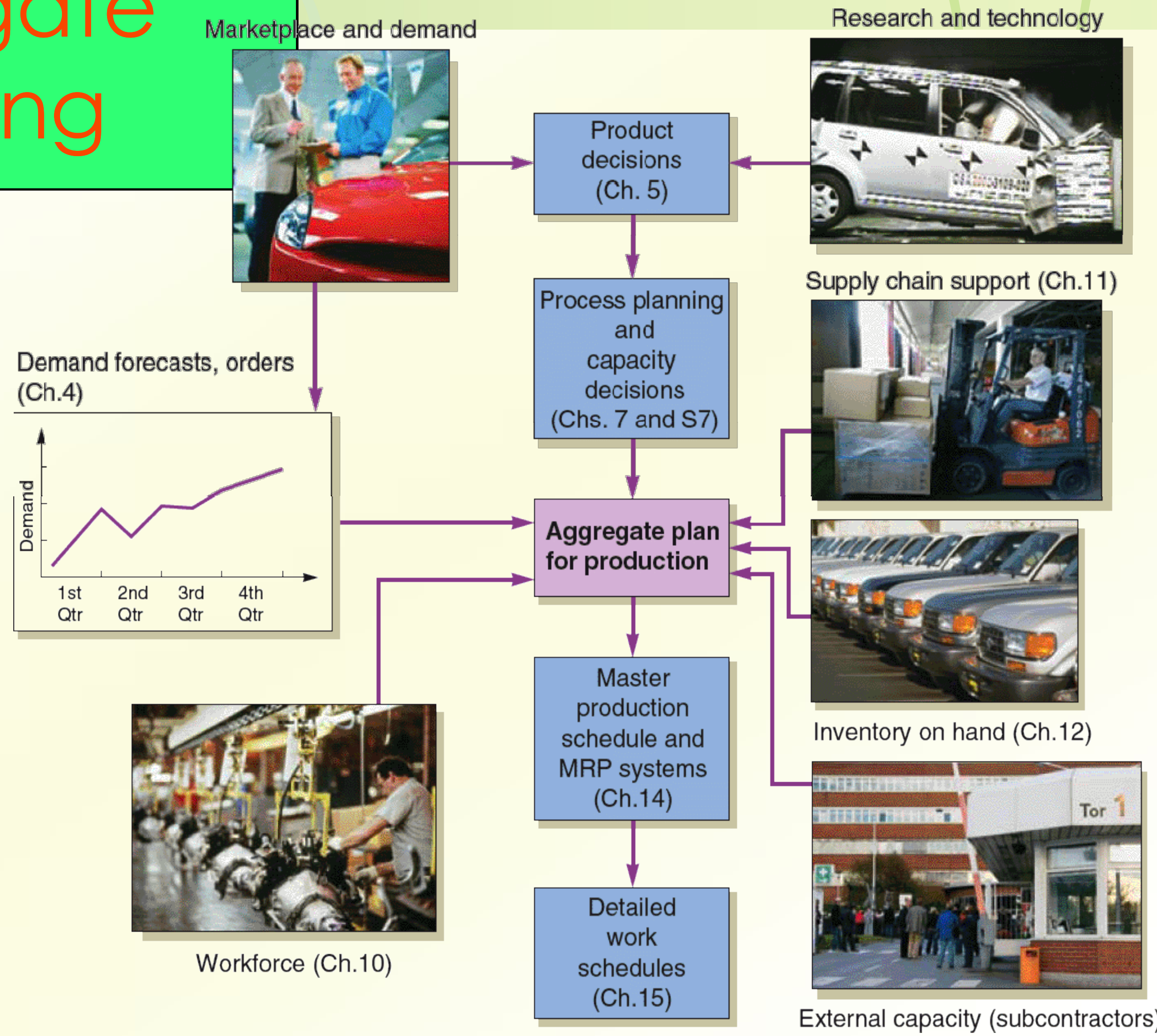


Figure 13.2

Aggregate Planning

- ☑ Combines appropriate resources into general terms
- ☑ Part of a larger production planning system
- ☑ Disaggregation breaks the plan down into greater detail
- ☑ Disaggregation results in a master production schedule

Aggregate Planning Strategies

1. Use inventories to absorb changes in demand
2. Accommodate changes by varying workforce size
3. Use part-timers, overtime, or idle time to absorb changes
4. Use subcontractors and maintain a stable workforce
5. Change prices or other factors to influence demand

Capacity Options

- ☑ Changing inventory levels
  - ☑ Increase inventory in low demand periods to meet high demand in the future
  - ☑ Increases costs associated with storage, insurance, handling, obsolescence, and capital investment 15% to 40%
  - ☑ Shortages can mean lost sales due to long lead times and poor customer service

Capacity Options

- ☑ Varying workforce size by hiring or layoffs
  - ☑ Match production rate to demand
  - ☑ Training and separation costs for hiring and laying off workers
  - ☑ New workers may have lower productivity
  - ☑ Laying off workers may lower morale and productivity

Capacity Options

- ☑ Varying production rate through overtime or idle time
  - ☑ Allows constant workforce
  - ☑ May be difficult to meet large increases in demand
  - ☑ Overtime can be costly and may drive down productivity
  - ☑ Absorbing idle time may be difficult

Capacity Options

- ☑ Subcontracting
  - ☑ Temporary measure during periods of peak demand
  - ☑ May be costly
  - ☑ Assuring quality and timely delivery may be difficult
  - ☑ Exposes your customers to a possible competitor

Capacity Options

- ☑ Using part-time workers
  - ☑ Useful for filling unskilled or low skilled positions, especially in services

Demand Options

- ☑ Influencing demand
  - ☑ Use advertising or promotion to increase demand in low periods
  - ☑ Attempt to shift demand to slow periods
  - ☑ May not be sufficient to balance demand and capacity

Demand Options

- ☑ Back ordering during high- demand periods
  - ☑ Requires customers to wait for an order without loss of goodwill or the order
  - ☑ Most effective when there are few if any substitutes for the product or service
  - ☑ Often results in lost sales

Demand Options

- ☑ Counterseasonal product and service mixing
  - ☑ Develop a product mix of counterseasonal items
  - ☑ May lead to products or services outside the company's areas of expertise

Aggregate Planning Options

Option	Advantages	Disadvantages	Some Comments
Changing inventory levels	Changes in human resources are gradual or none; no abrupt production changes.	Inventory holding cost may increase. Shortages may result in lost sales.	Applies mainly to production, not service, operations.
Varying workforce size by hiring or layoffs	Avoids the costs of other alternatives.	Hiring, layoff, and training costs may be significant.	Used where size of labor pool is large.

Table 13.1

Aggregate Planning Options

Option	Advantages	Disadvantages	Some Comments
Varying production rates through overtime or idle time	*Matches seasonal fluctuations without hiring/ training costs.*	*Overtime premiums; tired workers; may not meet demand.*	*Allows flexibility within the aggregate plan.*
Sub-contracting	*Permits flexibility and smoothing of the firm's output.*	*Loss of quality control; reduced profits; loss of future business.*	*Applies mainly in production settings.*

Table 13.1

Aggregate Planning Options

Option	Advantages	Disadvantages	Some Comments
Using part-time workers	Is less costly and more flexible than full-time workers.	High turnover/ training costs; quality suffers; scheduling difficult.	Good for unskilled jobs in areas with large temporary labor pools.
Influencing demand	Tries to use excess capacity. Discounts draw new customers.	Uncertainty in demand. Hard to match demand to supply exactly.	Creates marketing ideas. Overbooking used in some businesses.

Table 13.1

Aggregate Planning Options

Option	Advantages	Disadvantages	Some Comments
Back ordering during high-demand periods	*May avoid overtime. Keeps capacity constant.*	*Customer must be willing to wait, but goodwill is lost.*	*Many companies back order.*
Counter-seasonal product and service mixing	*Fully utilizes resources; allows stable workforce.*	*May require skills or equipment outside the firm's areas of expertise.*	*Risky finding products or services with opposite demand patterns.*

Table 13.1

Methods for Aggregate Planning

- ☑ A mixed strategy may be the best way to achieve minimum costs
- ☑ There are many possible mixed strategies
- ☑ Finding the optimal plan is not always possible

Mixing Options to Develop a Plan

- ☑ Chase strategy
  - ☑ Match output rates to demand forecast for each period
  - ☑ Vary workforce levels or vary production rate
  - ☑ Favored by many service organizations

Mixing Options to Develop a Plan

- ☑ Level strategy
  - ☑ Daily production is uniform
  - ☑ Use inventory or idle time as buffer
  - ☑ Stable production leads to better quality and productivity
- ☑ Some combination of capacity options, a mixed strategy, might be the best solution

Graphical Methods

- ☑ Popular techniques
- ☑ Easy to understand and use
- ☑ Trial-and-error approaches that do not guarantee an optimal solution
- ☑ Require only limited computations

Graphical Methods

1. Determine the demand for each period
2. Determine the capacity for regular time, overtime, and subcontracting each period
3. Find labor costs, hiring and layoff costs, and inventory holding costs
4. Consider company policy on workers and stock levels
5. Develop alternative plans and examine their total costs

Roofing Supplier Example 1

Month	Expected Demand	Production Days	Demand Per Day (computed)
Jan	900	22	41
Feb	700	18	39
Mar	800	21	38
Apr	1,200	21	57
May	1,500	22	68
June	1,100	20	55
	6,200	124	

Table 13.2

$$\text{Average requirement} = \frac{\text{Total expected demand}}{\text{Number of production days}}$$

$$= \frac{6{,}200}{124} = 50 \text{ units per day}$$

Roofing Supplier Example 1

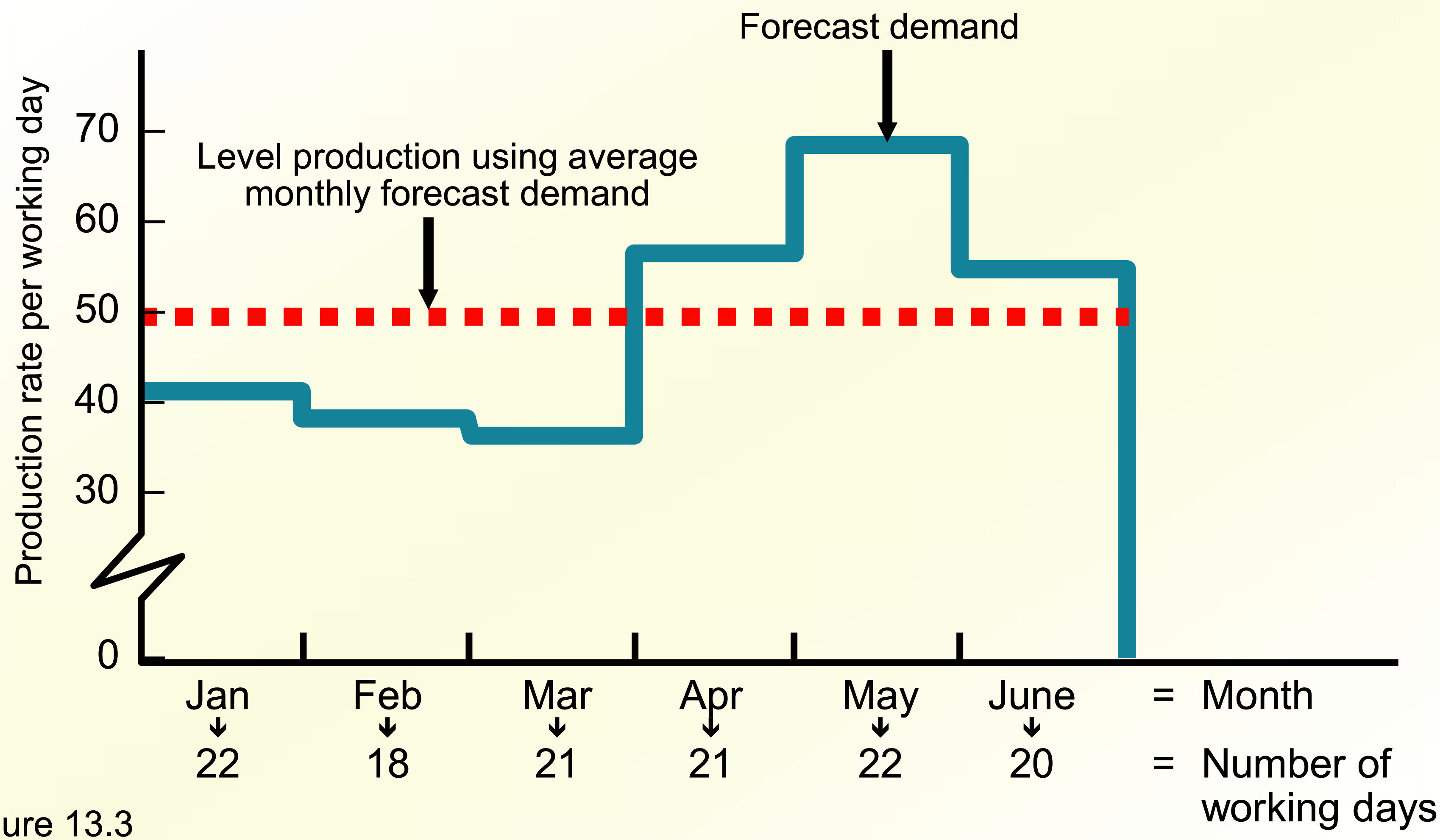


Figure 13.3

Roofing Supplier Example 2

Cost Information	
Inventory carrying cost	$ 5 *per unit per month*
Subcontracting cost per unit	$10 *per unit*
Average pay rate	$ 5 *per hour* ($40 *per day*)
Overtime pay rate	$ 7 *per hour* (*above* 8 *hours per day*)
Labor-hours to produce a unit	1.6 *hours per unit*
Cost of increasing daily production rate (hiring and training)	$300 *per unit*
Cost of decreasing daily production rate (layoffs)	$600 *per unit*

Table 13.3

Plan 1 – constant workforce

Roofing Supplier Example 2

Month	Production at 50 Units per Day	Demand Forecast	Monthly Inventory Change	Ending Inventory
Jan	1,100	900	+200	200
Feb	900	700	+200	400
Mar	1,050	800	+250	650
Apr	1,050	1,200	-150	500
May	1,100	1,500	-400	100
June	1,000	1,100	-100	0
				1,850

Total units of inventory carried over from one month to the next = 1,850 units

Workforce required to produce 50 units per day = 10 workers

Roofing Supplier Example 2

Costs		Calculations
Inventory carrying	$9,250	(= 1,850 *units carried x* $5 *per unit*)
Regular-time labor	49,600	(= 10 *workers x* $40 *per day x* 124 *days*)
Other costs (overtime, hiring, layoffs, subcontracting)	0	
Total cost	$58,850	

Total units of inventory carried over from one month to the next = 1,850 units

Workforce required to produce 50 units per day = 10 workers

Roofing Supplier Example 2

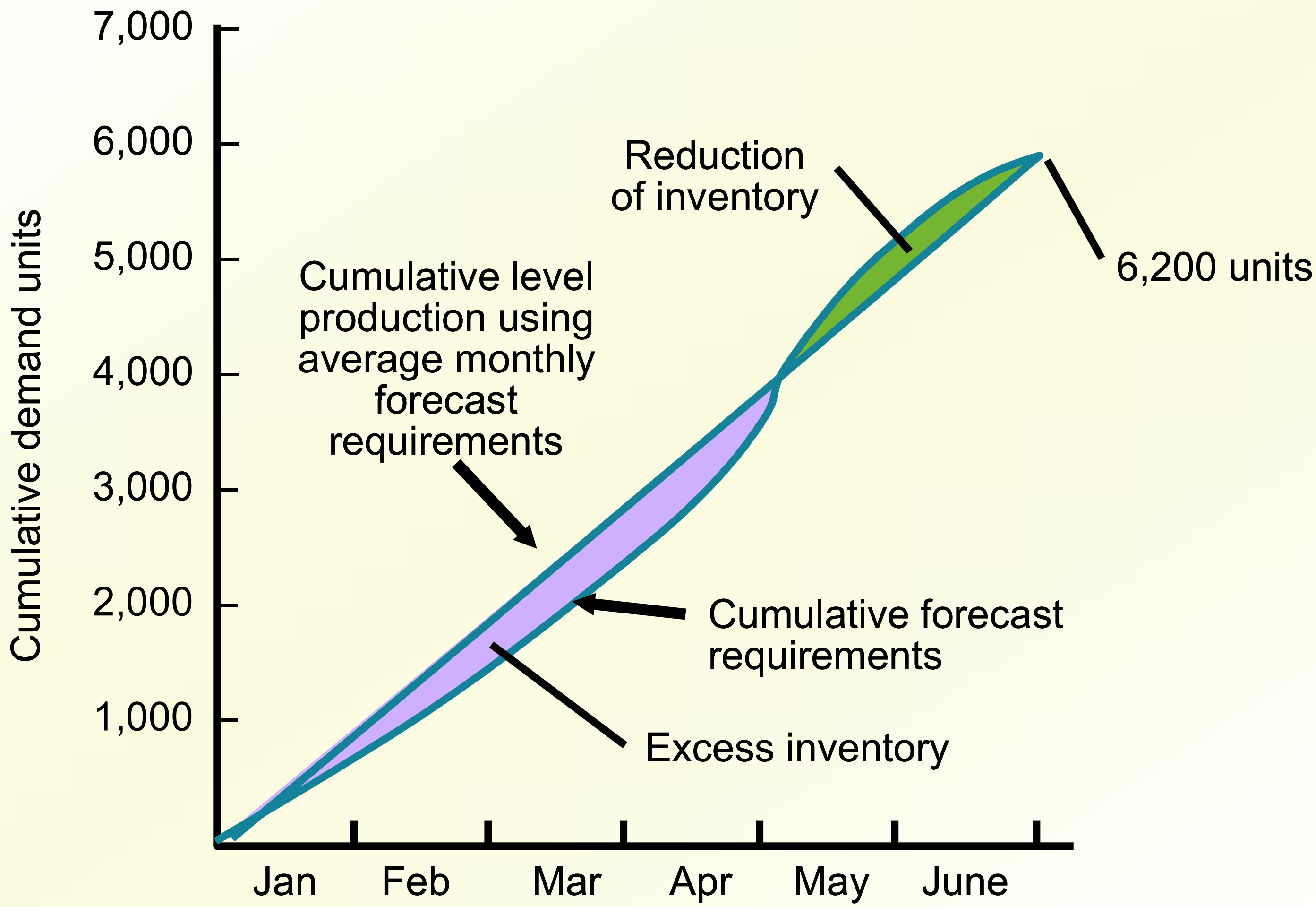


Figure 13.4

Roofing Supplier Example 3

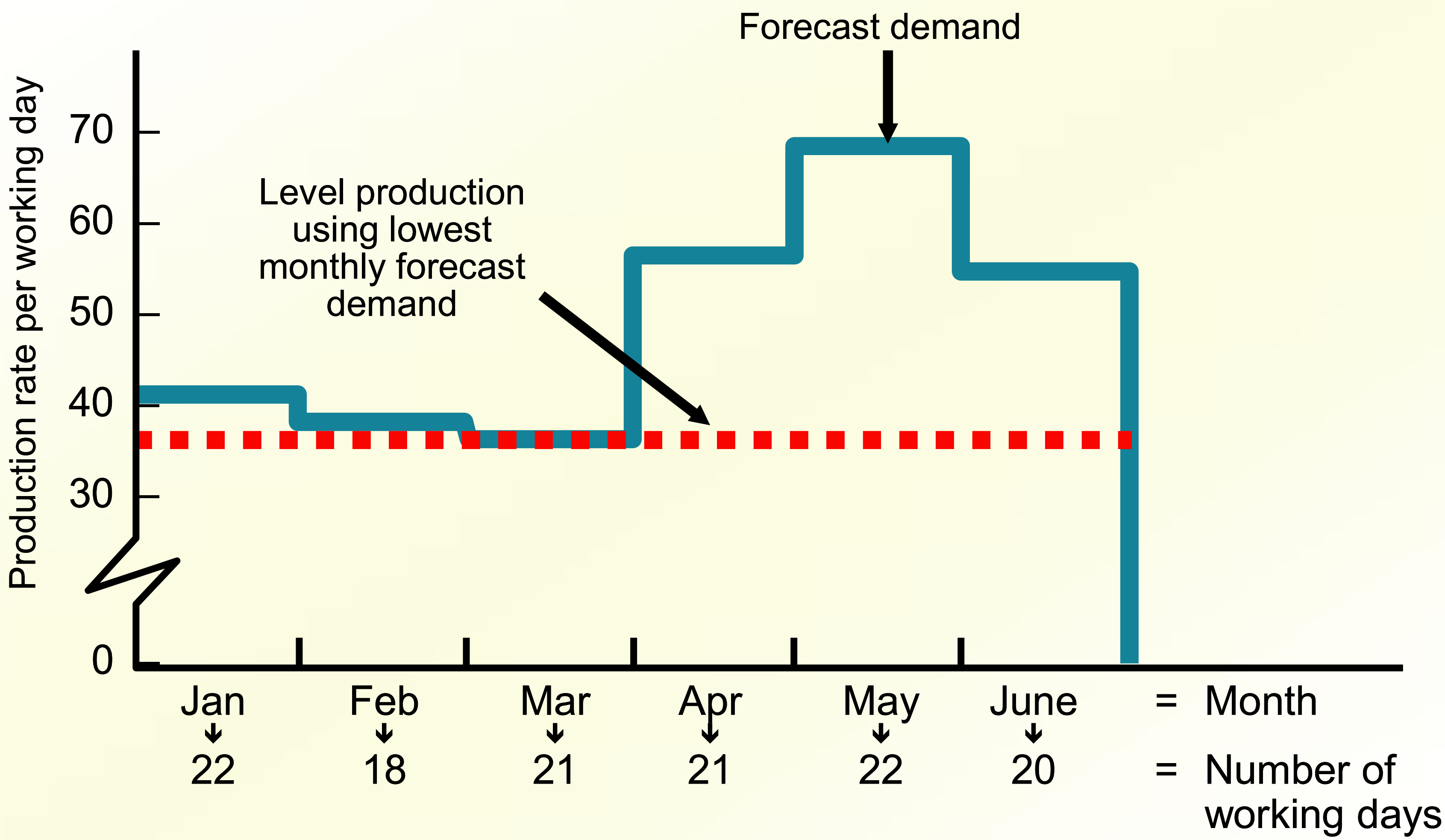
Month	Expected Demand	Production Days	Demand Per Day (computed)
Jan	900	22	41
Feb	700	18	39
Mar	800	21	38
Apr	1,200	21	57
May	1,500	22	68
June	1,100	20	55
	6,200	124	

Table 13.2

Plan 2 – subcontracting

Minimum requirement = 38 units per day

Roofing Supplier Example 3



Roofing Supplier Example 3

Cost Information	
Inventory carrying cost	$ 5 *per unit per month*
Subcontracting cost per unit	$10 *per unit*
Average pay rate	$ 5 *per hour* ($40 *per day*)
Overtime pay rate	$ 7 *per hour* (*above* 8 *hours per day*)
Labor-hours to produce a unit	1.6 *hours per unit*
Cost of increasing daily production rate (hiring and training)	$300 *per unit*
Cost of decreasing daily production rate (layoffs)	$600 *per unit*

Table 13.3

Roofing Supplier Example 3

Cost Information	
Inventory carry cost	$ 5 per unit per month
Subcontracting cost per unit	$10 per unit
Average pay rate	$ 5 per hour ($40 per day)
Overtime pay rate	$ 7 per hour (above 8 hours per day)
Labor-hours to produce a unit	1.6 hours per unit
Cost of increasing daily production rate (hiring and training)	$300 per unit
Cost of decreasing daily production rate (layoffs)	$600 per unit

Table 13.3

Roofing Supplier Example 3

In-house production = 38 units per day x 124 days = 4,712 units

Costs		Calculations
Regular-time labor	$37,696	(= 7.6 *workers* x $40 *per day* x 124 *days*)
Subcontracting	14,880	(= 1,488 *units* x $10 *per unit*)
Total cost	$52,576	

Roofing Supplier Example 4

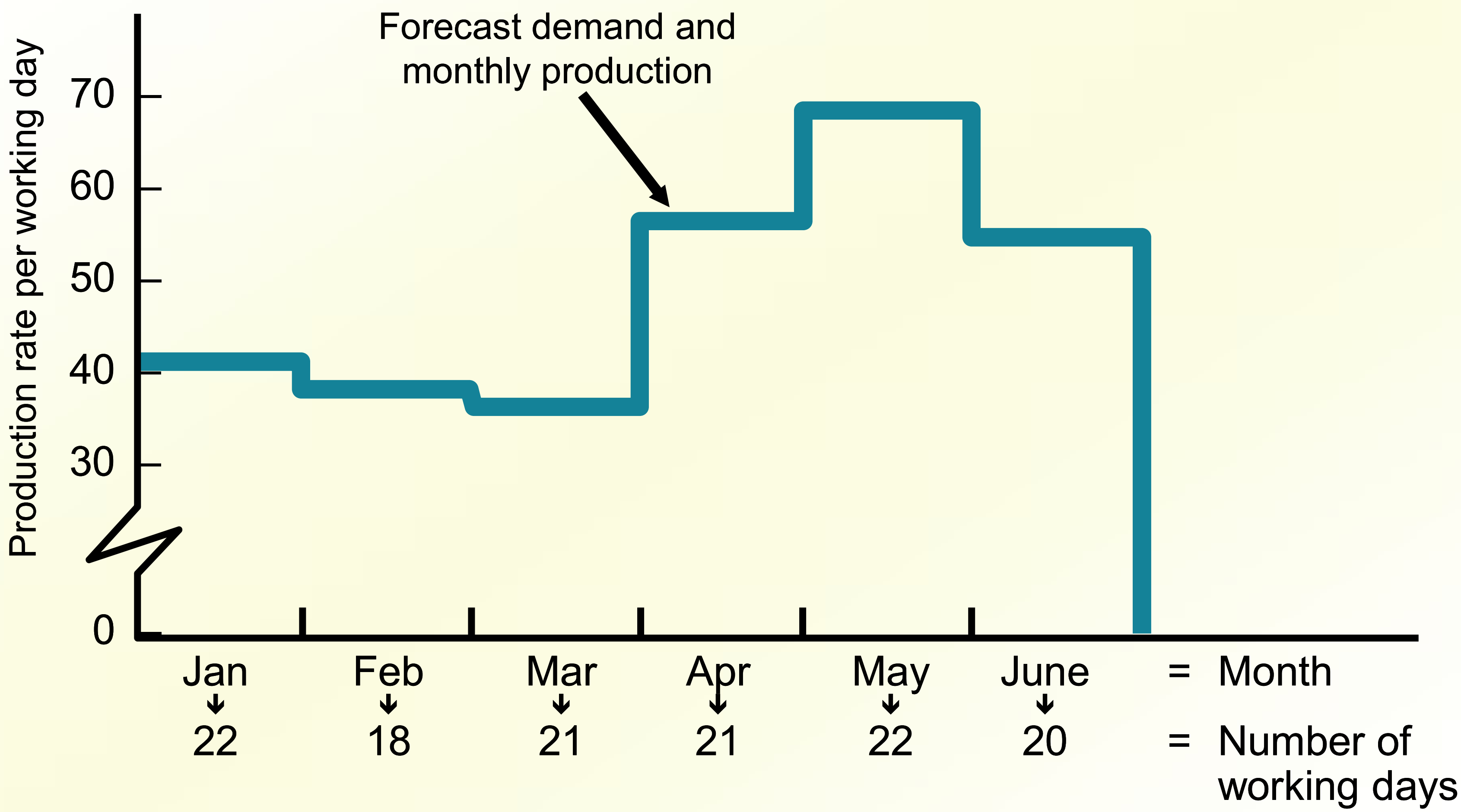
Month	Expected Demand	Production Days	Demand Per Day (computed)
Jan	900	22	41
Feb	700	18	39
Mar	800	21	38
Apr	1,200	21	57
May	1,500	22	68
June	1,100	20	55
	6,200	124	

Table 13.2

Plan 3 – hiring and firing

Production = Expected Demand

Roofing Supplier Example 4



Roofing Supplier Example 4

Cost Information	
Inventory carrying cost	$ 5 *per unit per month*
Subcontracting cost per unit	$10 *per unit*
Average pay rate	$ 5 *per hour* ($40 *per day*)
Overtime pay rate	$ 7 *per hour* (*above* 8 *hours per day*)
Labor-hours to produce a unit	1.6 *hours per unit*
Cost of increasing daily production rate (hiring and training)	$300 *per unit*
Cost of decreasing daily production rate (layoffs)	$600 *per unit*

Table 13.3

Roofing Supplier Example 4

Month	Forecast (units)	Daily Prod Rate	Basic Production Cost (demand x 1.6 hrs/unit x $5/hr)	Extra Cost of Increasing Production (hiring cost)	Extra Cost of Decreasing Production (layoff cost)	Total Cost
Jan	900	41	$ 7,200	—	—	$ 7,200
Feb	700	39	5,600	—	$1,200 (= 2 x $600)	6,800
Mar	800	38	6,400	—	$600 (= 1 x $600)	7,000
Apr	1,200	57	9,600	$5,700 (= 19 x $300)	—	15,300
May	1,500	68	12,000	$3,300 (= 11 x $300)	—	15,300
June	1,100	55	8,800	—	$7,800 (= 13 x $600)	16,600
			$49,600	$9,000	$9,600	$68,200

Table 13.4

Comparison of Three Plans

Cost	Plan 1	Plan 2	Plan 3
Inventory carrying	$ 9,250	$ 0	$ 0
Regular labor	49,600	37,696	49,600
Overtime labor	0	0	0
Hiring	0	0	9,000
Layoffs	0	0	9,600
Subcontracting	0	14,880	0
Total cost	$58,850	$52,576	$68,200

Plan 2 is the lowest cost option

Table 13.5

Mathematical Approaches

- ☑ Useful for generating strategies
  - ☑ Transportation Method of Linear Programming
    - ☑ Produces an optimal plan
  - ☑ Management Coefficients Model
    - ☑ Model built around manager's experience and performance
  - ☑ Other Models
    - ☑ Linear Decision Rule
    - ☑ Simulation

Transportation Method

	Sales Period		
	Mar	Apr	May
Demand	800	1,000	750
Capacity:			
Regular	700	700	700
Overtime	50	50	50
Subcontracting	150	150	130
Beginning inventory	100		

tires

	Costs
Regular time	$40 per tire
Overtime	$50 per tire
Subcontracting	$70 per tire
Carrying	$ 2 per tire per month

Table 13.6

Transportation Example

Important points

1. Carrying costs are $2/tire/month. If goods are made in one period and held over to the next, holding costs are incurred
2. Supply must equal demand, so a dummy column called “unused capacity” is added
3. Because back ordering is not viable in this example, cells that might be used to satisfy earlier demand are not available

Transportation Example

Important points

4. Quantities in each column designate the levels of inventory needed to meet demand requirements
5. In general, production should be allocated to the lowest cost cell available without exceeding unused capacity in the row or demand in the column

Transp
Examp

	SUPPLY FROM	DEMAND FOR *Period 1 (Mar.)*	*Period 2 (Apr.)*	*Period 3 (May)*	*Unused Capacity (dummy)*	TOTAL CAPACITY AVAILABLE (supply)
	Beginning inventory	0 100	2	4	0	100
Period 1	*Regular time*	40 700	42	44	0	700
	Overtime	50	52 50	54	0	50
	Subcontract	70	72 150	74	0	150
Period 2	*Regular time*	×	40 700	42	0	700
	Overtime	×	50 50	52	0	50
	Subcontract	×	70 50	72	0 100	150
Period 3	*Regular time*	×	×	40 700	0	700
	Overtime	×	×	50 50	0	50
	Subcontract	×	×	70	0 130	130
	TOTAL DEMAND	800	1,000	750	230	2,780

Table 13.7

Management Coefficients Model

- ☑ Builds a model based on manager’s experience and performance
- ☑ A regression model is constructed to define the relationships between decision variables
- ☑ Objective is to remove inconsistencies in decision making

Other Models

Linear Decision Rule

- ☑ Minimizes costs using quadratic cost curves
- ☑ Operates over a particular time period

Simulation

- ☑ Uses a search procedure to try different combinations of variables
- ☑ Develops feasible but not necessarily optimal solutions

Summary of Aggregate Planning Methods

Techniques	Solution Approaches	Important Aspects
Graphical methods	Trial and error	Simple to understand and easy to use. Many solutions; one chosen may not be optimal.
Transportation method of linear programming	Optimization	LP software available; permits sensitivity analysis and new constraints; linear functions may not be realistic.

Table 13.8

Summary of Aggregate Planning Methods

Techniques	Solution Approaches	Important Aspects
Management coefficients model	***Heuristic***	***Simple, easy to implement; tries to mimic manager's decision process; uses regression.***
Simulation	***Change parameters***	***Complex; may be difficult to build and for managers to understand.***

Table 13.8

Aggregate Planning in Services

Controlling the cost of labor is critical

1. Accurate scheduling of labor-hours to assure quick response to customer demand
2. An on-call labor resource to cover unexpected demand
3. Flexibility of individual worker skills
4. Flexibility in rate of output or hours of work

Five Service Scenarios

- ☑ Restaurants
  - ☑ Smoothing the production process
  - ☑ Determining the optimal workforce size
- ☑ Hospitals
  - ☑ Responding to patient demand

Five Service Scenarios

- ☑ National Chains of Small Service Firms
  - ☑ Planning done at national level and at local level
- ☑ Miscellaneous Services
  - ☑ Plan human resource requirements
  - ☑ Manage demand

Law Firm Example

(1) Category of Legal Business	Labor-Hours Required: Forecasts (2) Best (hours)	(3) Likely (hours)	(4) Worst (hours)	Capacity Constraints: (5) Maximum Demand in People	(6) Number of Qualified Personnel
Trial work	1,800	1,500	1,200	3.6	4
Legal research	4,500	4,000	3,500	9.0	32
Corporate law	8,000	7,000	6,500	16.0	15
Real estate law	1,700	1,500	1,300	3.4	6
Criminal law	3,500	3,000	2,500	7.0	12
Total hours	19,500	17,000	15,000		
Lawyers needed	39	34	30		

Table 13.9

Five Service Scenarios

- ☑ Airline industry
  - ☑ Extremely complex planning problem
  - ☑ Involves number of flights, number of passengers, air and ground personnel, allocation of seats to fare classes
  - ☑ Resources spread through the entire system

Yield Management

Allocating resources to customers at prices that will maximize yield or revenue

1. Service or product can be sold in advance of consumption
2. Demand fluctuates
3. Capacity is relatively fixed
4. Demand can be segmented
5. Variable costs are low and fixed costs are high

Yield Management Example

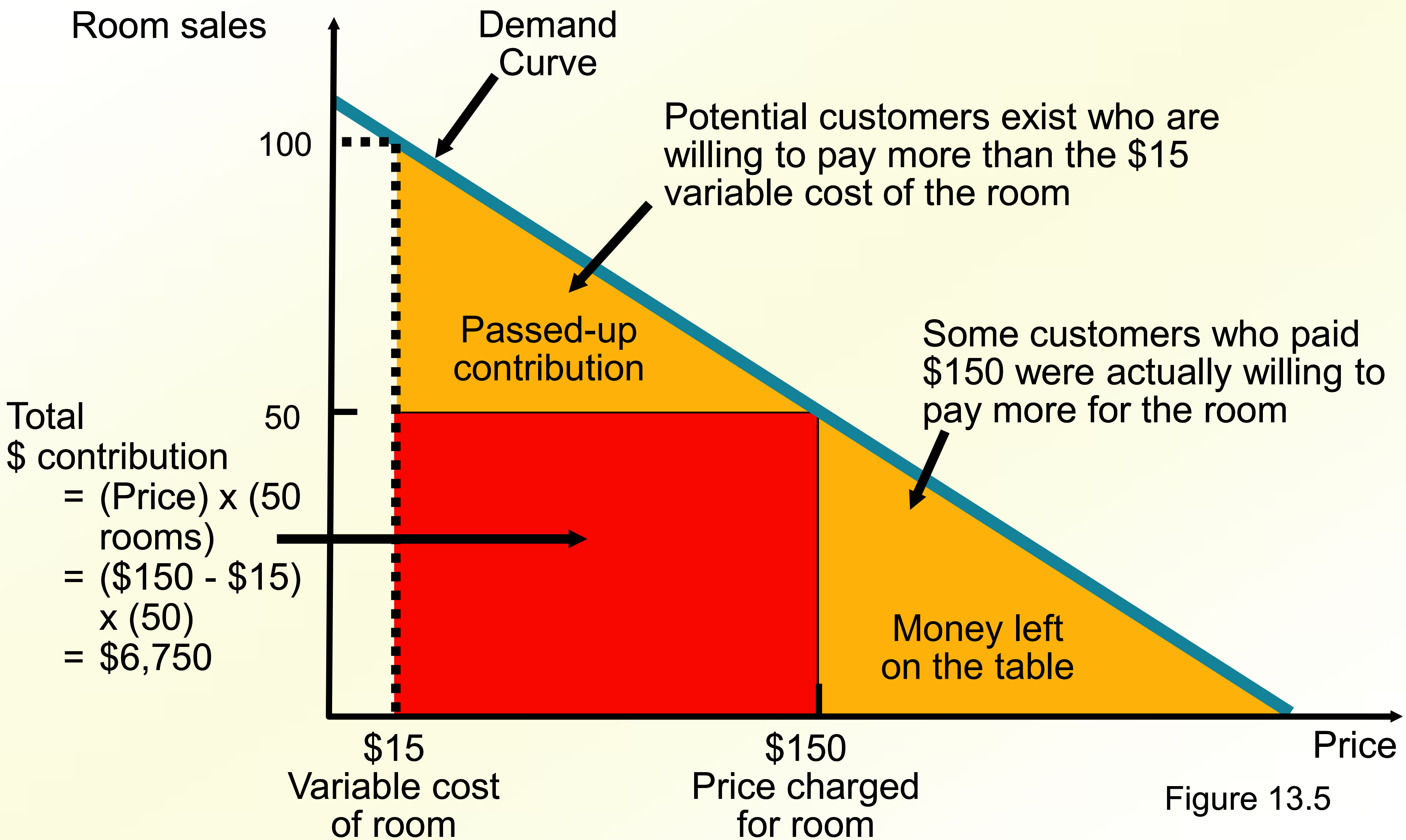
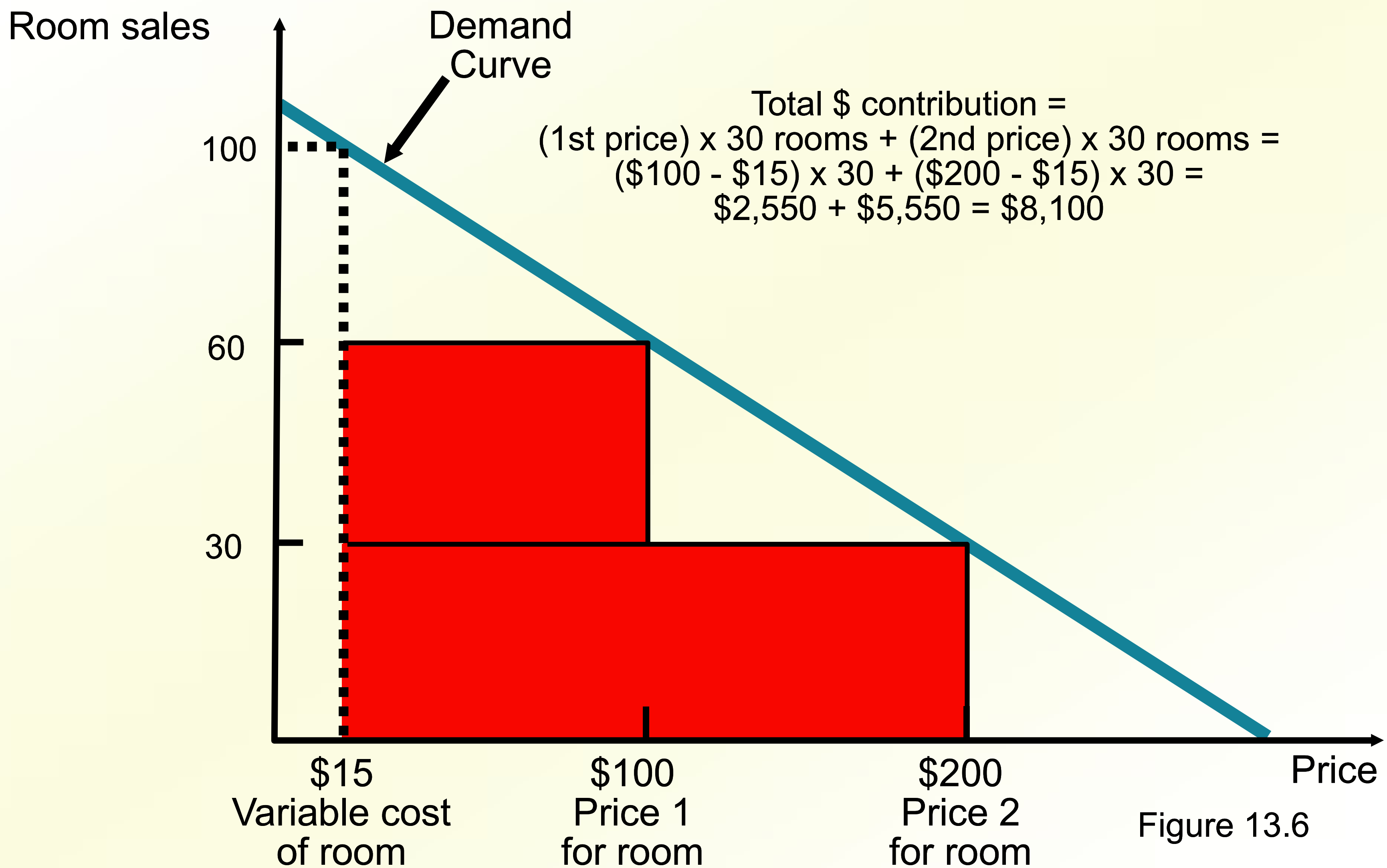


Figure 13.5

Yield Management Example



Total $ contribution =
(1st price) x 30 rooms + (2nd price) x 30 rooms =
($100 - $15) x 30 + ($200 - $15) x 30 =
$2,550 + $5,550 = $8,100

Figure 13.6

Yield Management Matrix

		Price	
		Tend to be fixed	Tend to be variable
Duration of use	Predictable	Quadrant 1: Movies Stadiums/arenas Convention centers Hotel meeting space	Quadrant 2: Hotels Airlines Rental cars Cruise lines
	Unpredictable	Quadrant 3: Restaurants Golf courses Internet service providers	Quadrant 4: Continuing care hospitals

Figure 13.7

Making Yield Management Work

1. Multiple pricing structures must be feasible and appear logical to the customer
2. Forecasts of the use and duration of use
3. Changes in demand

CHAPTER
3

Capacity Planning For Products and Services

McGraw-Hill/Irwin

Operations Management, Eighth Edition, by William J. Stevenson

Capacity Planning

- Capacity is the upper limit or ceiling on the load that an operating unit can handle.
- The basic questions in capacity handling are:
  - What kind of capacity is needed?
  - How much is needed?
  - When is it needed?

Importance of Capacity Decisions

1. Impacts ability to meet future demands
2. Affects operating costs
3. Major determinant of initial costs
4. Involves long-term commitment
5. Affects competitiveness
6. Affects ease of management
7. Globalization adds complexity
8. Impacts long range planning

Capacity

- Design capacity
  - maximum output rate or service capacity an operation, process, or facility is designed for
- Effective capacity
  - Design capacity minus allowances such as personal time, maintenance, and scrap
- Actual output
  - rate of output actually achieved--cannot exceed effective capacity.

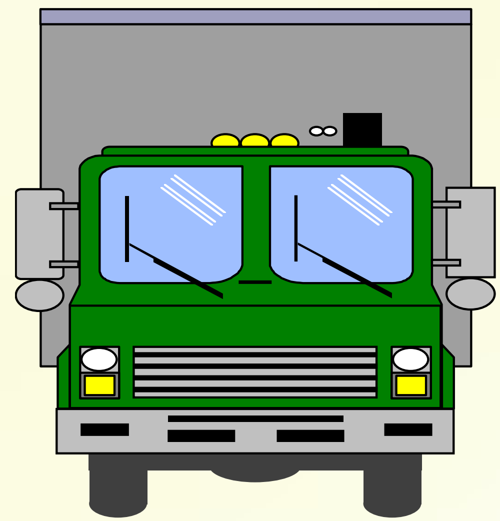
Efficiency and Utilization

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}}$$

$$\text{Utilization} = \frac{\text{Actual output}}{\text{Design capacity}}$$

Both measures expressed as percentages

Efficiency/Utilization Example



Design capacity = 50 trucks/day

Effective capacity = 40 trucks/day

Actual output = 36 units/day

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}} = \frac{36 \text{ units/day}}{40 \text{ units/ day}} = 90\%$$

$$\text{Utilization} = \frac{\text{Actual output}}{\text{Design capacity}} = \frac{36 \text{ units/day}}{50 \text{ units/day}} = 72\%$$

Determinants of Effective Capacity

- Facilities
- Product and service factors
- Process factors
- Human factors
- Operational factors
- Supply chain factors
- External factors

Strategy Formulation

- Capacity strategy for long-term demand
- Demand patterns
- Growth rate and variability
- Facilities
  - Cost of building and operating
- Technological changes
  - Rate and direction of technology changes
- Behavior of competitors
- Availability of capital and other inputs

Key Decisions of Capacity Planning

1. Amount of capacity needed
2. Timing of changes
3. Need to maintain balance
4. Extent of flexibility of facilities

Capacity cushion – extra demand intended to offset uncertainty

Steps for Capacity Planning

1. Estimate future capacity requirements
2. Evaluate existing capacity
3. Identify alternatives
4. Conduct financial analysis
5. Assess key qualitative issues
6. Select one alternative
7. Implement alternative chosen
8. Monitor results

Make or Buy

1. Available capacity
2. Expertise
3. Quality considerations
4. Nature of demand
5. Cost
6. Risk

Developing Capacity Alternatives

1. Design flexibility into systems
2. Take stage of life cycle into account
3. Take a "big picture" approach to capacity changes
4. Prepare to deal with capacity "chunks"
5. Attempt to smooth out capacity requirements
6. Identify the optimal operating level

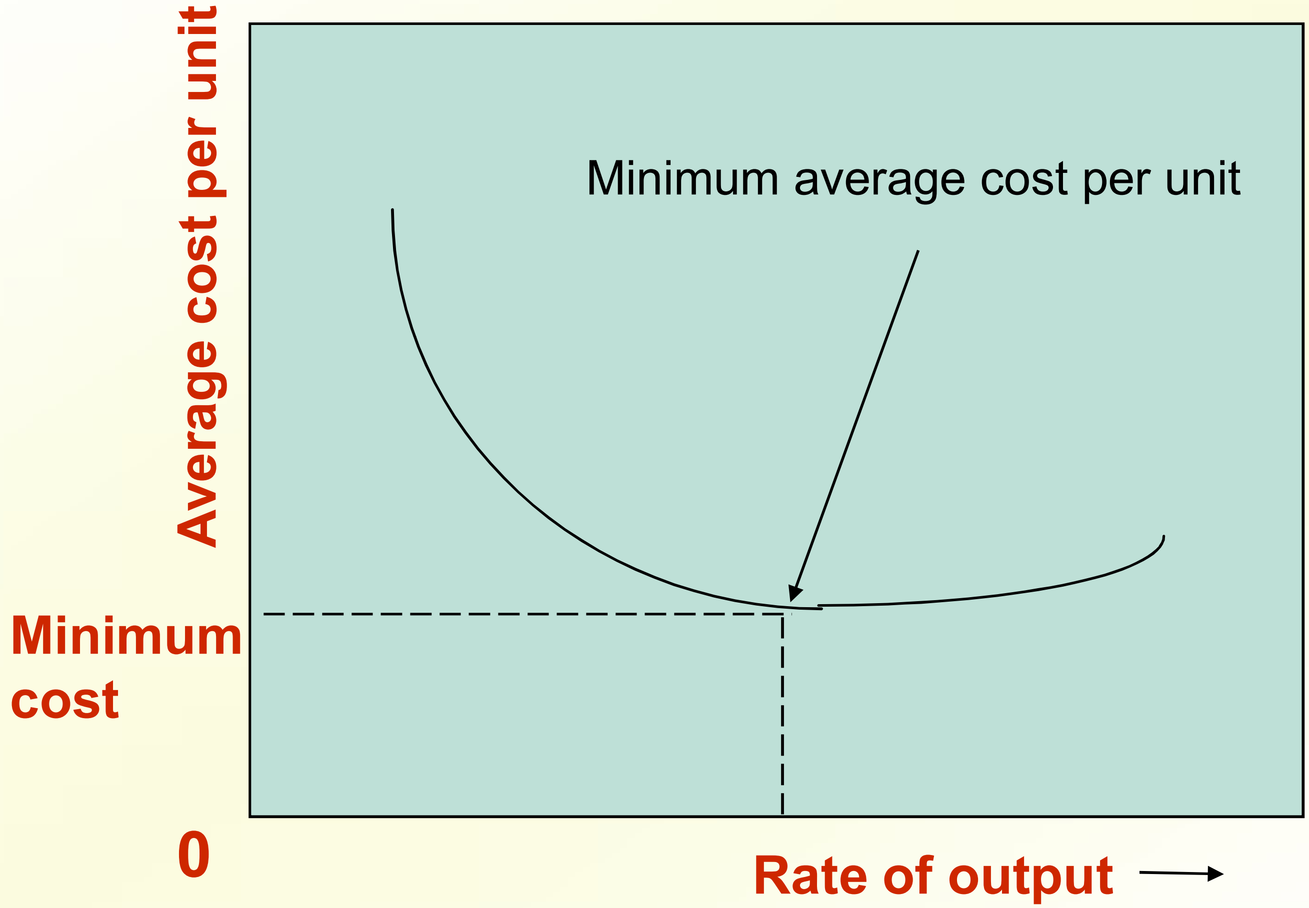
Economies of Scale

- Economies of scale
  - If the output rate is less than the optimal level, increasing output rate results in decreasing average unit costs
- Diseconomies of scale
  - If the output rate is more than the optimal level, increasing the output rate results in increasing average unit costs

Evaluating Alternatives

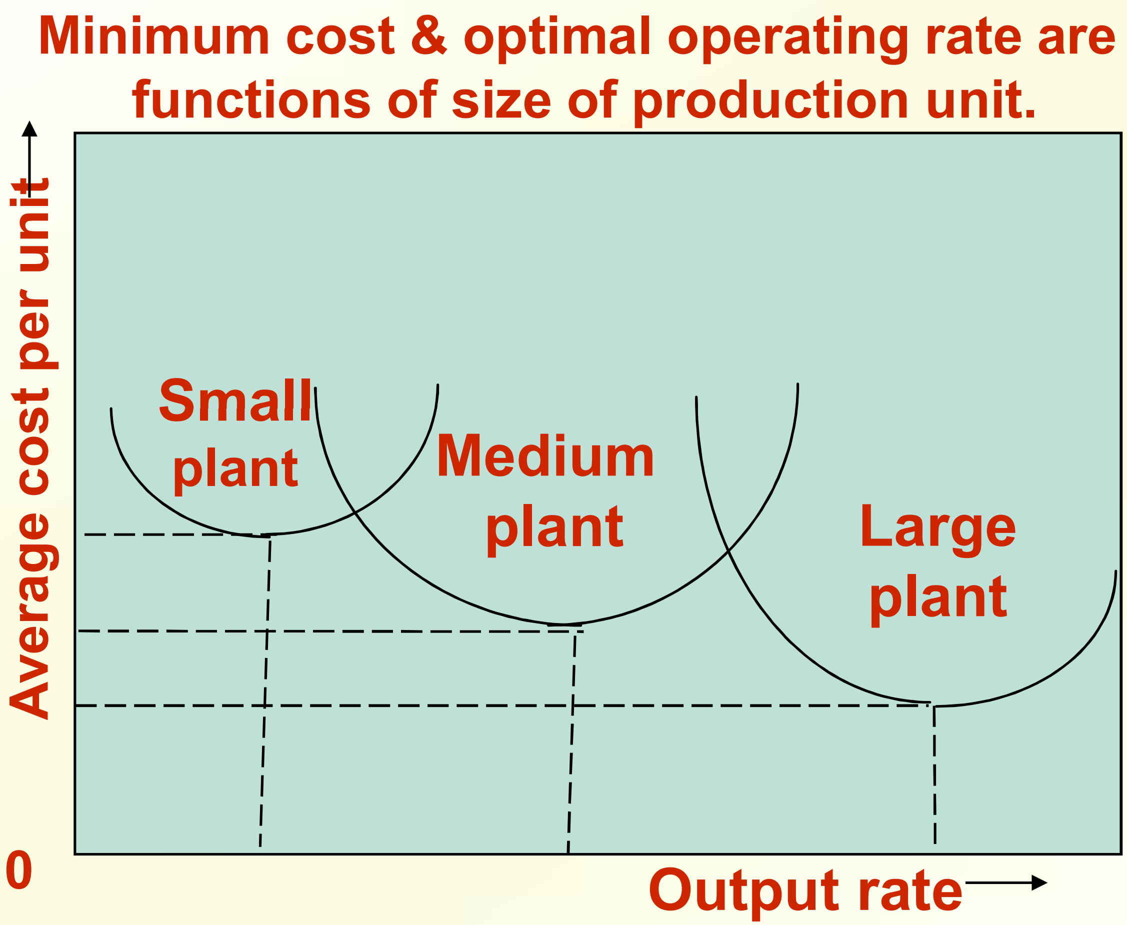
Figure 5.3

Production units have an optimal rate of output for minimal cost.



Evaluating Alternatives

Figure 5.4

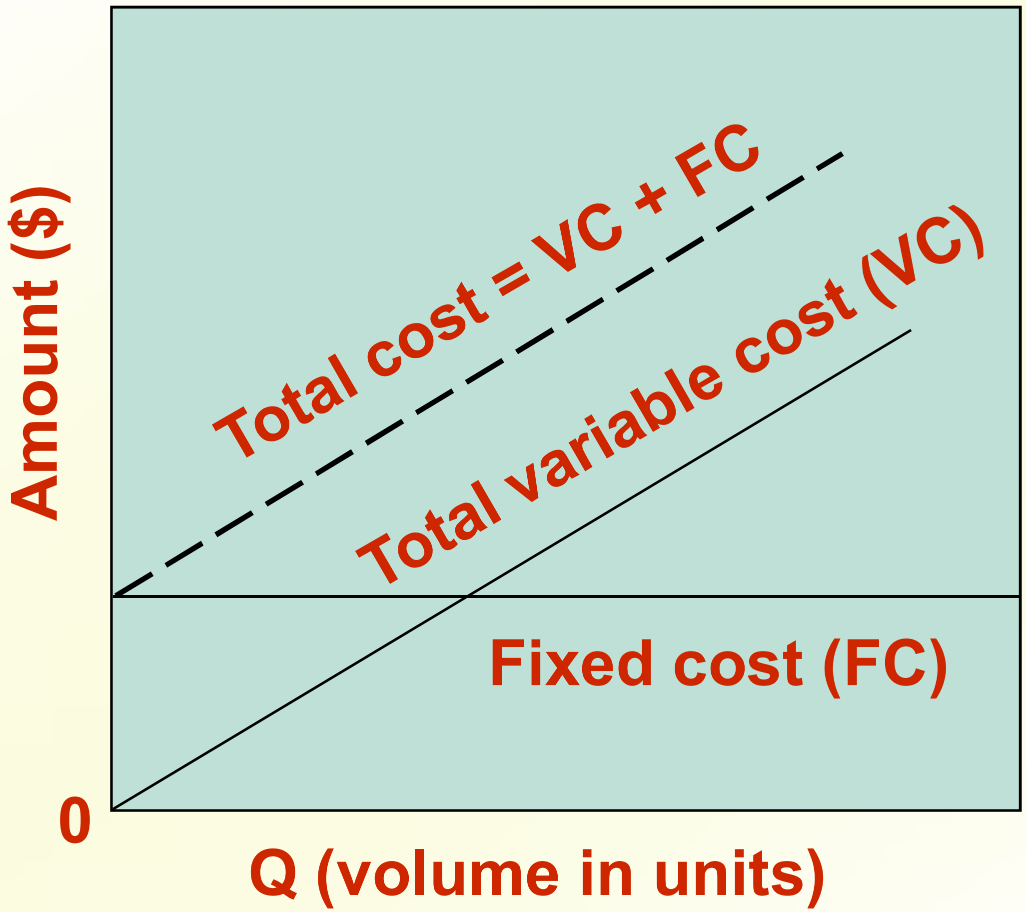


Planning Service Capacity

- Need to be near customers
  - Capacity and location are closely tied
- Inability to store services
  - Capacity must be matched with timing of demand
- Degree of volatility of demand
  - Peak demand periods

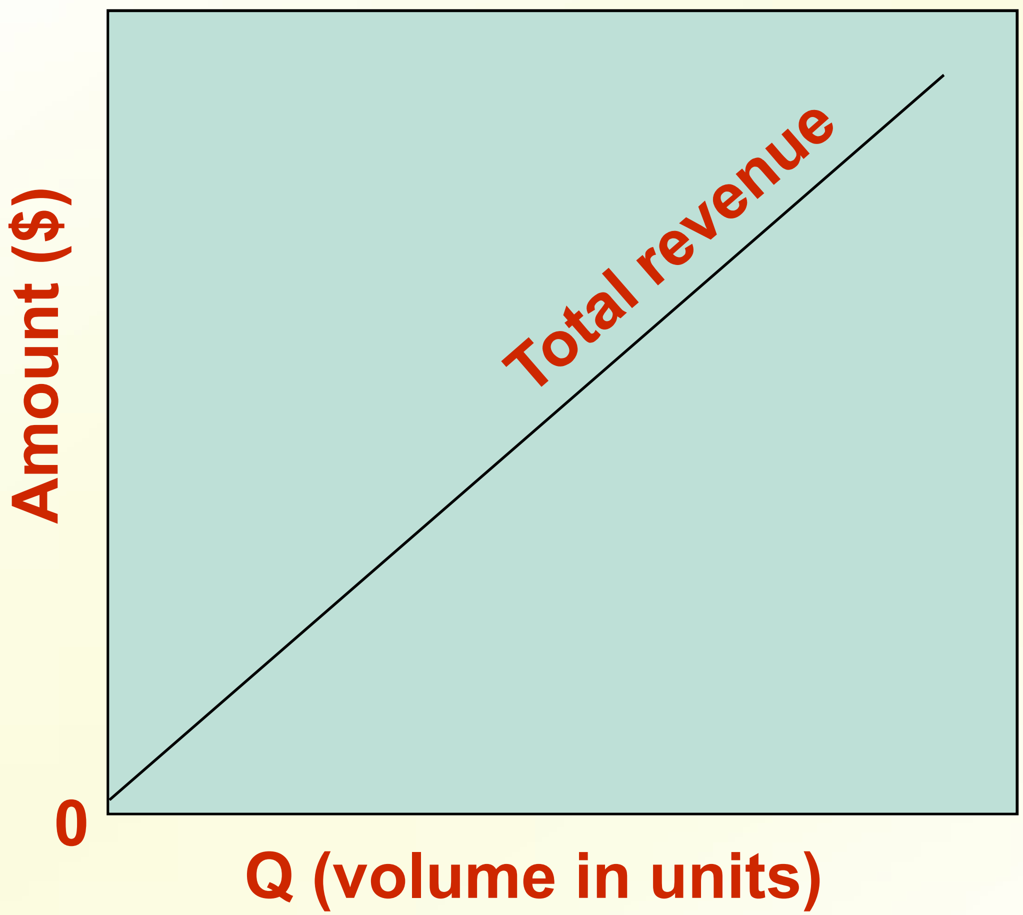
Cost-Volume Relationships

Figure 5.5a



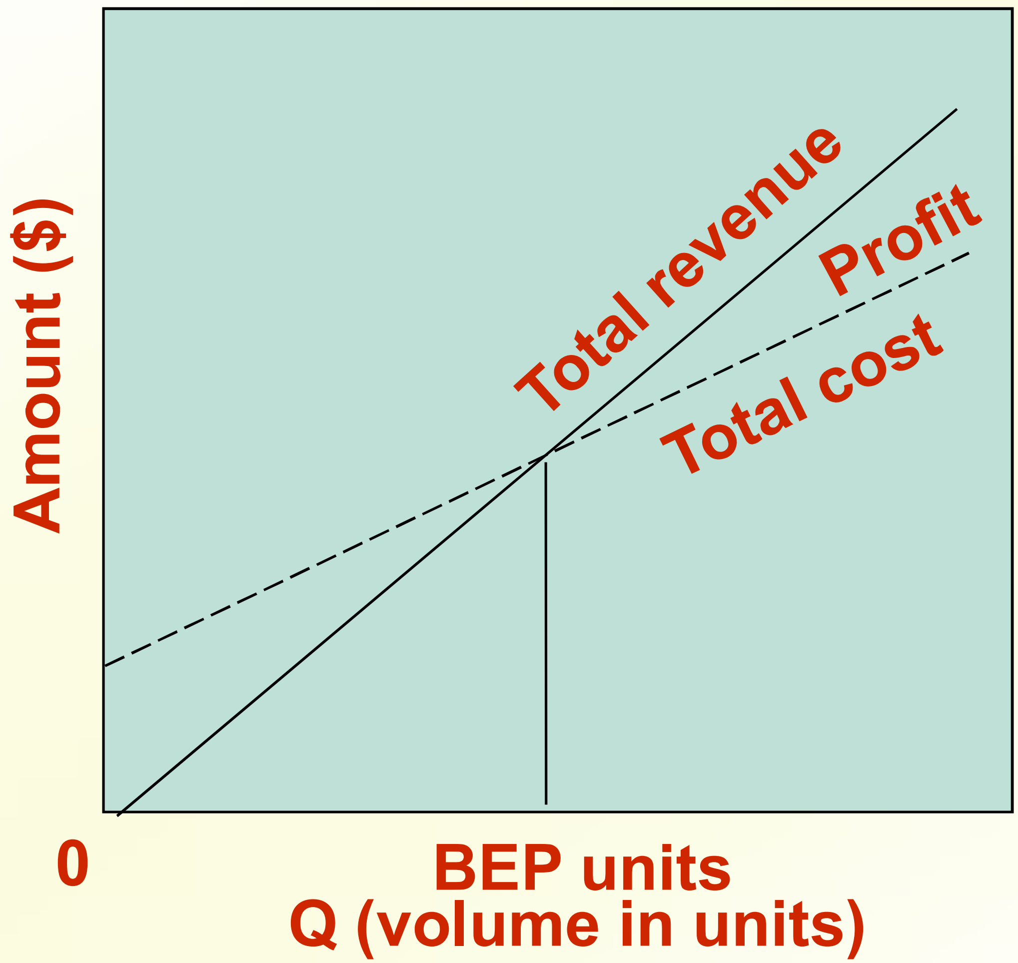
Cost-Volume Relationships

Figure 5.5b



Cost-Volume Relationships

Figure 5.5c



Assumptions of Cost-Volume Analysis

1. One product is involved
2. Everything produced can be sold
3. Variable cost per unit is the same regardless of volume
4. Fixed costs do not change with volume
5. Revenue per unit constant with volume
6. Revenue per unit exceeds variable cost per unit

Financial Analysis

- Cash Flow - the difference between cash received from sales and other sources, and cash outflow for labor, material, overhead, and taxes.
- Present Value - the sum, in current value, of all future cash flows of an investment proposal.

Calculating Processing Requirements

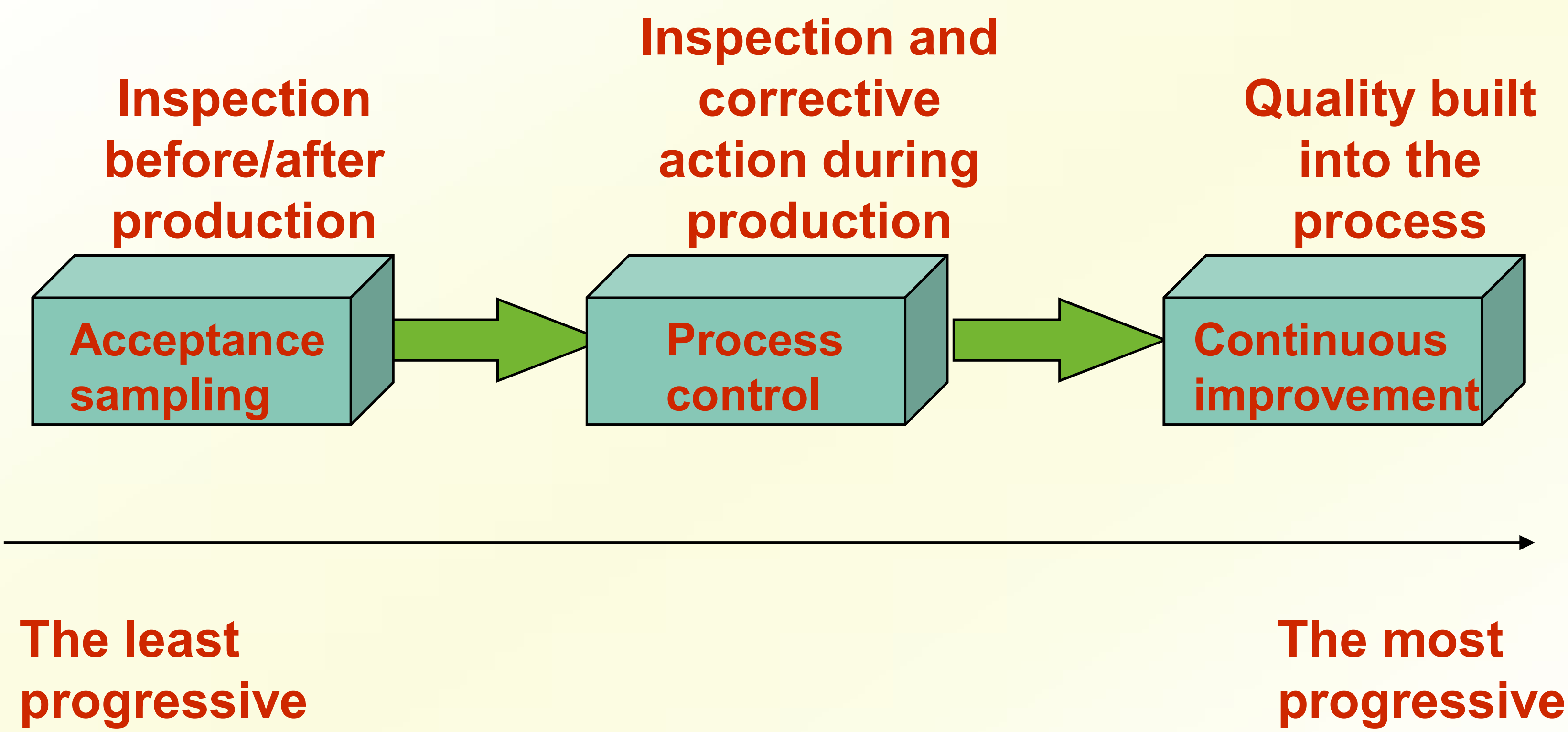
Product	Annual Demand	Standard processing time per unit (hr.)	Processing time needed (hr.)
#1	400	5.0	2,000
#2	300	8.0	2,400
#3	700	2.0	1,400
			5,800

CHAPTER 4

Quality Control

Phases of Quality Assurance

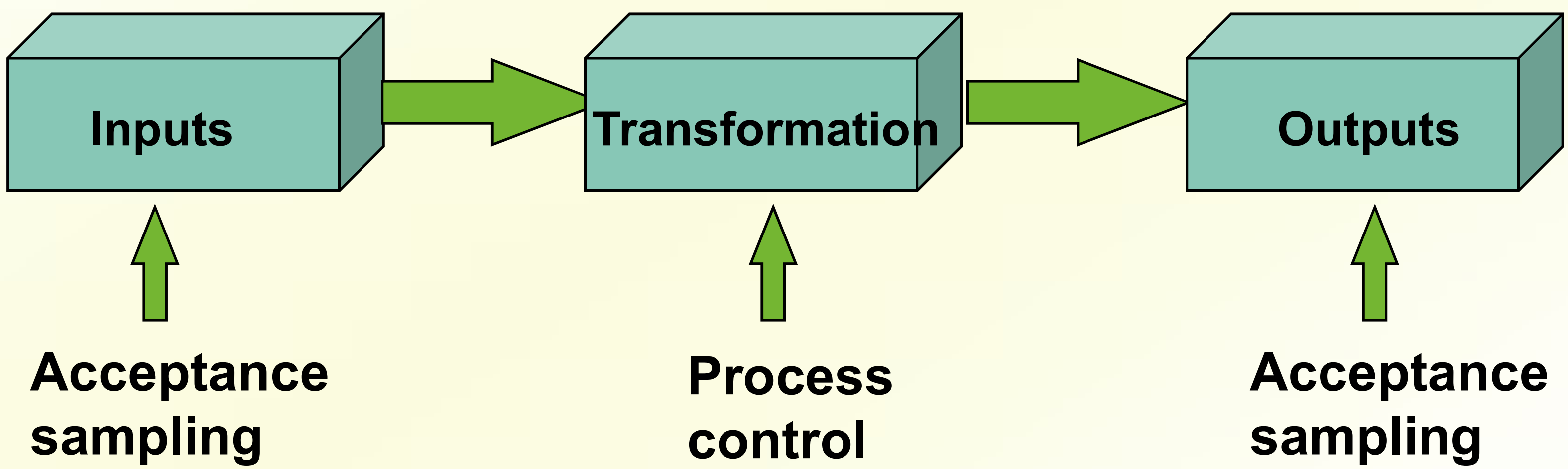
Figure 10.1



Inspection

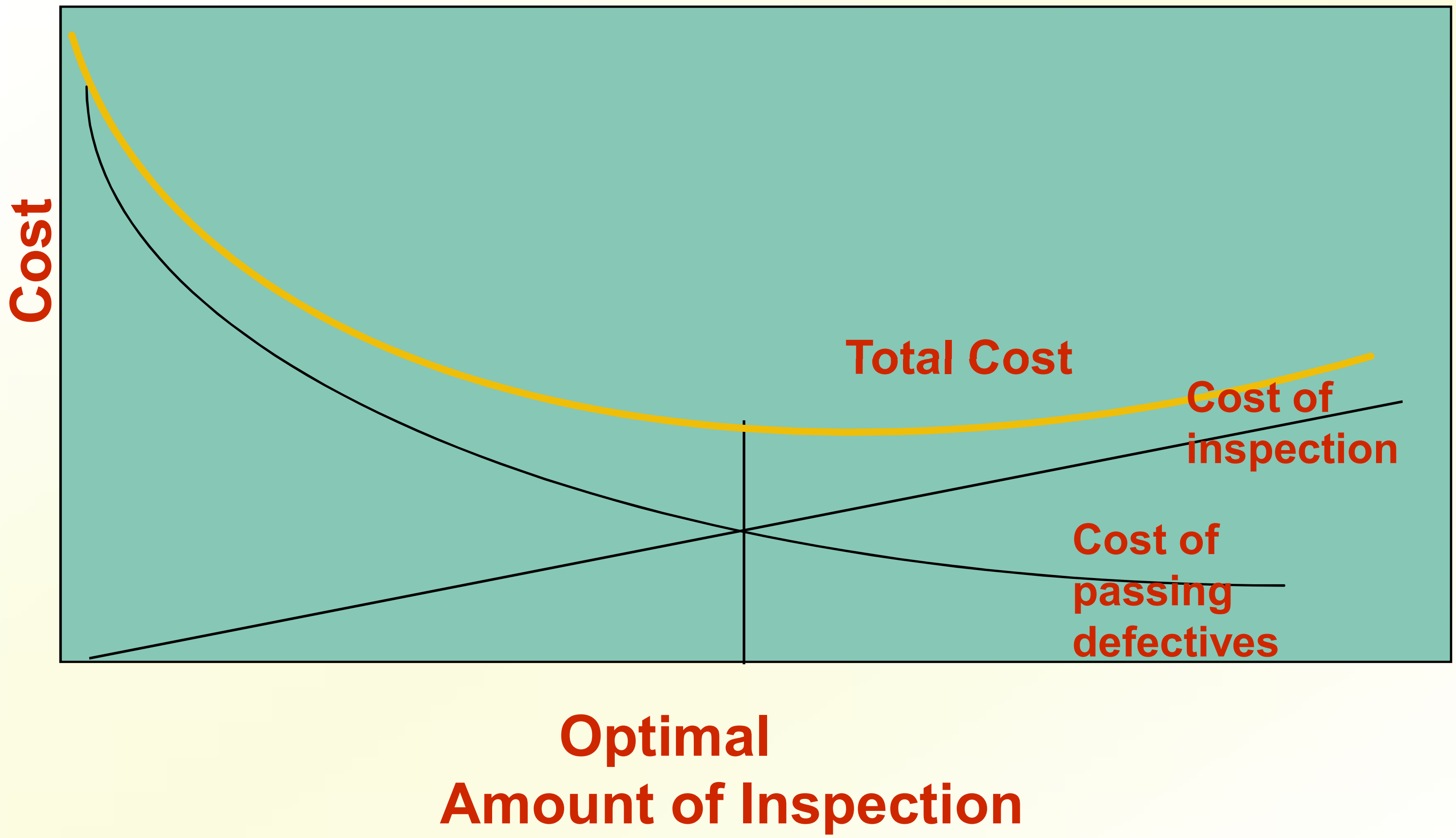
Figure 10.2

- How Much/How Often
- Where/When
- Centralized vs. On-site



Inspection Costs

Figure 10.3



Where to Inspect in the Process

- Raw materials and purchased parts
- Finished products
- Before a costly operation
- Before an irreversible process
- Before a covering process

Examples of Inspection Points

Table 10.1

Type of business	Inspection points	Characteristics
Fast Food	Cashier	Accuracy
	Counter area	Appearance, productivity
	Eating area	Cleanliness
	Building	Appearance
	Kitchen	Health regulations
Hotel/motel	Parking lot	Safe, well lighted
	Accounting	Accuracy, timeliness
	Building	Appearance, safety
	Main desk	Waiting times
Supermarket	Cashiers	Accuracy, courtesy
	Deliveries	Quality, quantity

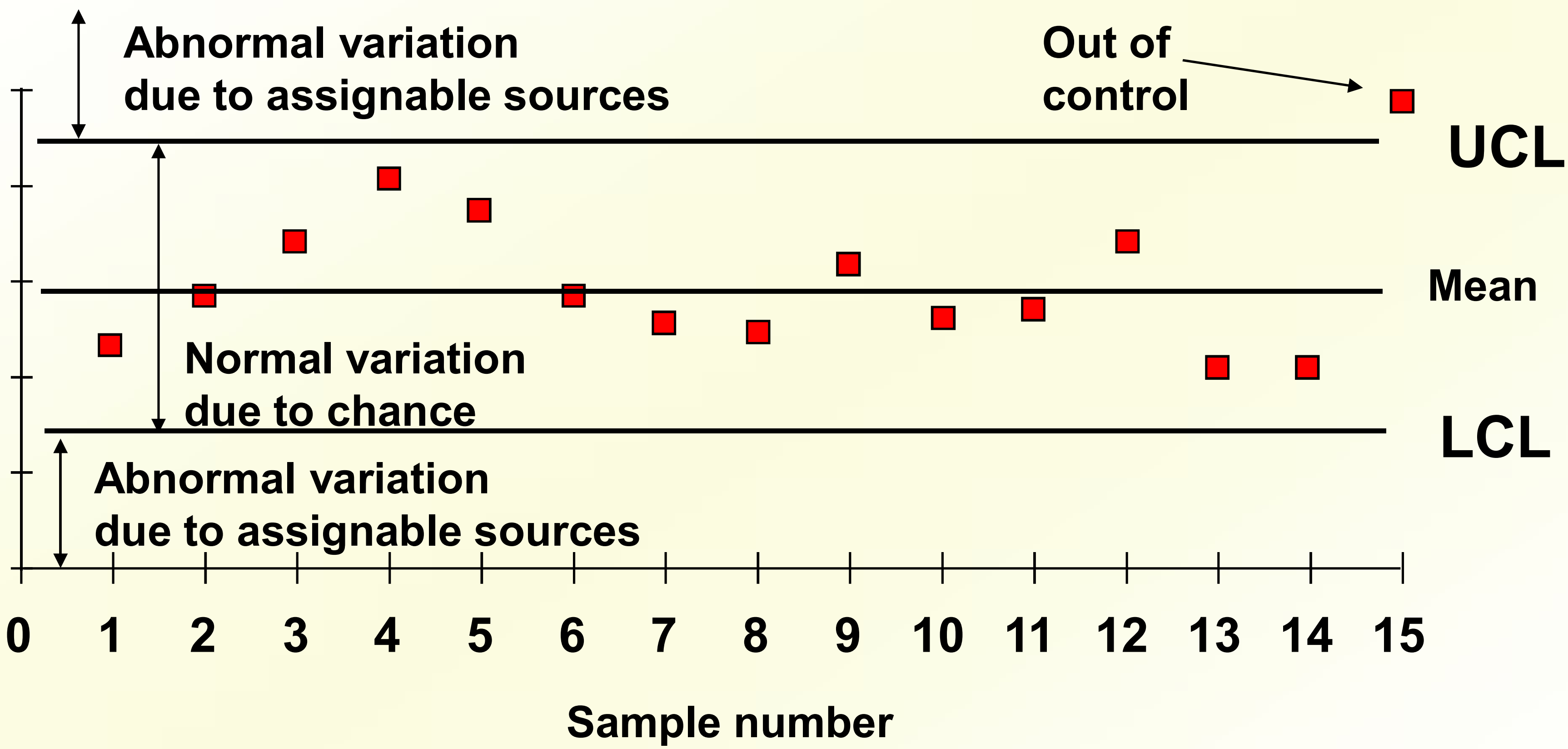
- *Statistical Process Control*:
  Statistical evaluation of the output of a process during production
- *Quality of Conformance:*
  A product or service conforms to specifications

Control Chart

- Control Chart
  - *Purpose:* to monitor process output to see if it is random
  - A time ordered plot representative sample statistics obtained from an on going process (e.g. sample means)
  - Upper and lower control limits define the range of acceptable variation

Control Chart

Figure 10.4



Statistical Process Control

- The essence of statistical process control is to assure that the output of a process is random so that *future output* will be random.

Statistical Process Control

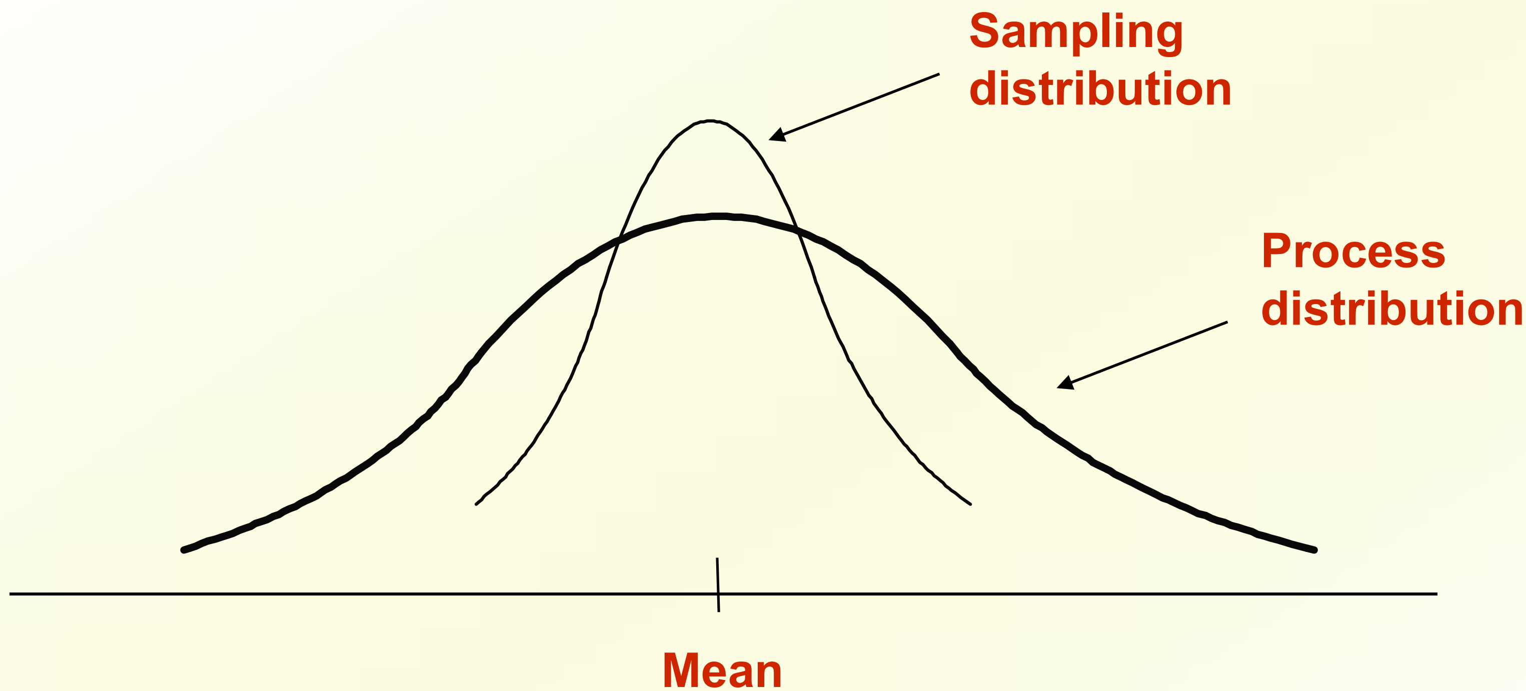
- The Control Process
  - Define
  - Measure
  - Compare
  - Evaluate
  - Correct
  - Monitor results

Statistical Process Control

- Variations and Control
  - *Random variation*: Natural variations in the output of a process, created by countless minor factors
  - *Assignable variation*: A variation whose source can be identified

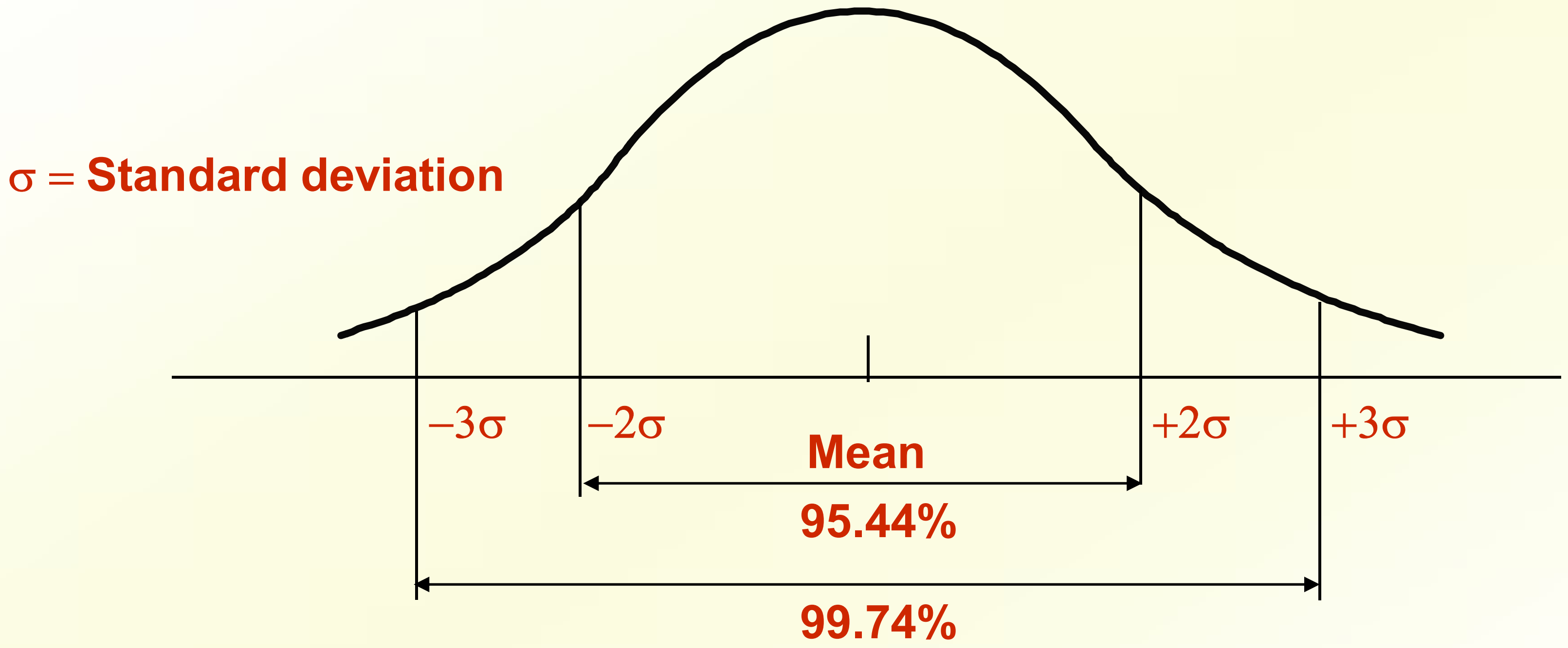
Sampling Distribution

Figure 10.5



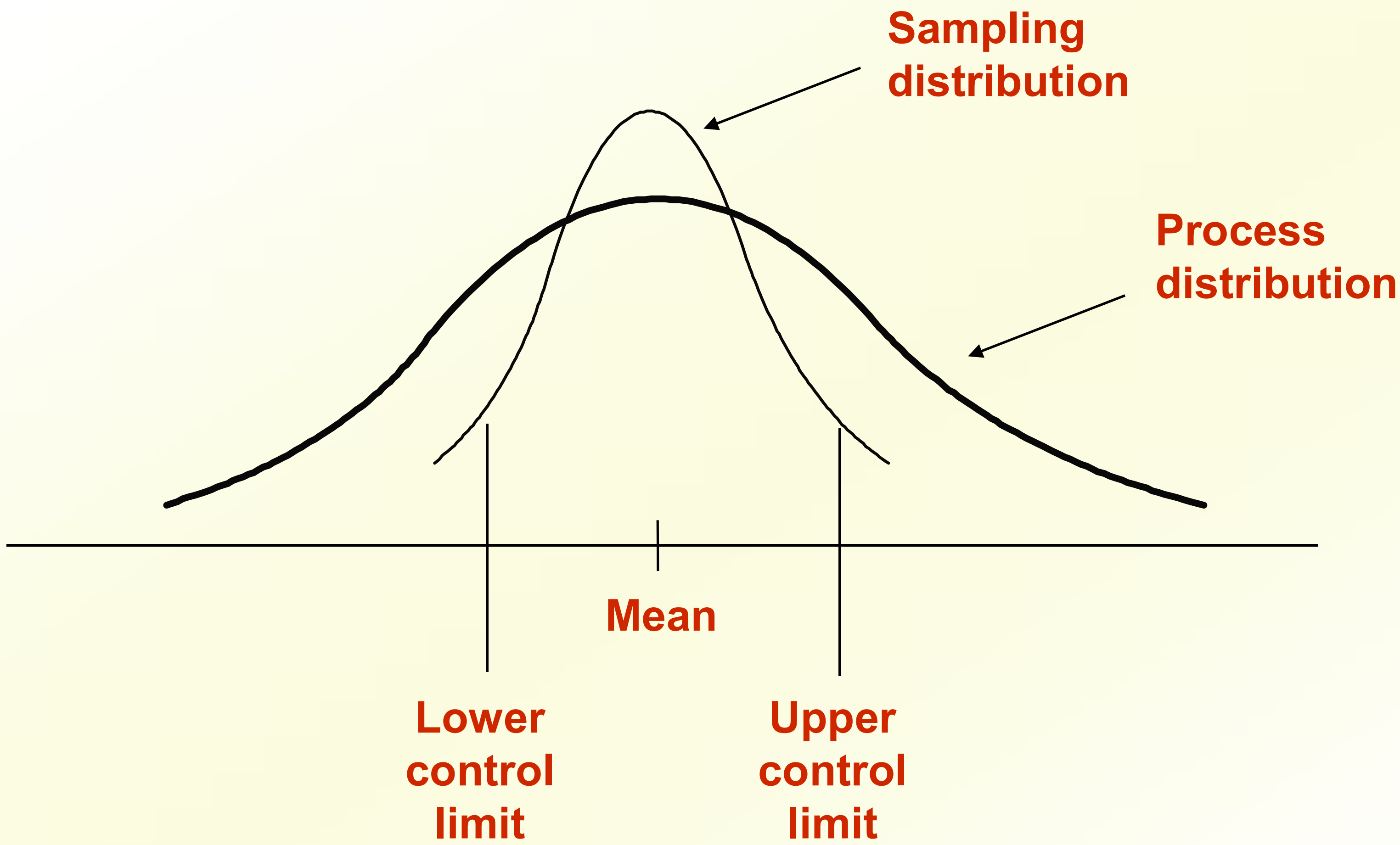
Normal Distribution

Figure 10.6



Control Limits

Figure 10.7



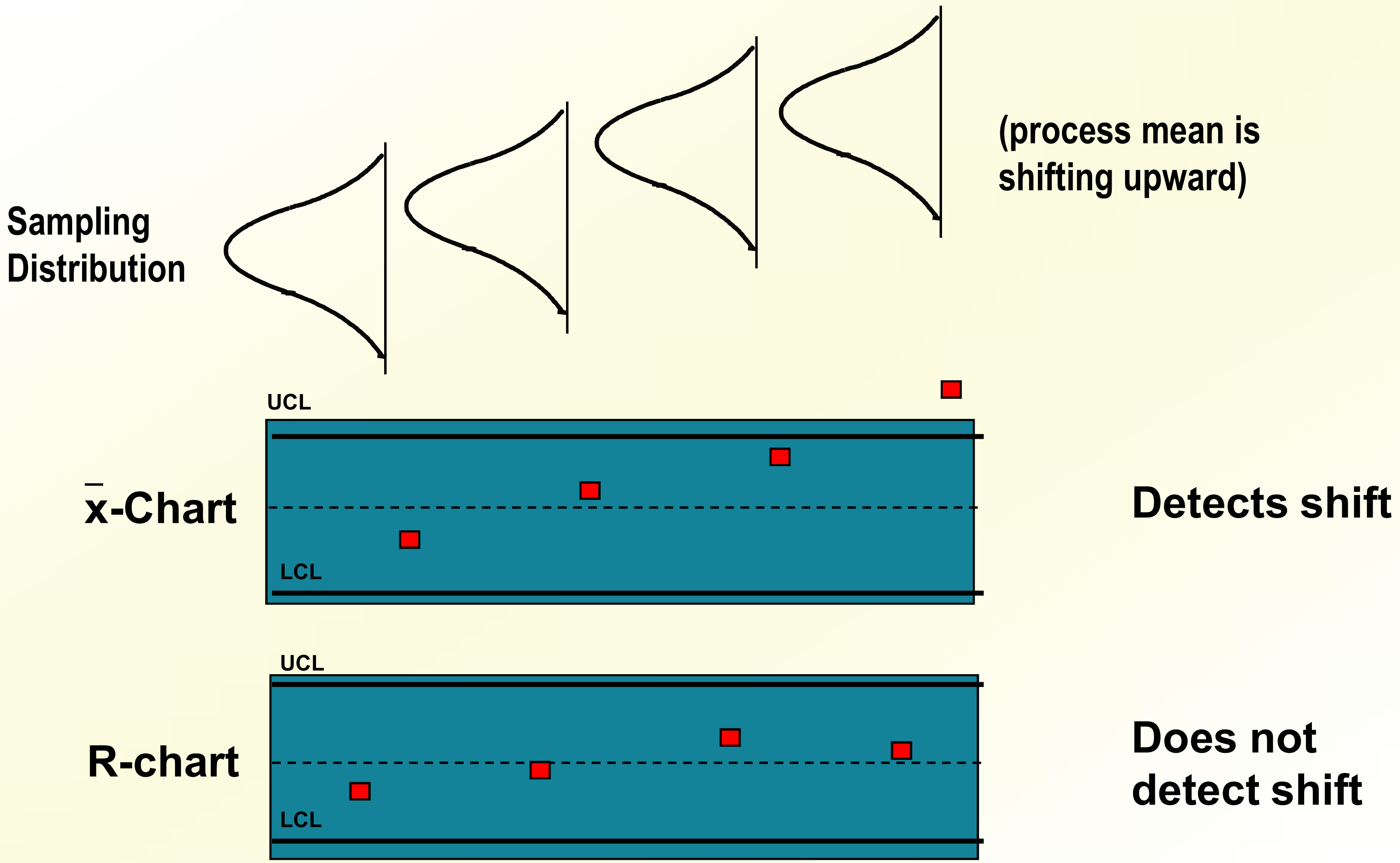
Control Charts for Variables

Variables generate data that are *measured*.

- Mean control charts
  - Used to monitor the central tendency of a process.
  - X bar charts
- Range control charts
  - Used to monitor the process dispersion
  - R charts

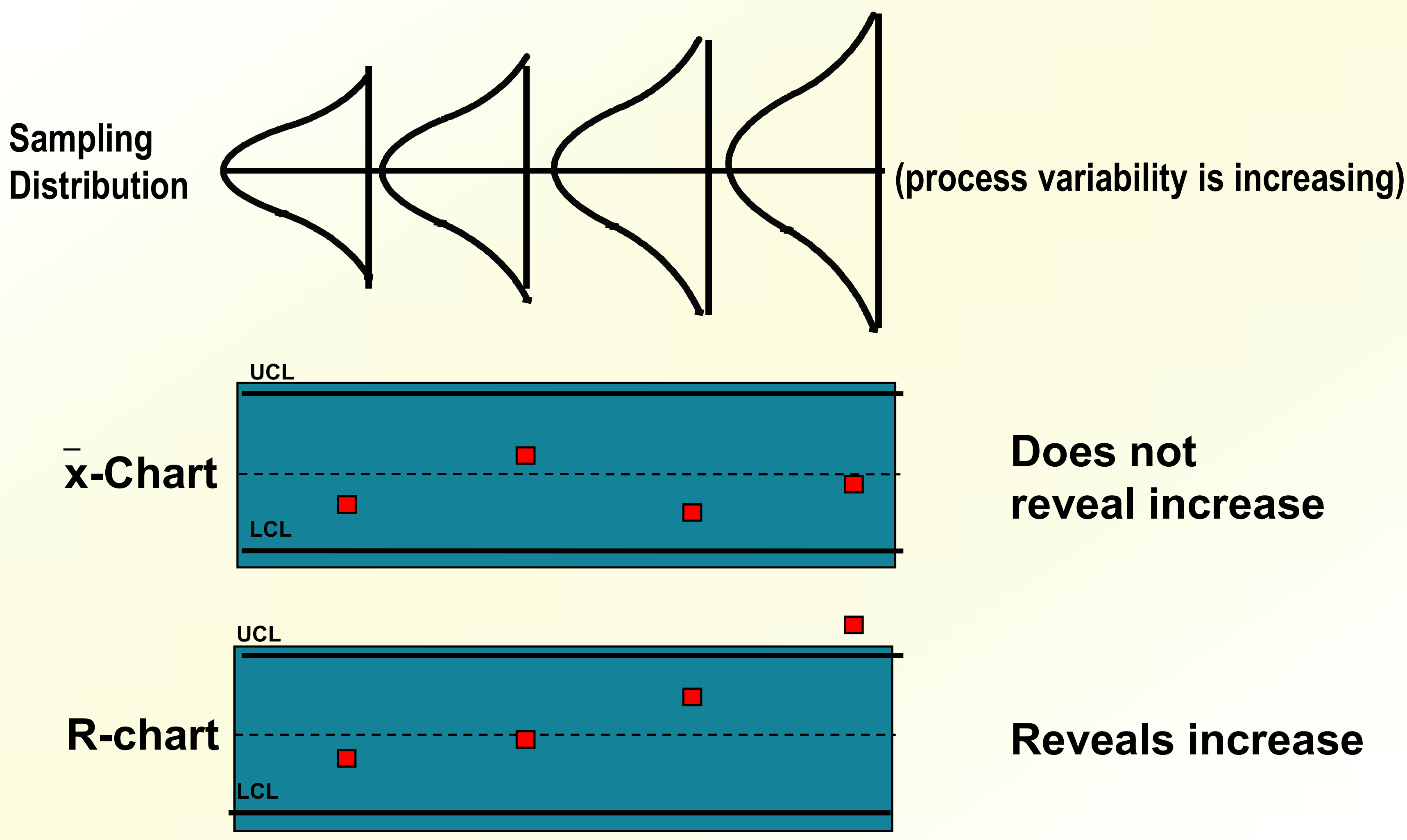
Mean and Range Charts

Figure 10.10A



Mean and Range Charts

Figure 10.10B



Control Chart for Attributes

- p-Chart - Control chart used to monitor the proportion of defectives in a process
- c-Chart - Control chart used to monitor the number of defects per unit

Attributes generate data that are *counted*.

Use of p-Charts

Table 10.3

- When observations can be placed into two categories.
  - Good or bad
  - Pass or fail
  - Operate or don't operate
- When the data consists of multiple samples of several observations each

Use of c-Charts

Table 10.3

- Use only when the number of occurrences per unit of measure can be counted; non-occurrences cannot be counted.
  - Scratches, chips, dents, or errors per item
  - Cracks or faults per unit of distance
  - Breaks or Tears per unit of area
  - Bacteria or pollutants per unit of volume
  - Calls, complaints, failures per unit of time

Use of Control Charts

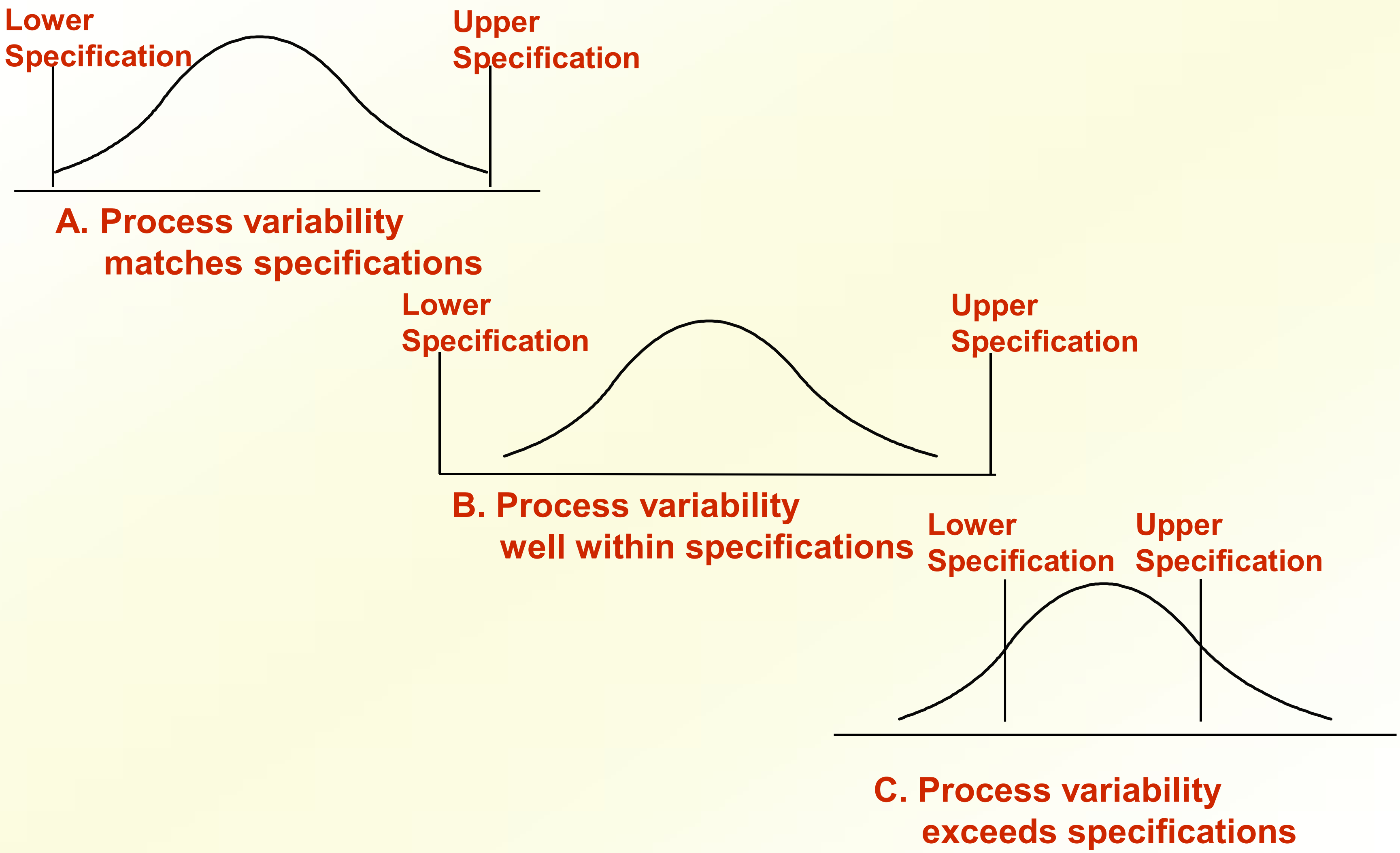
- At what point in the process to use control charts
- What size samples to take
- What type of control chart to use
  - Variables
  - Attributes

Process Capability

- Tolerances or specifications
  - Range of acceptable values established by engineering design or customer requirements
- Process variability
  - Natural variability in a process
- Process capability
  - Process variability relative to specification

Process Capability

Figure 10.15

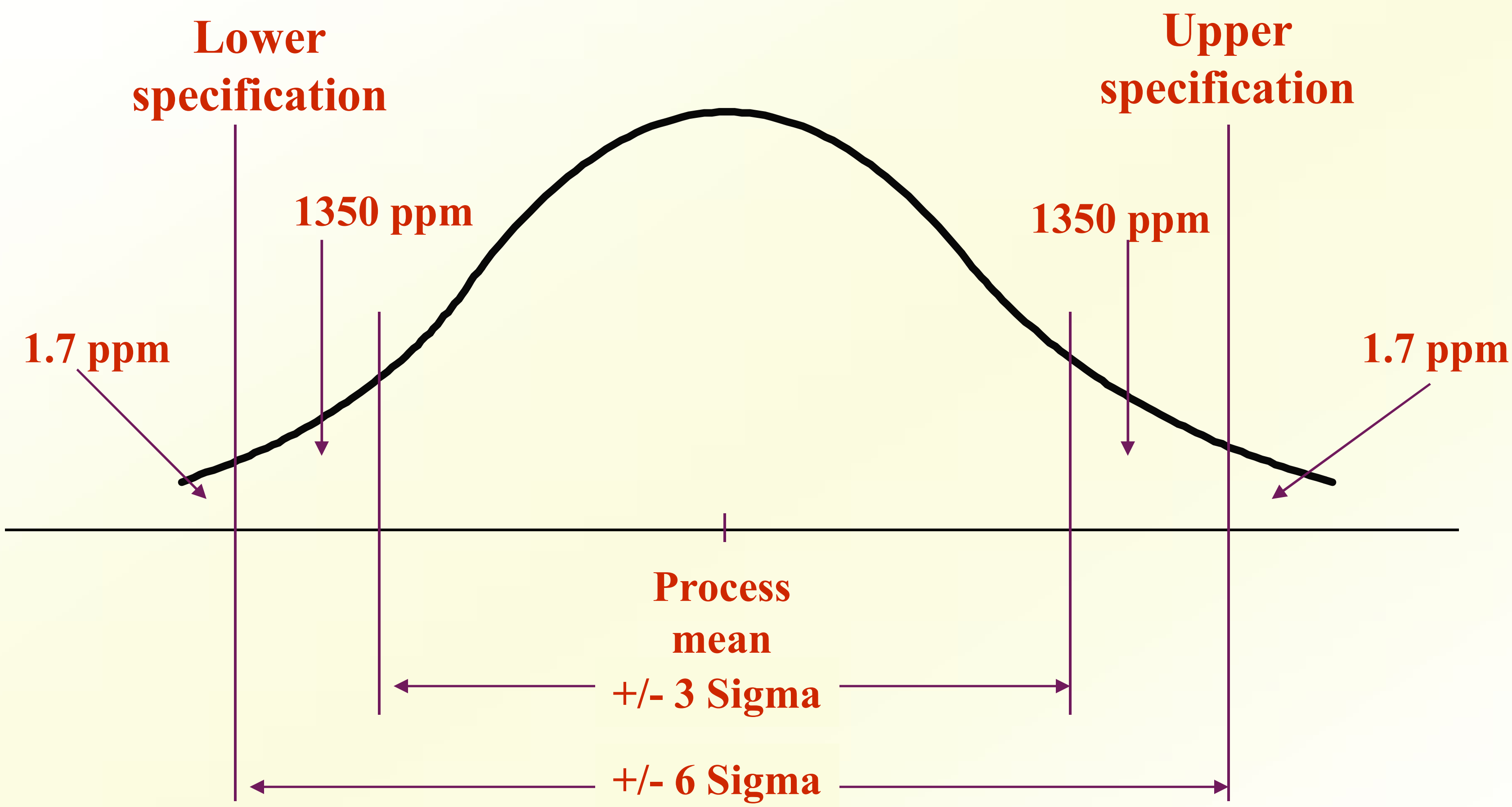


Process Capability Ratio

$$\text{Process capability ratio, Cp} = \frac{\text{specification width}}{\text{process width}}$$

$$\text{Cp} = \frac{\text{Upper specification} - \text{lower specification}}{6\sigma}$$

3 Sigma and 6 Sigma Quality



Improving Process Capability

- Simplify
- Standardize
- Mistake-proof
- Upgrade equipment
- Automate

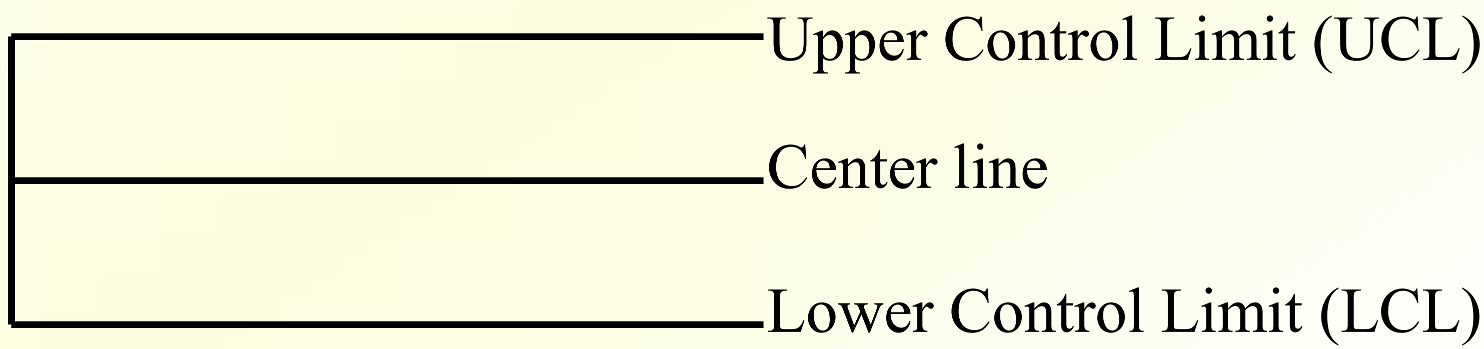
Limitations of Capability Indexes

1. Process may not be stable
2. Process output may not be normally distributed
3. Process not centered but C_p is used

Additional PowerPoint slides contributed by
Geoff Willis,
University of Central Oklahoma.

Control Charts in General

- Are named according to the statistics being plotted, i.e., X bar, R, p, and c
- Have a center line that is the overall average
- Have limits above and below the center line at ± 3 standard deviations (usually)



Variables Data Charts

- Process Centering
  - X bar chart
  - X bar is a sample mean

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

- Process Dispersion (consistency)
  - R chart
  - R is a sample range

$$R = \max(X_i) - \min(X_i)$$

X bar charts

- Center line is the grand mean (X double bar)
- Points are X bars

$$\sigma_{\bar{x}} = \sigma / \sqrt{n}$$

$$\overline{\overline{X}} = \frac{\sum_{j=1}^{m} \overline{X_j}}{m}$$

$$UCL = \overline{\overline{X}} + z\sigma_{\bar{x}} \qquad LCL = \overline{\overline{X}} - z\sigma_{\bar{x}}$$

-OR-

$$UCL = \overline{\overline{X}} + A_2\overline{R} \qquad LCL = \overline{\overline{X}} - A_2\overline{R}$$

R Charts

- Center line is the grand mean (R bar)
- Points are R
- D_3 and D_4 values are tabled according to n (sample size)

$$UCL = D_4 \overline{R}$$

$$LCL = D_3 \overline{R}$$

Use of X bar & R charts

- Charts are always used in tandem
- Data are collected (20-25 samples)
- Sample statistics are computed
- All data are plotted on the 2 charts
- Charts are examined for randomness
- If random, then limits are used “forever”

Attribute Charts

- c charts – used to count defects in a constant sample size

$$UCL = \overline{c} + z\sqrt{\overline{c}}$$

$$\overline{c} = \frac{\sum_{i=1}^{n} c}{m} = centerline$$

$$LCL = \overline{c} - z\sqrt{\overline{c}}$$

Attribute Charts

- p charts – used to track a proportion (fraction) defective

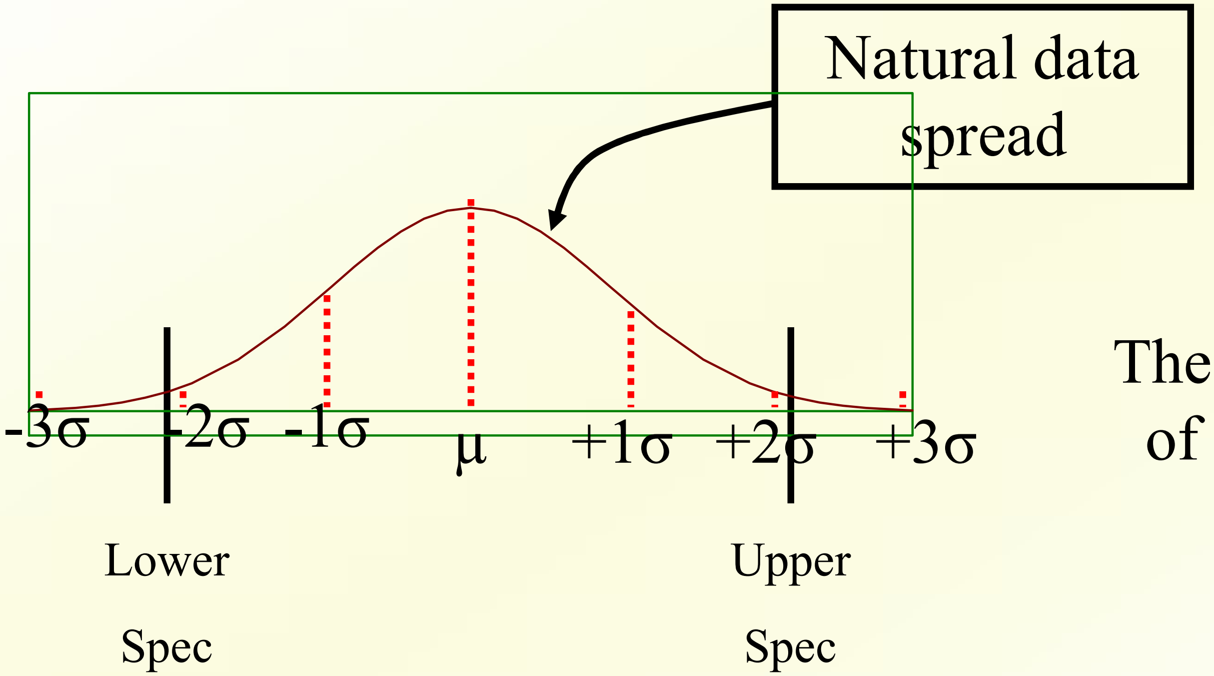
$$p_i = \frac{\sum_{i=1}^{n} x_i}{n}$$

$$\bar{p} = \sum_{j=1}^{m} p \Big/ m = \sum_{ij} x \Big/ nm = centerline$$

$$UCL = \bar{p} + z\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \qquad LCL = \bar{p} - z\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

Process Capability

The ratio of process variability to design specifications



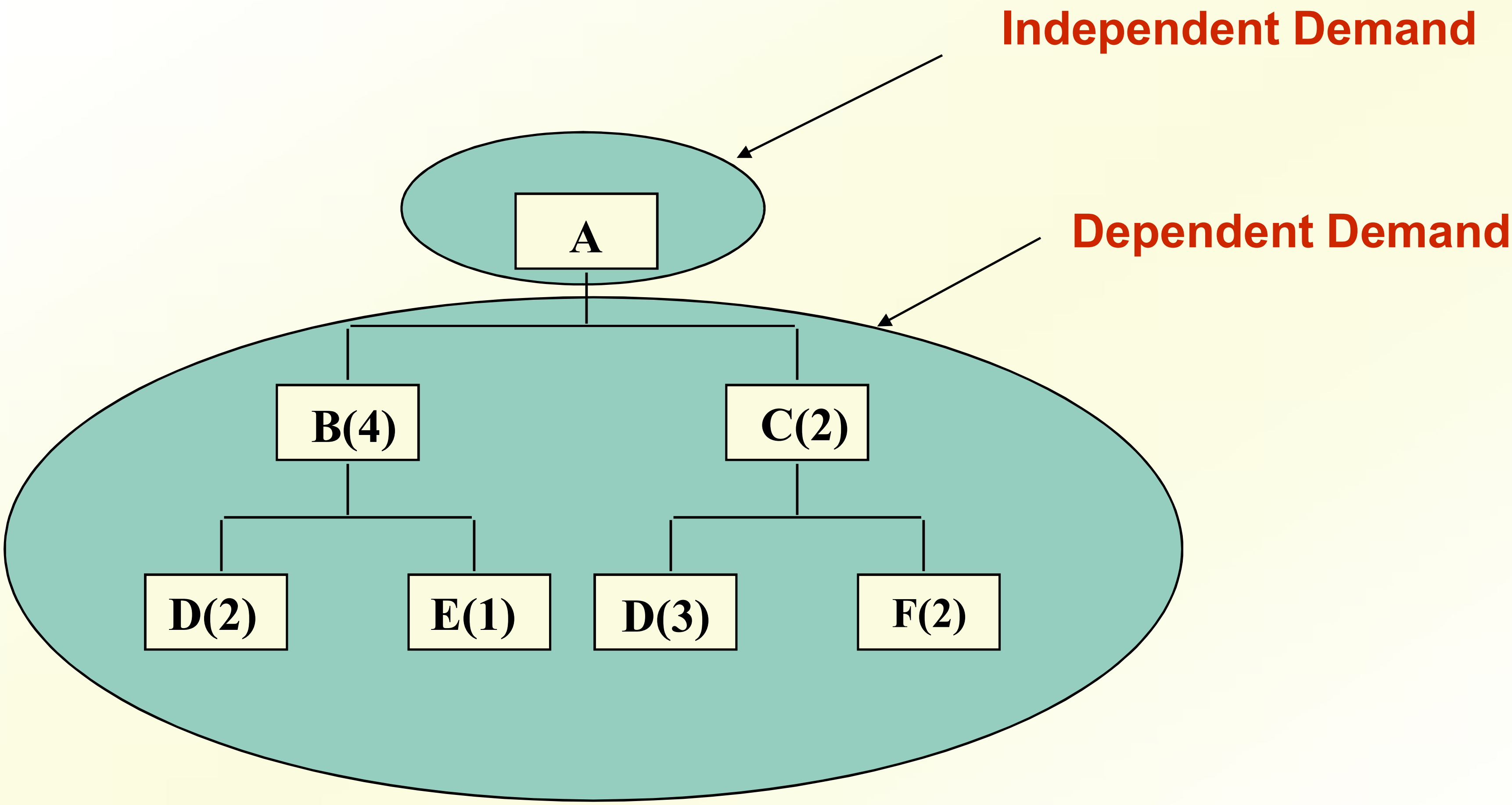
The natural spread of the data is 6σ

Chapter 5
MRP and ERP

MRP

- *<u>Material requirements planning (MRP):</u>* Computer-based information system that translates master schedule requirements for end items into time-phased requirements for subassemblies, components, and raw materials.

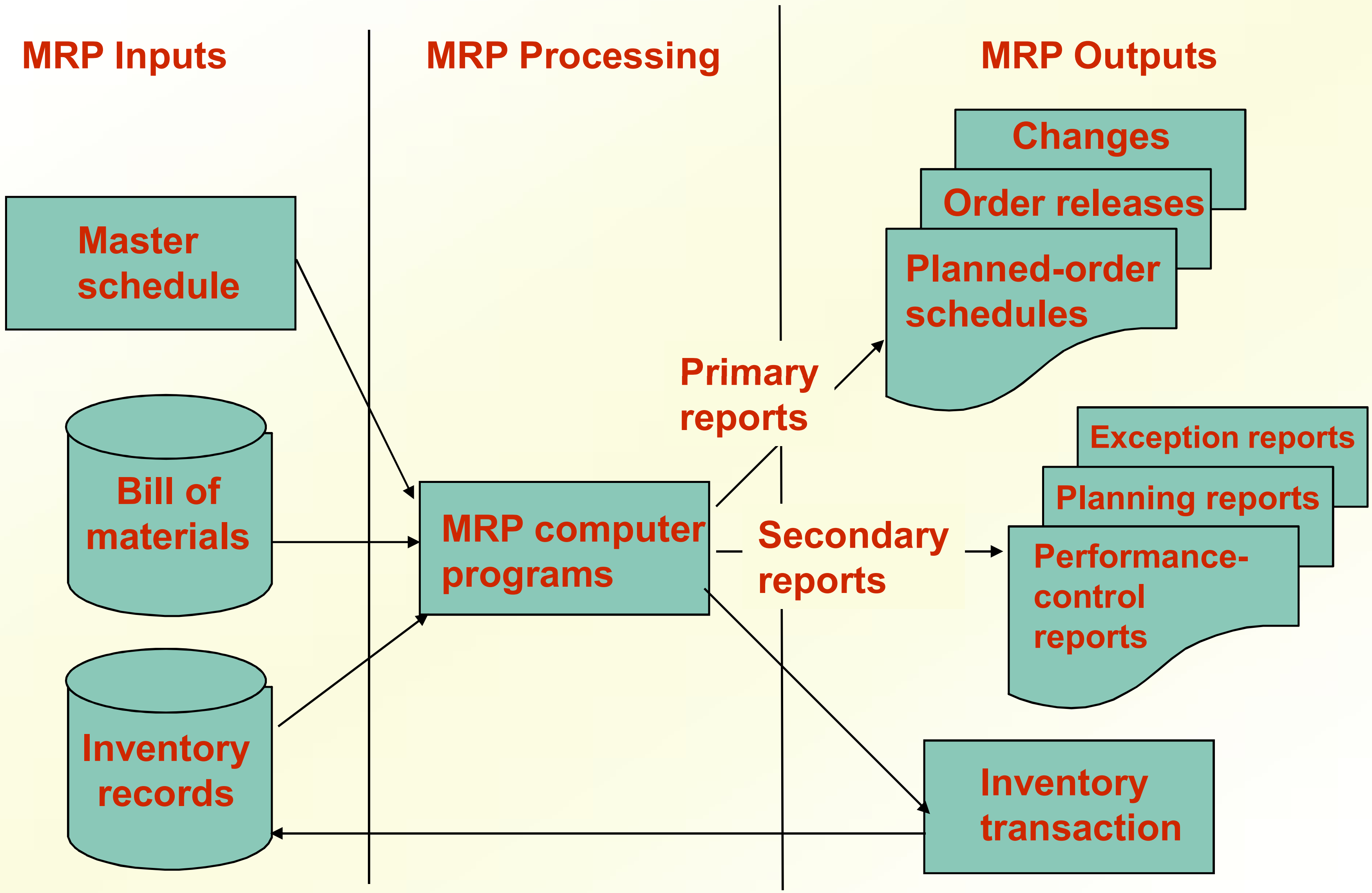
Independent and Dependent Demand



Independent demand is uncertain.
Dependent demand is certain.

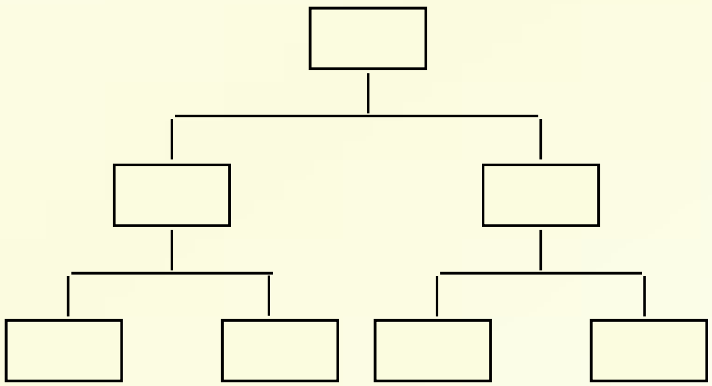
Dependant Demand

- *Dependent demand*: Demand for items that are subassemblies or component parts to be used in production of finished goods.
- Once the independent demand is known, the dependent demand can be determined.


MRP Inputs
MRP Processing
MRP Outputs
Master schedule
Bill of materials
Inventory records
MRP computer programs
Primary reports
Secondary reports
Changes
Order releases
Planned-order schedules
Exception reports
Planning reports
Performance-control reports
Inventory transaction

MPR Inputs

- Master Production Schedule
- Time-phased plan specifying timing and quantity of production for each end item.
- Material Requirement Planning Process



Product Structure Tree

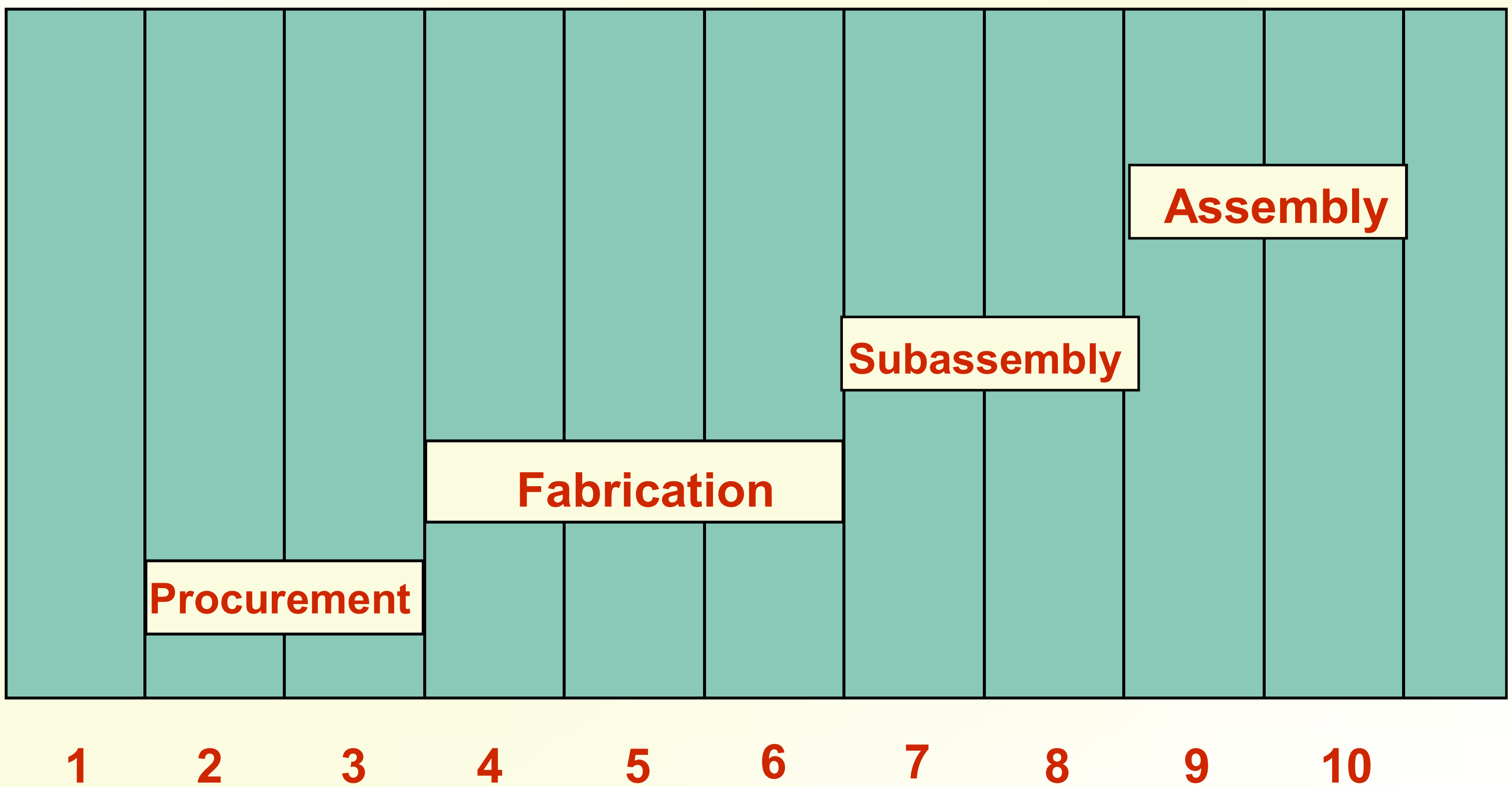
Lead Times

Master Schedule

Master schedule: One of three primary inputs in MRP; states which end items are to be produced, when these are needed, and in what quantities.

Cumulative lead time: The sum of the lead times that sequential phases of a process require, from ordering of parts or raw materials to completion of final assembly.

Planning Horizon

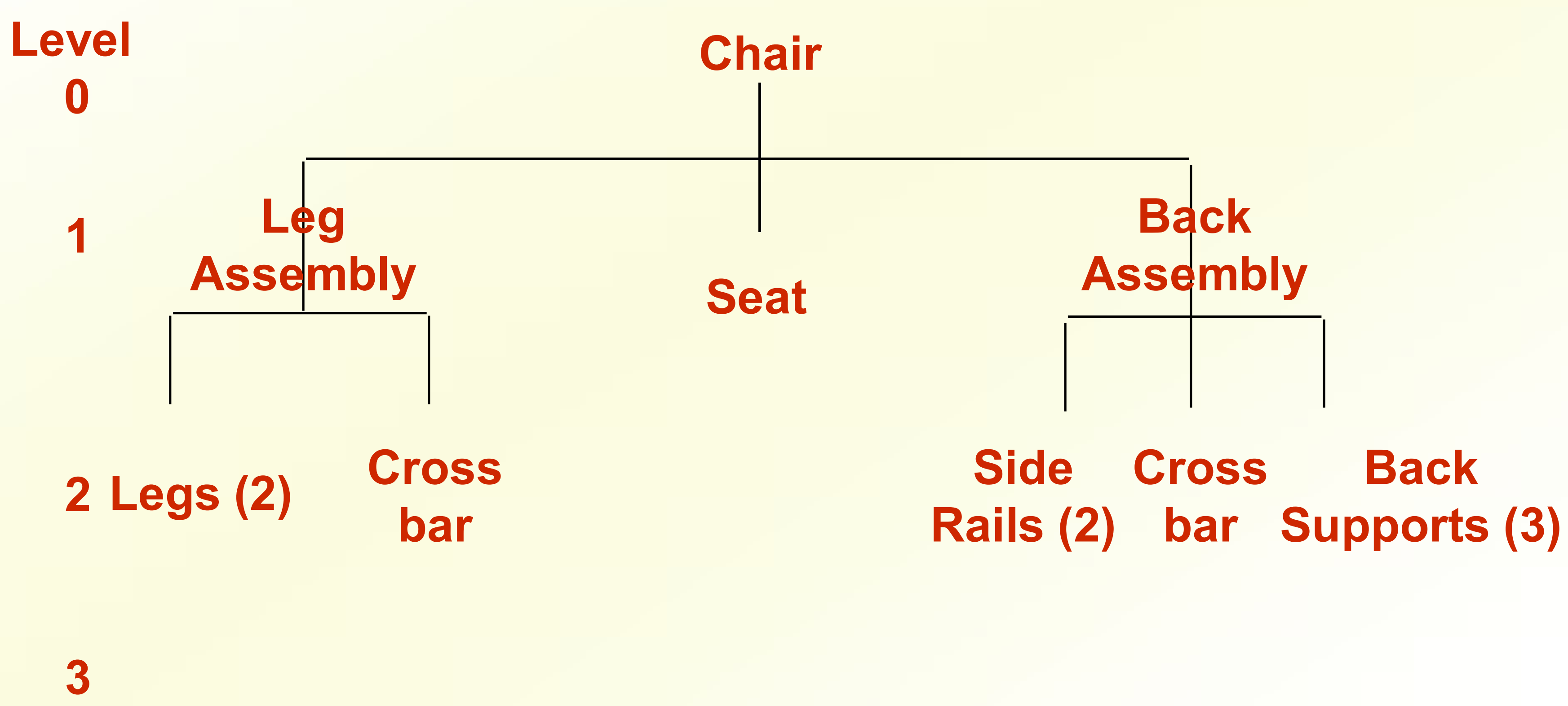


Bill-of-Materials

Bill of materials (BOM): One of the three primary inputs of MRP; a listing of all of the raw materials, parts, subassemblies, and assemblies needed to produce one unit of a product.

Product structure tree: Visual depiction of the requirements in a bill of materials, where all components are listed by levels.

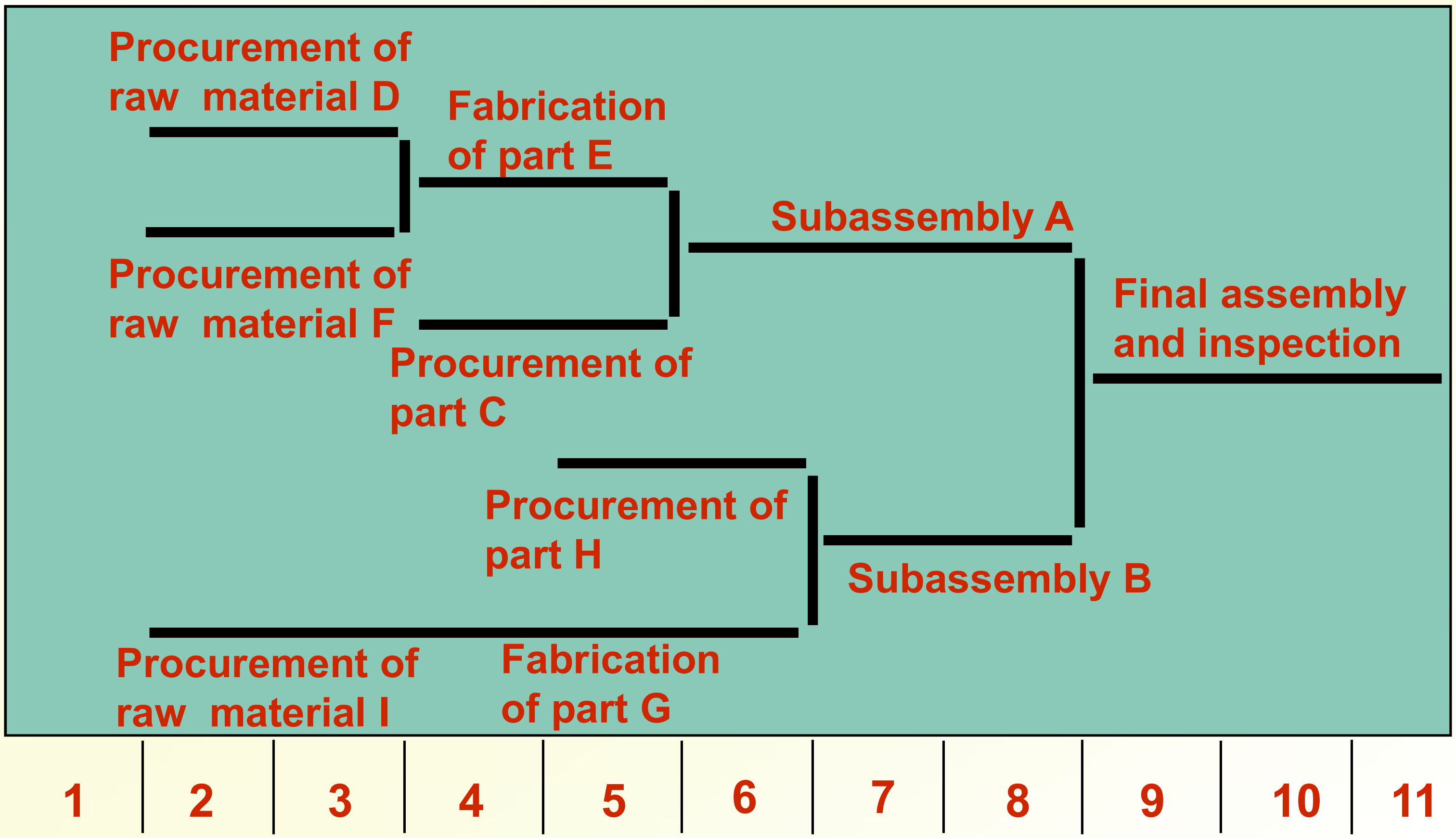
Product Structure Tree



Inventory Records

- One of the three primary inputs in MRP
- Includes information on the status of each item by time period
  - Gross requirements
  - Scheduled receipts
  - Amount on hand
  - Lead times
  - Lot sizes
  - And more …

Assembly Time Chart



MRP Processing

- Gross requirements
- Schedule receipts
- Projected on hand
- Net requirements
- Planned-order receipts
- Planned-order releases

MPR Processing

- Gross requirements
  - Total expected demand
- Scheduled receipts
  - Open orders scheduled to arrive
- Planned on hand
  - Expected inventory on hand at the beginning of each time period

MPR Processing

- Net requirements
  - Actual amount needed in each time period
- Planned-order receipts
  - Quantity expected to received at the beginning of the period
  - Offset by lead time
- Planned-order releases
  - Planned amount to order in each time period

Updating the System

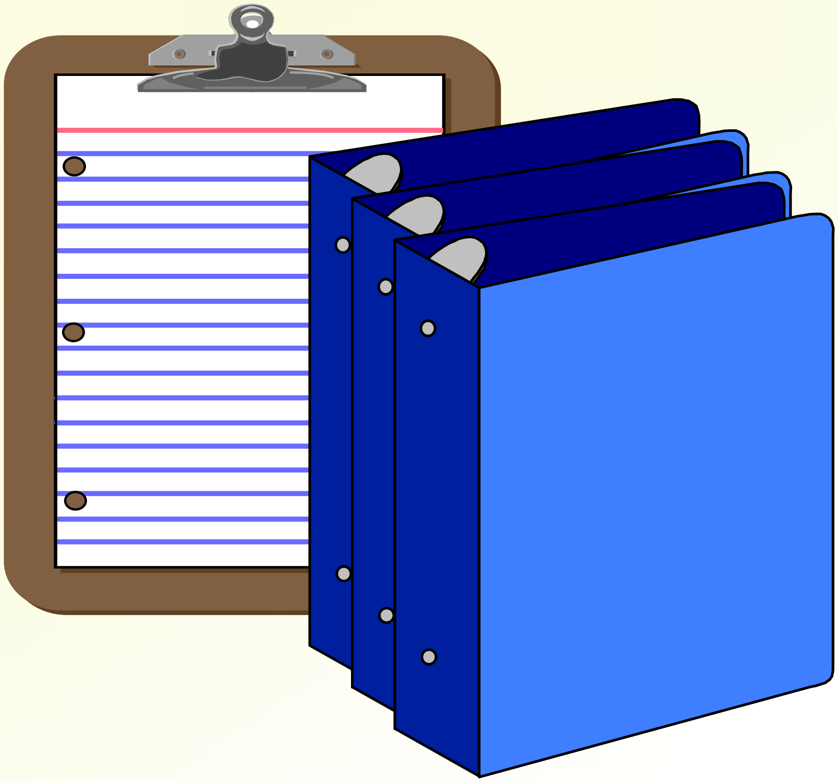
- Regenerative system
  - Updates MRP records periodically
- Net-change system
  - Updates MPR records continuously

MRP Outputs

- Planned orders - schedule indicating the amount and timing of future orders.
- Order releases - Authorization for the execution of planned orders.
- Changes - revisions of due dates or order quantities, or cancellations of orders.

MRP Secondary Reports

- Performance-control reports
- Planning reports
- Exception reports



MRP in Services

- Food catering service
  - End item => catered food
  - Dependent demand => ingredients for each recipe, i.e. bill of materials
- Hotel renovation
  - Activities and materials “exploded” into component parts for cost estimation and scheduling

Benefits of MRP

- Low levels of in-process inventories
- Ability to track material requirements
- Ability to evaluate capacity requirements
- Means of allocating production time

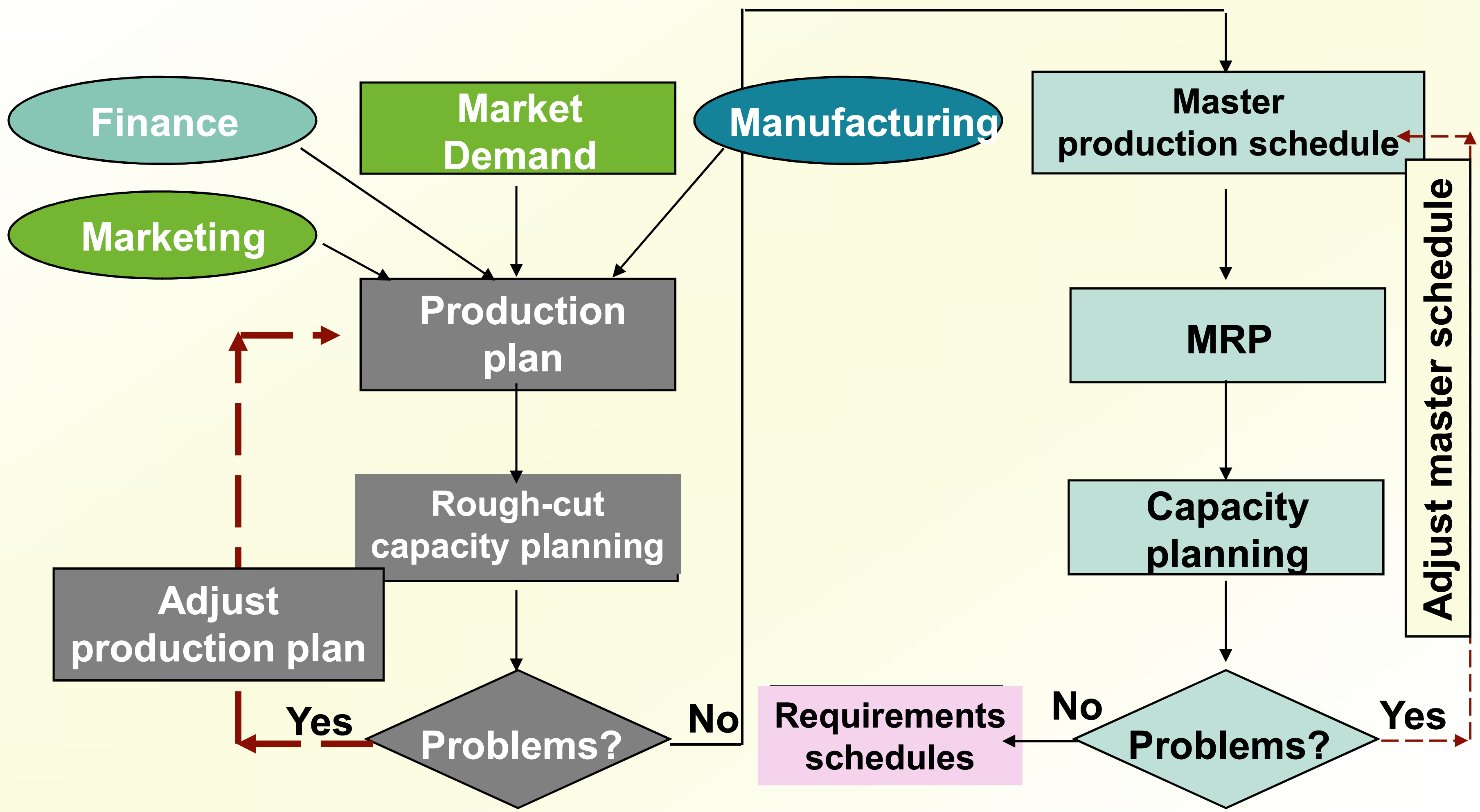
Requirements of MRP

- Computer and necessary software
- Accurate and up-to-date
  - Master schedules
  - Bills of materials
  - Inventory records
- Integrity of data

MRP II

- Expanded MRP with emphasis placed on integration
  - Financial planning
  - Marketing
  - Engineering
  - Purchasing
  - Manufacturing

MRP II



Finance
Market Demand
Manufacturing
Master production schedule
Marketing
Production plan
MRP
Rough-cut capacity planning
Capacity planning
Adjust master schedule
Adjust production plan
Yes
Problems?
No
Requirements schedules
No
Problems?
Yes

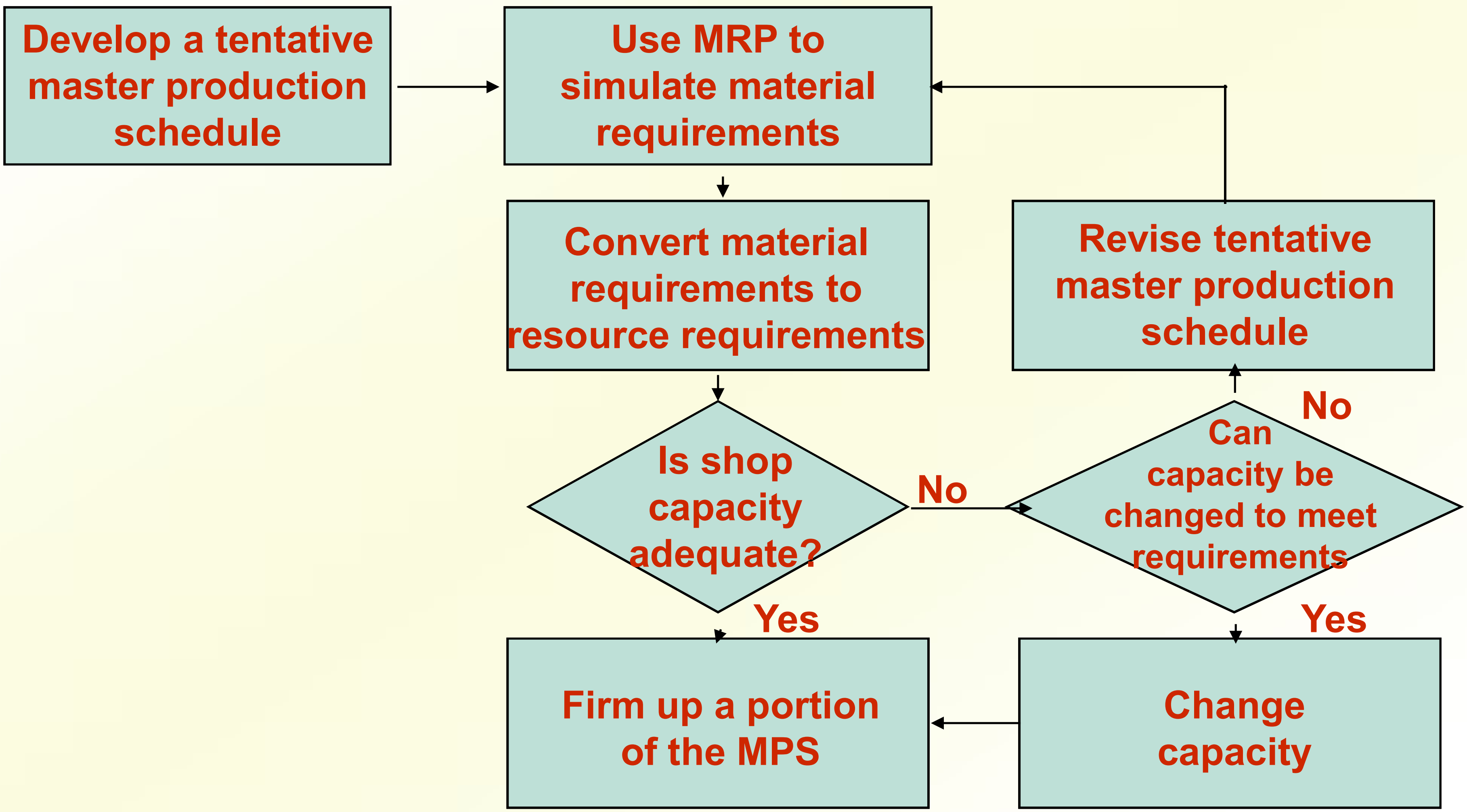
Capacity Planning

Capacity requirements planning: The process of determining short-range capacity requirements.

Load reports: Department or work center reports that compare known and expected future capacity requirements with projected capacity availability.

Time fences: Series of time intervals during which order changes are allowed or restricted.

Capacity Planning



ERP

- *Enterprise resource planning (ERP):*
  - Next step in an evolution that began with MPR and evolved into MRPII
  - Integration of financial, manufacturing, and human resources on a single computer system.

ERP Strategy Considerations

- High initial cost
- High cost to maintain
- Future upgrades
- Training

- Another one chapter will be discusses from the reference book.
- We will try to solve numerical problem from the text and reference books.

Thank You