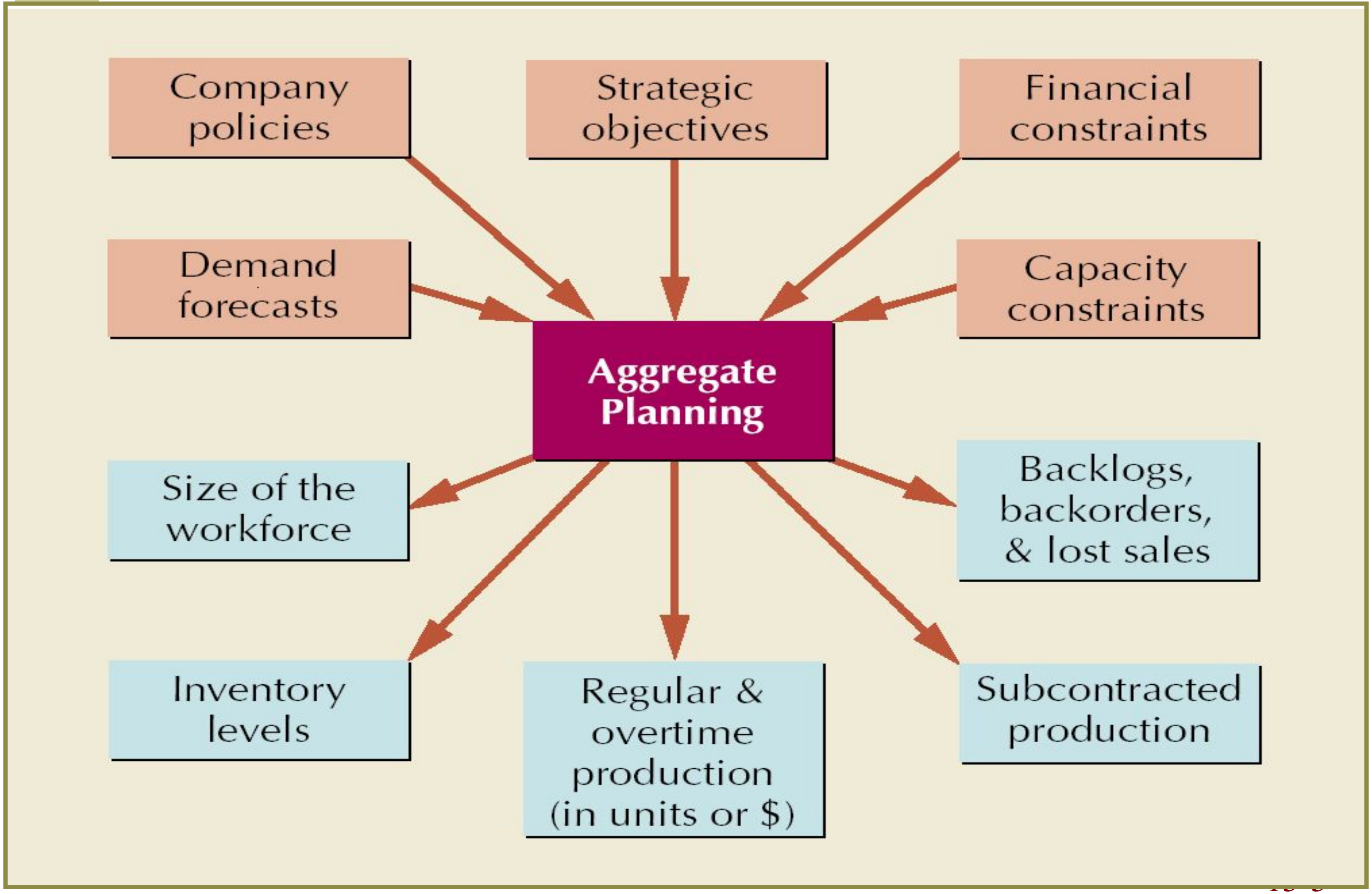
CHAPTER 6

AGGREGATE PLANNING
And Capacity Planning

Aggregate Planning

- Determine the resource capacity needed to meet demand over an **intermediate time horizon**
  - *Aggregate* refers to product lines or families
  - Aggregate planning matches supply and demand
- **Objectives:**
  - Establish a company wide game plan for allocating resources
  - Develop an economic strategy for meeting demand

Aggregate Planning Process



Company policies

Strategic objectives

Financial constraints

Demand forecasts

Capacity constraints

Aggregate Planning

Size of the workforce

Backlogs, backorders, & lost sales

Inventory levels

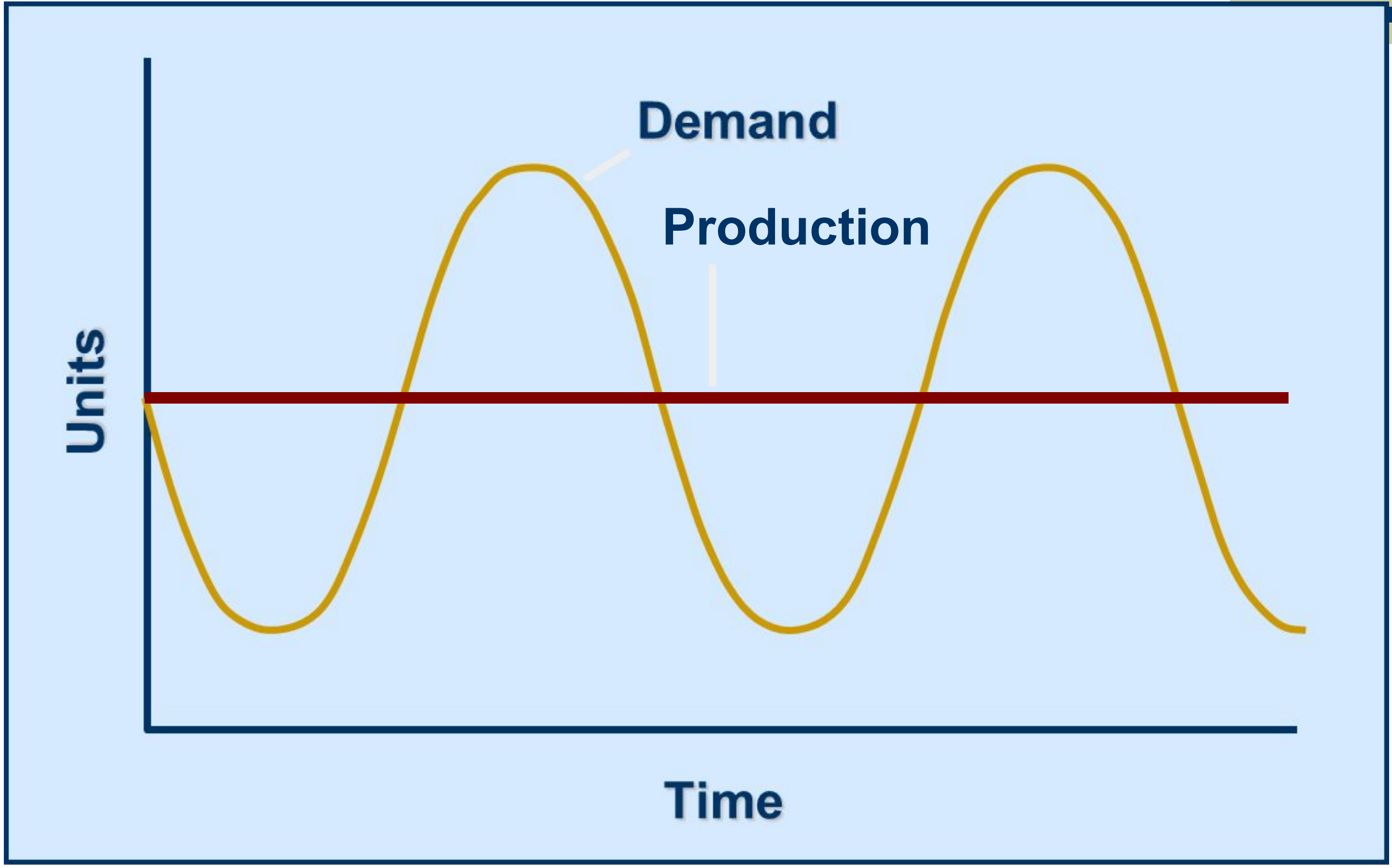
Regular & overtime production (in units or $)

Subcontracted production

Aggregate Planning Strategies

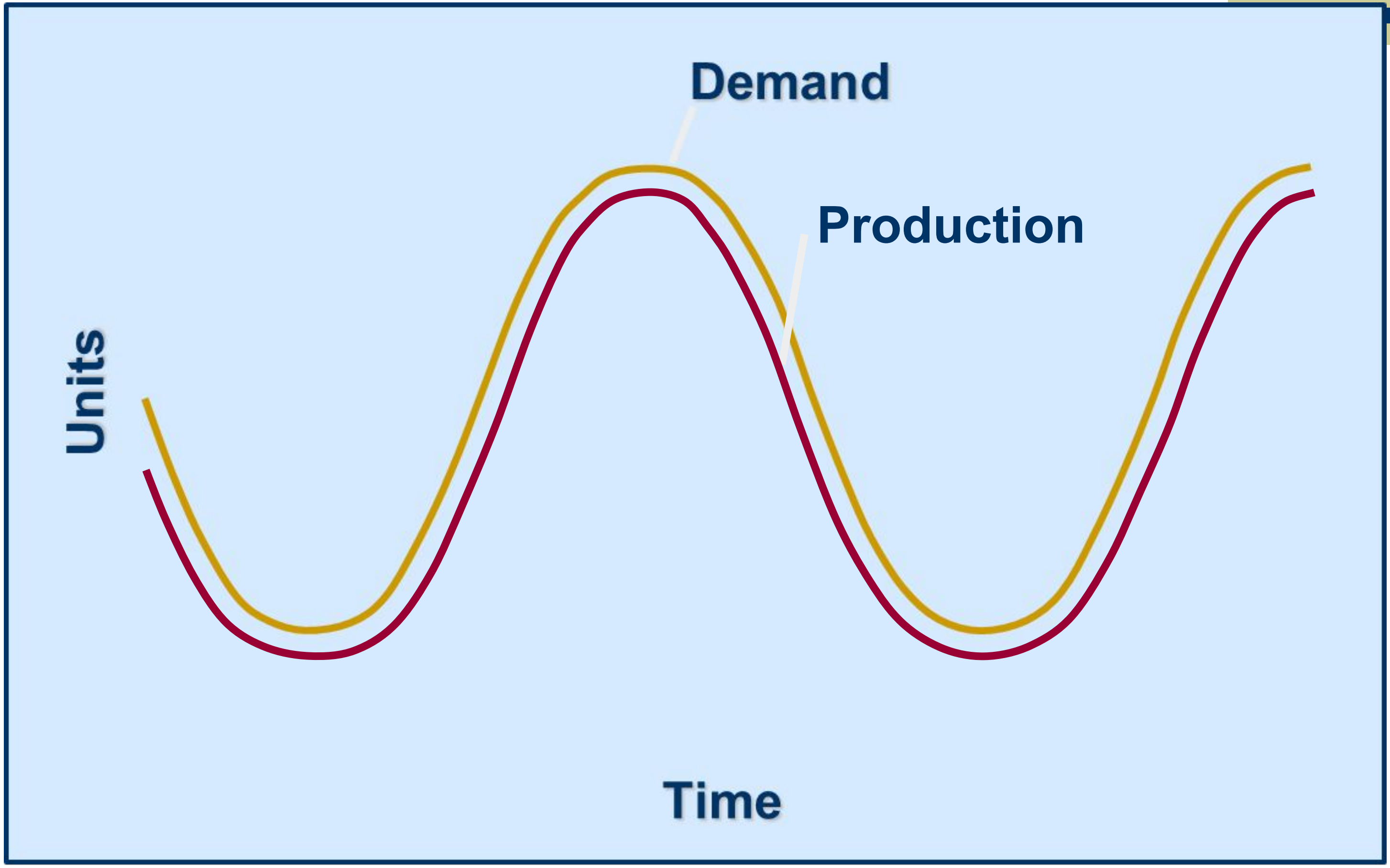
- **Level production**
  - Producing at a constant rate and using inventory to absorb fluctuations in demand

Level Production



- **Chase demand**
  - Hiring and firing workers to match demand

Chase Demand



Strategies for Adjusting Capacity

- **Overtime and under-time**
  - Increasing or decreasing working hours
- **Subcontracting**
  - Let outside companies complete the work
- **Part-time workers**
  - Hiring part time workers to complete the work
- **Backordering**
  - Providing the service or product at a later time period

Strategies for Managing Demand

- Shifting demand into other time periods
  - Incentives
  - Sales promotions
- Offering products or services with counter-cyclical demand patterns
- Partnering with suppliers to reduce information distortion along the supply chain
- Pricing

i. Pure Strategies

Example:

QUARTER	SALES FORECAST (LB)
Spring	80,000
Summer	50,000
Fall	120,000
Winter	150,000

Hiring cost = $100 per worker

Firing cost = $500 per worker

Regular production cost per pound = $2.00

Inventory carrying cost = $0.50 pound per quarter

Production per employee = 1,000 pounds per quarter

Beginning workforce = 100 workers

Level Production Strategy

Level production

$$\frac{(50{,}000 + 120{,}000 + 150{,}000 + 80{,}000)}{4} = 100{,}000 \text{ pounds}$$

QUARTER	SALES FORECAST	PRODUCTION PLAN	INVENTORY
Spring	80,000	100,000	20,000
Summer	50,000	100,000	70,000
Fall	120,000	100,000	50,000
Winter	150,000	100,000	0
Total		400,000	140,000

Cost of Level Production Strategy

(400,000 X \$2.00) + (140,00 X \$.50) = \$870,000

Chase Demand Strategy

QUARTER	SALES FORECAST	PRODUCTION PLAN	WORKERS NEEDED	WORKERS HIRED	WORKERS FIRED
Spring	80,000	80,000	80	0	20
Summer	50,000	50,000	50	0	30
Fall	120,000	120,000	120	70	0
Winter	150,000	150,000	150	30	0
Total		400,000		100	50

Cost of Chase Demand Strategy

(400,000 X \$2.00) + (100 x \$100) + (50 x \$500) = **\$835,000**

ii. Mixed Strategy

- Combination of Level Production and Chase Demand strategies
- Examples of management policies
  - no more than *x*% of the workforce can be laid off in one quarter
  - inventory levels cannot exceed *x* dollars
- Many industries may simply shut down manufacturing during the low demand season and schedule employee vacations during that time

General Linear Programming (LP) Model

- LP gives an optimal solution, but demand and costs must be linear
- *Let*
  - W_t = workforce size for period *t*
  - P_t =units produced in period *t*
  - I_t =units in inventory at the end of period *t*
  - F_t =number of workers fired for period *t*
  - H_t = number of workers hired for period *t*

LP MODEL

Minimize $Z = \$100\,(H_1 + H_2 + H_3 + H_4)$
$+ \$500\,(F_1 + F_2 + F_3 + F_4)$
$+ \$0.50\,(I_1 + I_2 + I_3 + I_4)$

Subject to

Demand constraints

$P_1 - I_1 = 80{,}000$ (1)
$I_1 + P_2 - I_2 = 50{,}000$ (2)
$I_2 + P_3 - I_3 = 120{,}000$ (3)
$I_3 + P_4 - I_4 = 150{,}000$ (4)

Production constraints

$1000\,W_1 = P_1$ (5)
$1000\,W_2 = P_2$ (6)
$1000\,W_3 = P_3$ (7)
$1000\,W_4 = P_4$ (8)

Work force constraints

$100 + H_1 - F_1 = W_1$ (9)
$W_1 + H_2 - F_2 = W_2$ (10)
$W_2 + H_3 - F_3 = W_3$ (11)
$W_3 + H_4 - F_4 = W_4$ (12)

Transportation Method

QUARTER	EXPECTED DEMAND	REGULAR CAPACITY	OVERTIME CAPACITY	SUBCONTRACT CAPACITY
1	900	1000	100	500
2	1500	1200	150	500
3	1600	1300	200	500
4	3000	1300	200	500

Regular production cost per unit	$20
Overtime production cost per unit	$25
Subcontracting cost per unit	$28
Inventory holding cost per unit per period	$3
Beginning inventory	300 units

Transportation Tableau

PERIOD OF USE

	PERIOD OF PRODUCTION			*1*	*Unused* *2*	*3*	*4*		*Capacity*		*Capacity*	
1	Beginning Inventory	300	0	—	3	—	6		—	9		300
	Regular	600		300	20	100	23	26	—	29		1000
2	Overtime				25		28	31	100	34		100
	Subcontract				28		31	34		37		500
	Regular			1200		—	20	23	—	26		1200
3	Overtime						25	28	150	31		150
	Subcontract						28	31	250	34	250	500
	Regular					1300		20	—	23		1300
4	Overtime					200		25	—	28		200
	Subcontract							28	500	31		500
	Regular								1300	20		1300
	Overtime								200	25		200
	Subcontract								500	28		500
	Demand	900		1500		1600			3000		250	

Capacity Planning

- The throughput, or the number of units a facility ***can hold, receive, store, or produce*** in a ***period of time.***
- Determines fixed costs
- Determines if demand will be satisfied
- Three time horizons

Measuring Capacity

Type of Business	Input Measures of Capacity	Output Measures of Capacity
Car manufacturer	Labor hours	Cars per shift
Hospital	Available beds	Patients per month
Pizza parlor	Labor hours	Pizzas per day
Retail store	Floor space in square feet	Revenue per foot

- **There is no one best way to measure capacity**
- **Output measures are easier to understand.**
- **With multiple products, inputs measures work better**

Design and Effective Capacity

- Design capacity is the maximum ***theoretical output*** of a system
  - Normally expressed as a rate
- Effective capacity is the capacity a firm expects to achieve given ***current operating constraints***
  - Often lower than design capacity

Utilization and Efficiency

- Utilization is the percent of design capacity achieved
    - Utilization = Actual Output/Design Capacity
- Efficiency is the percent of effective capacity achieved
    - Efficiency = Actual Output/Effective Capacity

Example of Computing Capacity Utilization: In the bakery example the design capacity is 30 custom cakes per day. Currently the bakery is producing 28 cakes per day. What is the bakery's capacity utilization relative to both design and effective capacity?

$$\text{Utilization}_{\text{effective}} = \frac{\text{actual output}}{\text{effective capacity}}(100\%) = \frac{28}{20}(100\%) = 140\%$$

$$\text{Utilization}_{\text{design}} = \frac{\text{actual output}}{\text{design capacity}}(100\%) = \frac{28}{30}(100\%) = 93\%$$

- **The current utilization is only slightly below its design capacity and considerably above its effective capacity**
- **The bakery can only operate at this level for a short period of time**

Example 2

- Actual production last week = 148,000 rolls
- Effective capacity = 175,000 rolls
- Design capacity = 1,200 rolls per hour
- Bakery operates 7 days/week, 3-eight hours shifts

- Design capacity = (7 x 3 x 8) x (1,200) = 201,600 rolls

- Utilization = 148,000/201,600 = 73.4%

- Efficiency = 148,000/175,000 = 84.6%

Cont…

- Actual production last week = 148,000 rolls
- Effective capacity = 175,000 rolls
- Design capacity = 1,200 rolls per hour
- Bakery operates 7 days/week, 3-eight hours shifts
- Efficiency = 84.6%
- Efficiency of new line = 75%

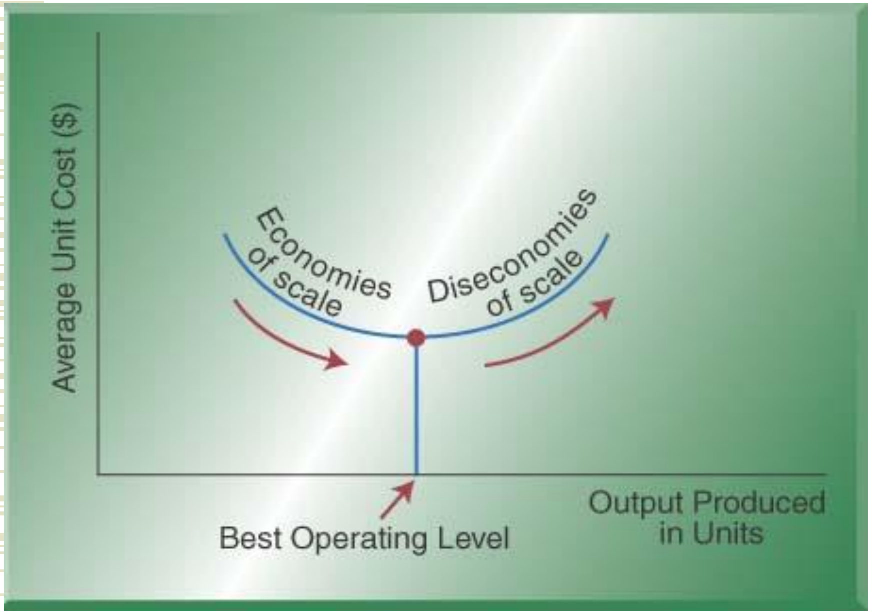
- Expected Output = (Effective Capacity)(Efficiency)

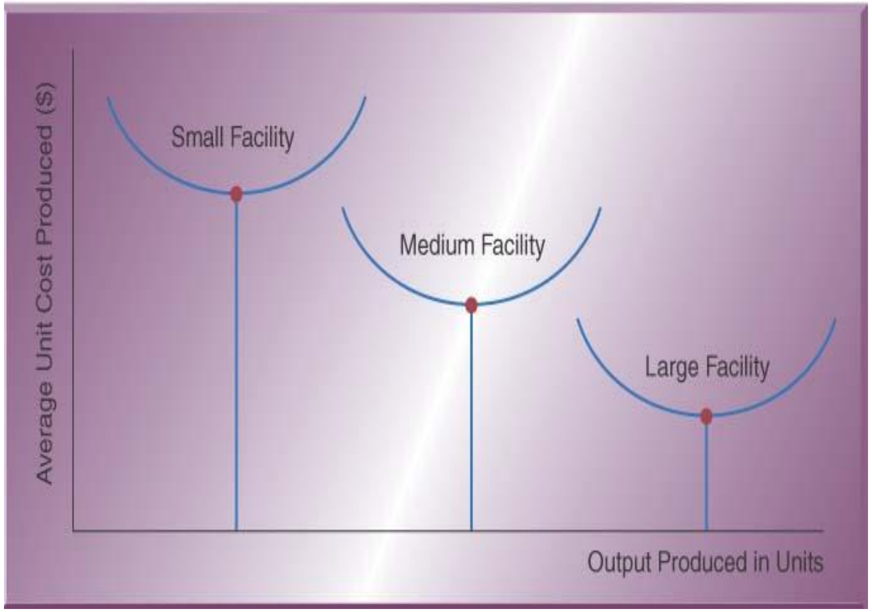
- = (175,000)(.75) = 131,250 rolls

How Much Capacity is Required?

- The Best Operating Level is the output that results in the lowest average unit cost
- Economies of Scale:
  - Where the cost per unit of output drops as volume of output increases
  - Spread the fixed costs of buildings & equipment over multiple units, allow bulk purchasing & handling of material
- Diseconomies of Scale:
  - Where the cost per unit rises as volume increases
  - Often caused by congestion (overwhelming the process with too much work-in-process) and scheduling complexity

Optimum Operating Level and Size





- **Alternative 1:** Purchase one large facility, requiring one large initial investment
- **Alternative 2:** Add capacity incrementally in smaller chunks as needed

Making Capacity Planning Decisions

- **The three-step procedure for making capacity planning decisions is as follows:**
  - Step 1: Identify Capacity Requirements
  - Step 2: Develop Capacity Alternatives
  - Step 3: Evaluate Capacity Alternatives

Evaluating Capacity Alternatives

- The desired capacity for a process or facility will often dictate the :

✓ The type and size of equipment to be used

✓ The size of the facility

✓ The number and skill level of workers that will be needed, and

✓ The type of raw materials that can be used.

Cont…

- These factors determine the production cost function, that is, how production cost is related to the output rate.
- Large-capacity processes normally utilize larger and more expensive equipment and larger facilities than do small-capacity processes.
-

Quantitative Techniques Employed
a) Breakeven Analysis

- Technique for evaluating process and equipment alternatives
- Objective is to find the point in dollars and units at which cost equals revenue
- Requires estimation of fixed costs, variable costs, and revenue

Cont…

- Fixed costs are costs that continue even if no units are produced
  - Depreciation, taxes, debt, mortgage payments
- Variable costs are costs that vary with the volume of units produced
  - Labor, materials, portion of utilities
  - Contribution is the difference between selling price and variable cost

Assumptions:

- Costs and revenue are linear functions
  - Generally not the case in the real world
- We actually know these costs
  - Very difficult to accomplish
- There is no time value of money

Example

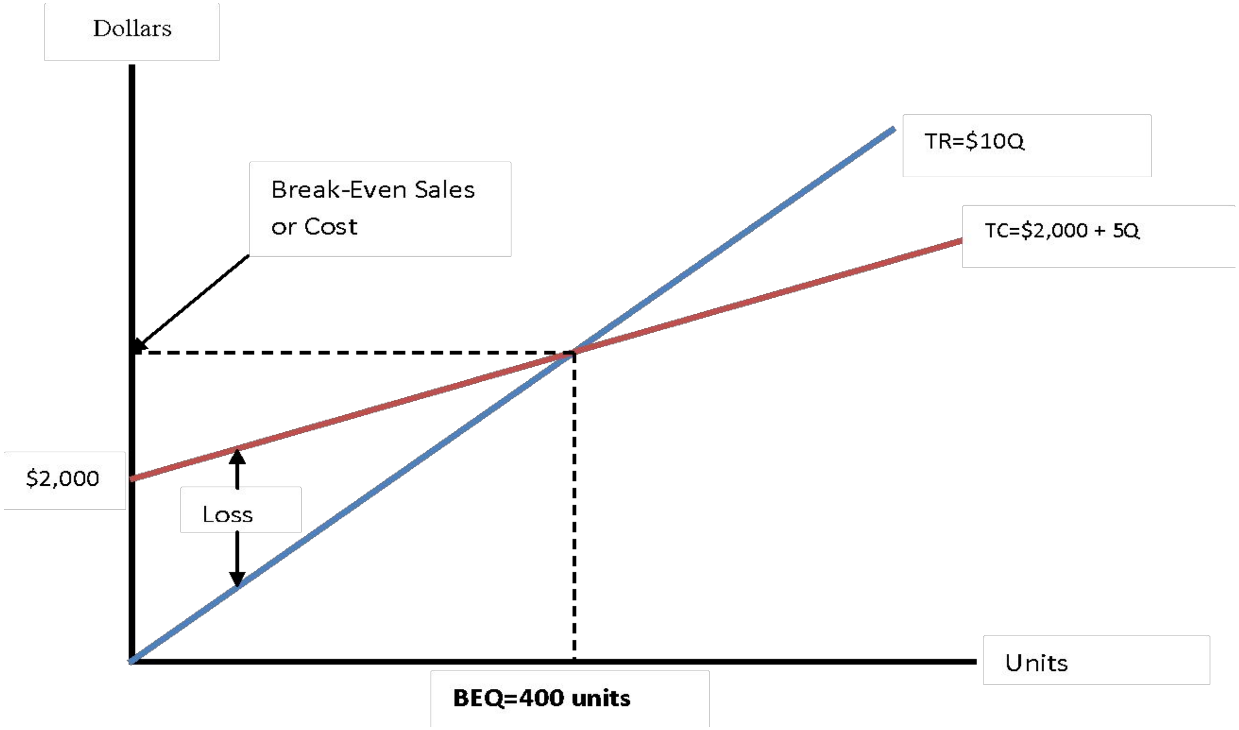
- Suppose a person in planning to flourish a bakery business with an initial investment in equipment of $2000. Labor and material cost is estimated to approximately be $5 per unit. If the product is to be sold at a price of $10 each, what volume of demand will be necessary to break even?

Solution:

- Fixed Cost =FC= \$2,000
- Variable cost = K= \$5 per unit
- Price =P=\$10 per unit
- Total variable cost=TVC=\$5Q
- Where Q is the volume of the output produced and sold

$$Q = \frac{FC}{P-K} = \frac{2000}{10-5} = \underline{\underline{400 units}}$$

Break-even graph



Extended Example:

- Assume the owner of the bakery business believes that demand for his product will far exceed the breakeven point (400 units). He is now contemplating a larger initial investment of $10,000 for more automated equipment that would reduce the variable cost of manufacturing to $2 per unit. The important question is that for what volume of demand should each process be chosen?

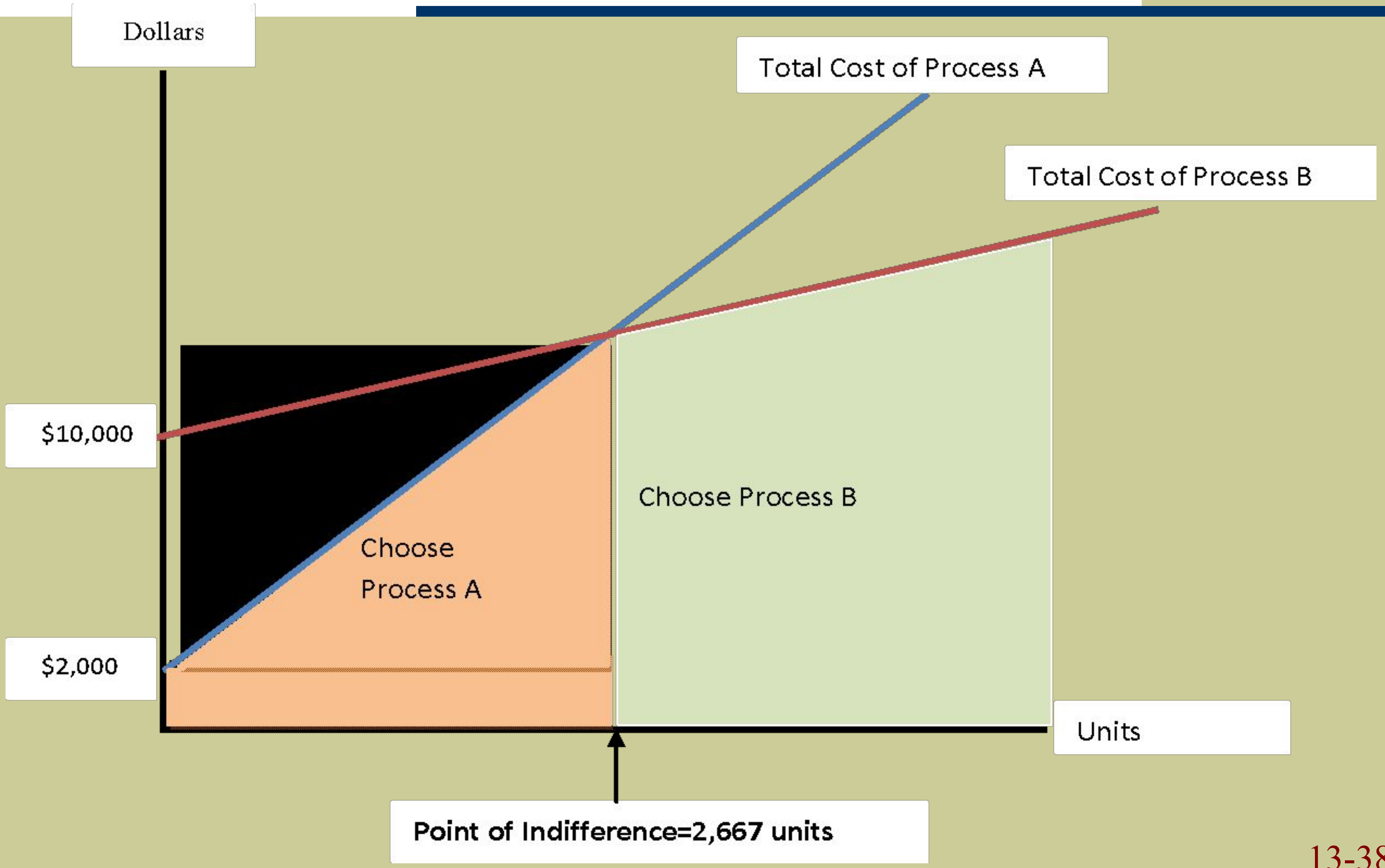
Solution:

- If we call the old process, A, and the new process, B, the point of indifference between A and B is:

- Process A Process B
- $\$2{,}000 + \$5Q \quad = \quad \$10{,}000 + \$2Q$

- $\$3Q = \$\ 8{,}000$
- $Q = 2667$ units.

Comparison of Two Processes



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- Since we have the same revenue graph for both, there is no need to draw it on the same x-y grid system.
- For a market demand less than 2,667 units, the bakery business owner prefers process A to process B, otherwise he chooses process B.

Multiple Product Case

$$BEP_{\$} = \frac{F}{\sum \left[\left(1 - \frac{V_i}{p_i} \right) w_i \right]}$$

- **Where:**

V = variable cost per unit

P = price per unit

F = fixed costs

W = percent each product is of total dollar sales

i = each product

Example

Fixed costs = $3,500 per month

Item	Price	Cost	Annual Forecasted Sales Units
Sandwich	$2.95	$1.25	7,000
Soft drink	.80	.30	7,000
Baked potato	1.55	.47	5,000
Tea	.75	.25	5,000
Salad bar	2.85	1.00	3,000

Cont…

Item (i)	Selling Price (P)	Variable Cost (V)	(V/P)	1 - (V/P)	Annual Forecasted Sales $	% of Sales	Weighted Contribution (col 5 x col 7)
Sandwich	$2.95	$1.25	.42	.58	$20,650	.446	.259
Soft drink	.80	.30	.38	.62	5,600	.121	.075
Baked potato	1.55	.47	.30	.70	7,750	.167	.117
Tea	.75	.25	.33	.67	3,750	.081	.054
Salad bar	2.85	1.00	.35	.65	8,550	.185	.120
					$46,300	1.000	.625

Cont…

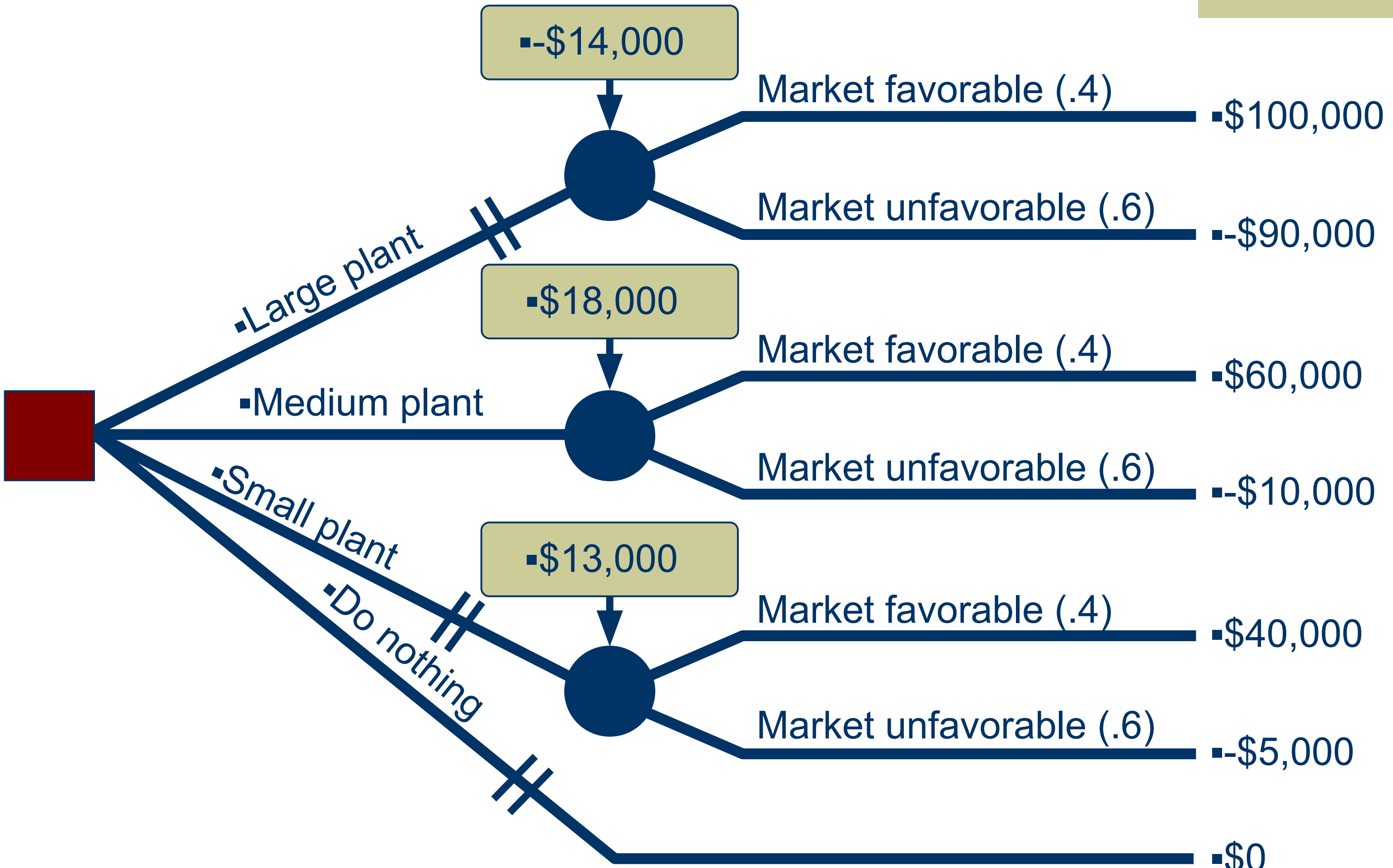
$$BEP_{\$} = \frac{F}{\sum\left[\left(1 - \frac{V_i}{p_i}\right)w_i\right]}$$

$$= \frac{\$3{,}500 \times 12}{.625} = \$67{,}200$$

$$\text{Daily sales} = \frac{\$67{,}200}{312 \text{ days}} = \$215.38$$

$$\frac{.446 \times \$215.38}{\$2.95} = 32.6 \approx 33 \text{ sandwiches per day}$$

Decision Tree Approach



Strategy Driven Investment

- Operations may be responsible for return-on-investment (ROI)
- Analyzing capacity alternatives should include capital investment, variable cost, cash flows, and net present value

Net Present Value

$$P = \frac{F}{(1+i)^n}$$

where F = future value

P = present value

i = interest rate

N = number of years

NPV Using Factors

$$P = \frac{F}{(1+i)^n} = FX$$

where X = a factor from **Table-1**

defined as = $1/(1 + i)^N$

and F = future value

Cont…

- Portion of Table -1

Year	5%	6%	7%	…	10%
1	.952	.943	.935		.909
2	.907	.890	.873		.826
3	.864	.840	.816		.751
4	.823	.792	.763		.683
5	.784	.747	.713		.621

Present Value of an Annuity

- An annuity is an investment which generates **uniform equal payments**

$$S = RX$$

where X = factor from Table -2

S = present value of a series of uniform annual receipts

R = receipts that are received every year of the life of the investment

Present Value of an Annuity

- **Portion of Table -2**

Year	5%	6%	7%	…	10%
1	.952	.943	.935		.909
2	1.859	1.833	1.808		1.736
3	2.723	2.676	2.624		2.487
4	4.329	3.465	3.387		3.170
5	5.076	**4.212**	4.100		3.791

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- $7,000 in receipts per for 5 years
- Interest rate = 6%

From Table -2

X = 4.212

- S = RX
- S = $7,000(4.212) = $29,484

Present Value of Annuity with Different Future Receipts

Investment A's Cash Flow	*Investment B's Cash Flow*	*Year*	*Present Value Factor at 8%*
$10,000	$9,000	*1*	.926
9,000	9,000	*2*	.857
8,000	9,000	*3*	.794
7,000	9,000	*4*	.735

Cont…

Year	Investment A's Present Values	Investment B's Present Values
1	$9,260 = (.926)($10,000)	$8,334 = (.926)($9,000)
2	7,713 = (.857)($9,000)	7,713 = (.857)($9,000)
3	6,352 = (.794)($8,000)	7,146 = (.794)($9,000)
4	5,145 = (.735)($7,000)	6,615 = (.735)($9,000)
Totals	$28,470	$29,808
Minus initial investment	-25,000	-26,000
NPV	$3,470	$3,808

Review Questions

1) What is aggregate planning?
2) What is the purpose of aggregate planning?
3) Briefly discuss most common decision variables of aggregate planning?
4) What are the advantages and disadvantages of using a level production and workforce strategy for developing an aggregate plan?
5) Discuss the options for modifying supply.