Capacity Planning

7 SUPPLEMENT

PowerPoint presentation to accompany
Heizer and Render
Operations Management, Global Edition, Eleventh Edition
Principles of Operations Management, Global Edition, Ninth Edition

PowerPoint slides by Jeff Heyl

Outline

- Capacity
- Bottleneck Analysis and the Theory of Constraints
- Break-Even Analysis
- Reducing Risk with Incremental Changes

Outline - Continued

- Applying Expected Monetary Value (EMV) to Capacity Decisions
- Applying Investment Analysis to Strategy-Driven Investments

Learning Objectives

When you complete this supplement you should be able to :

1. **Define** capacity
2. **Determine** design capacity, effective capacity, and utilization
3. **Perform** bottleneck analysis
4. **Compute** break-even

Learning Objectives

When you complete this supplement you should be able to :

5. **Determine** the expected monetary value of a capacity decision
6. **Compute** net present value

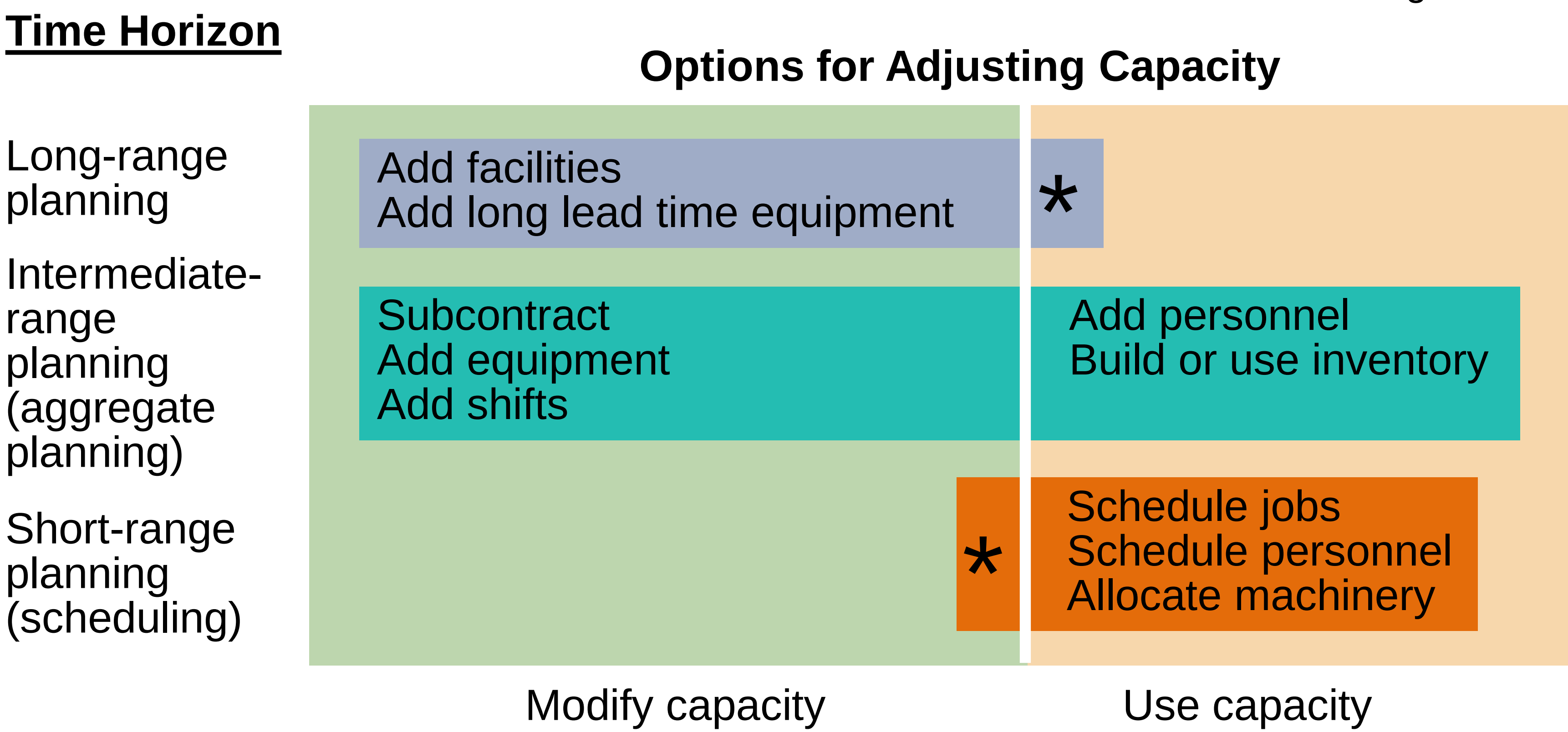
Capacity

- 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

Planning Over a Time Horizon

Figure S7.1



* Difficult to adjust capacity as limited options exist

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 actually achieved

Utilization = Actual output/Design capacity

Efficiency is the percent of effective capacity actually achieved

Efficiency = Actual output/Effective capacity

Bakery Example

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 - 8 hour shifts

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

Bakery Example

Actual production last week = 148,000 rolls
Effective capacity = 175,000 rolls
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Utilization = 148,000/201,600 = 73.4%

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

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

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Efficiency = 84.6%
Efficiency of new line = 75%

Expected Output = (Effective Capacity)(Efficiency)

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

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Capacity and Strategy

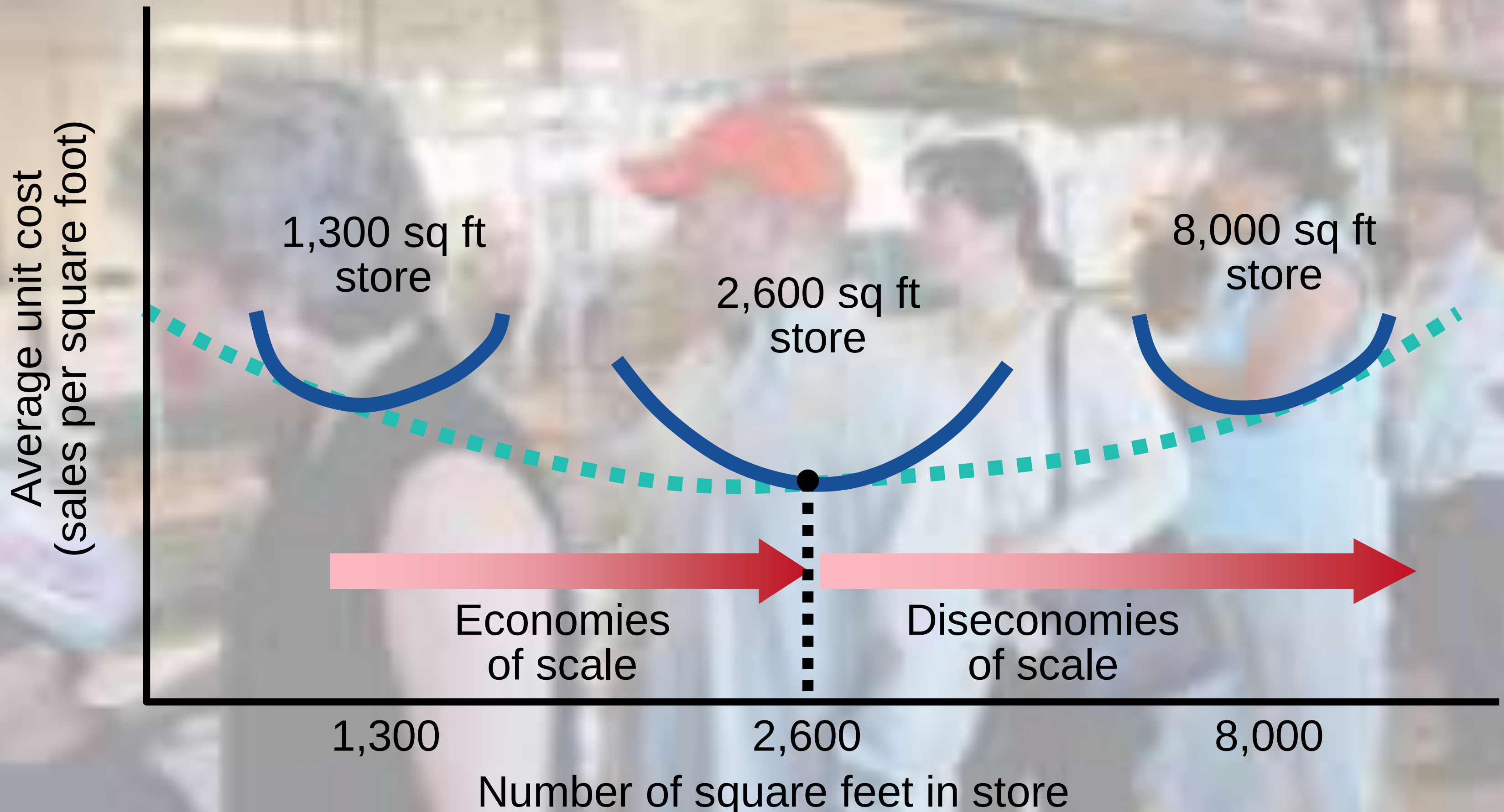
- Capacity decisions impact all 10 decisions of operations management as well as other functional areas of the organization
- Capacity decisions must be integrated into the organization's mission and strategy

Capacity Considerations

1. Forecast demand accurately
2. Match technology increments and sales volume
3. Find the optimum operating size (volume)
4. Build for change

Economies and Diseconomies of Scale

Figure S7.2

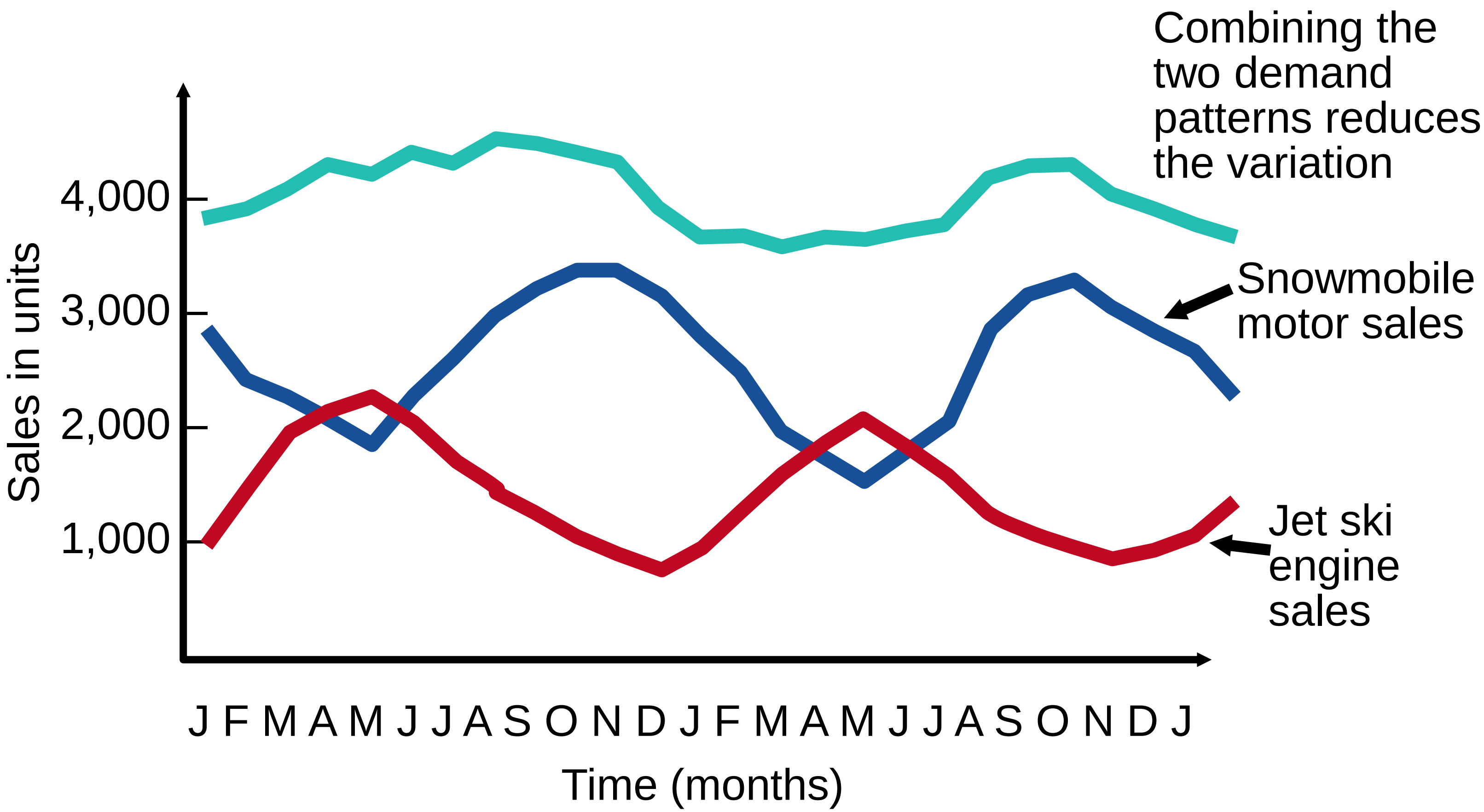


Managing Demand

- Demand exceeds capacity
  - Curtail demand by raising prices, scheduling longer lead time
  - Long term solution is to increase capacity
- Capacity exceeds demand
  - Stimulate market
  - Product changes
- Adjusting to seasonal demands
  - Produce products with complementary demand patterns

Complementary Demand Patterns

Figure S7.3



Tactics for Matching Capacity to Demand

1. Making staffing changes
2. Adjusting equipment
   - Purchasing additional machinery
   - Selling or leasing out existing equipment
3. Improving processes to increase throughput
4. Redesigning products to facilitate more throughput
5. Adding process flexibility to meet changing product preferences
6. Closing facilities

Service-Sector Demand and Capacity Management

- Demand management
  - Appointment, reservations, FCFS rule
- Capacity management
  - Full time, temporary, part-time staff

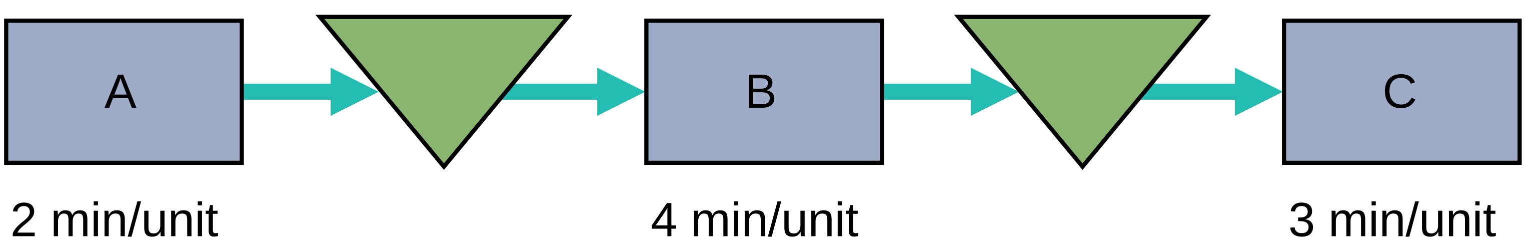
Bottleneck Analysis and the Theory of Constraints

- Each work area can have its own unique capacity
- **Capacity analysis** determines the throughput capacity of workstations in a system
- A **bottleneck** is a limiting factor or constraint
- A bottleneck has the lowest effective capacity in a system

Bottleneck Analysis and the Theory of Constraints

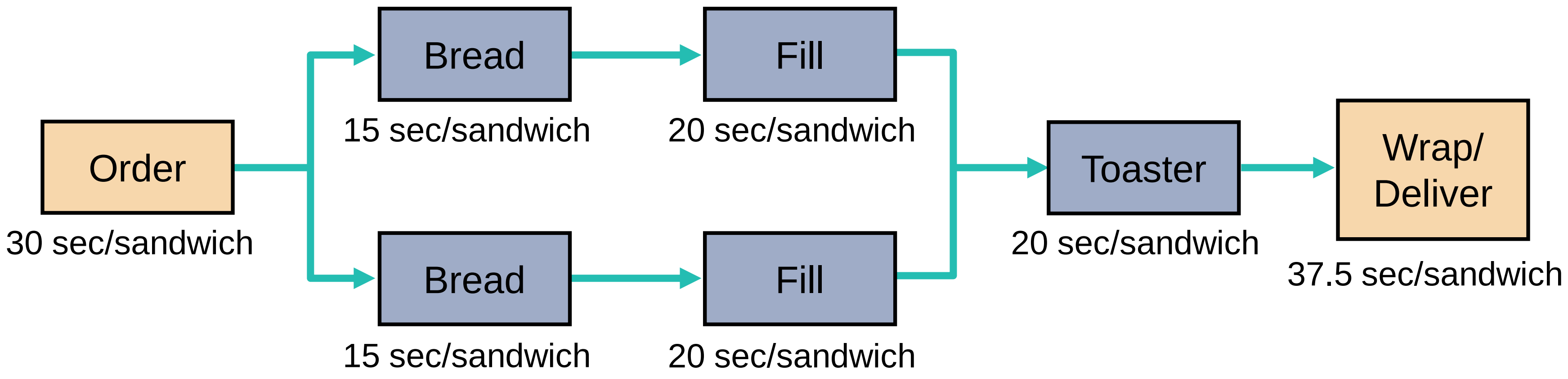
- The **bottleneck time** is the time of the slowest workstation (the one that takes the longest) in a production system
- The **throughput time** is the time it takes a unit to go through production from start to end

Figure S7.4

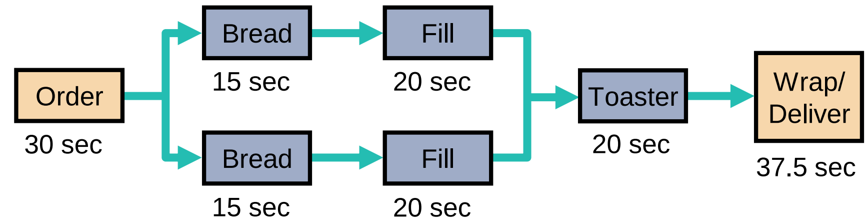


Capacity Analysis

- Two identical sandwich lines
- Lines have two workers and three operations
- All completed sandwiches are wrapped



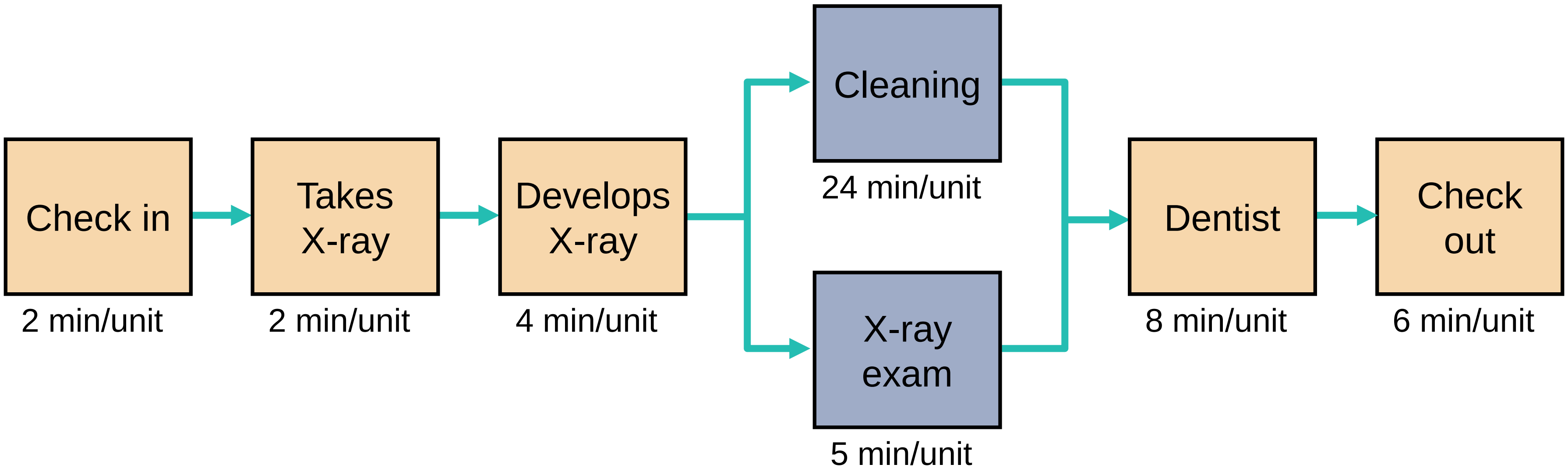
Capacity Analysis



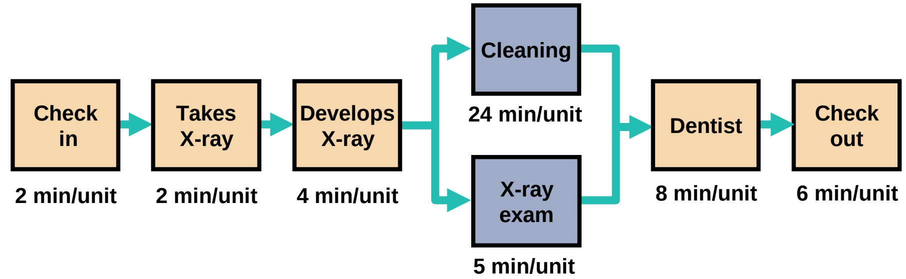
- The two lines each deliver a sandwich every 20 seconds
- At 37.5 seconds, wrapping and delivery has the longest processing time and is the bottleneck
- Capacity per hour is 3,600 seconds/37.5 seconds/sandwich = 96 sandwiches per hour
- Throughput time is 30 + 15 + 20 + 20 + 37.5 = 122.5 seconds

Capacity Analysis

- Standard process for cleaning teeth
- Cleaning and examining X-rays can happen simultaneously



Capacity Analysis



- All possible paths must be compared
- Bottleneck is the hygienist at 24 minutes
- Hourly capacity is 60/24 = 2.5 patients
- X-ray exam path is 2 + 2 + 4 + 5 + 8 + 6 = 27 minutes
- Cleaning path is 2 + 2 + 4 + 24 + 8 + 6 = 46 minutes
- Longest path involves the hygienist cleaning the teeth, patient should complete in 46 minutes

Theory of Constraints

- Five-step process for recognizing and managing limitations

Step 1: Identify the constraints

Step 2: Develop a plan for overcoming the constraints

Step 3: Focus resources on accomplishing Step 2

Step 4: Reduce the effects of constraints by offloading work or expanding capability

Step 5: Once overcome, go back to Step 1 and find new constraints

Bottleneck Management

1. Release work orders to the system at the pace of set by the bottleneck
   - Drum, Buffer, Rope
2. Lost time at the bottleneck represents lost time for the whole system
3. Increasing the capacity of a non-bottleneck station is a mirage
4. Increasing the capacity of a bottleneck increases the capacity of the whole system

Break-Even 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

Break-Even Analysis

- 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

Break-Even Analysis

- Revenue function begins at the origin and proceeds upward to the right, increasing by the selling price of each unit
- Where the revenue function crosses the total cost line is the break-even point

Break-Even Analysis

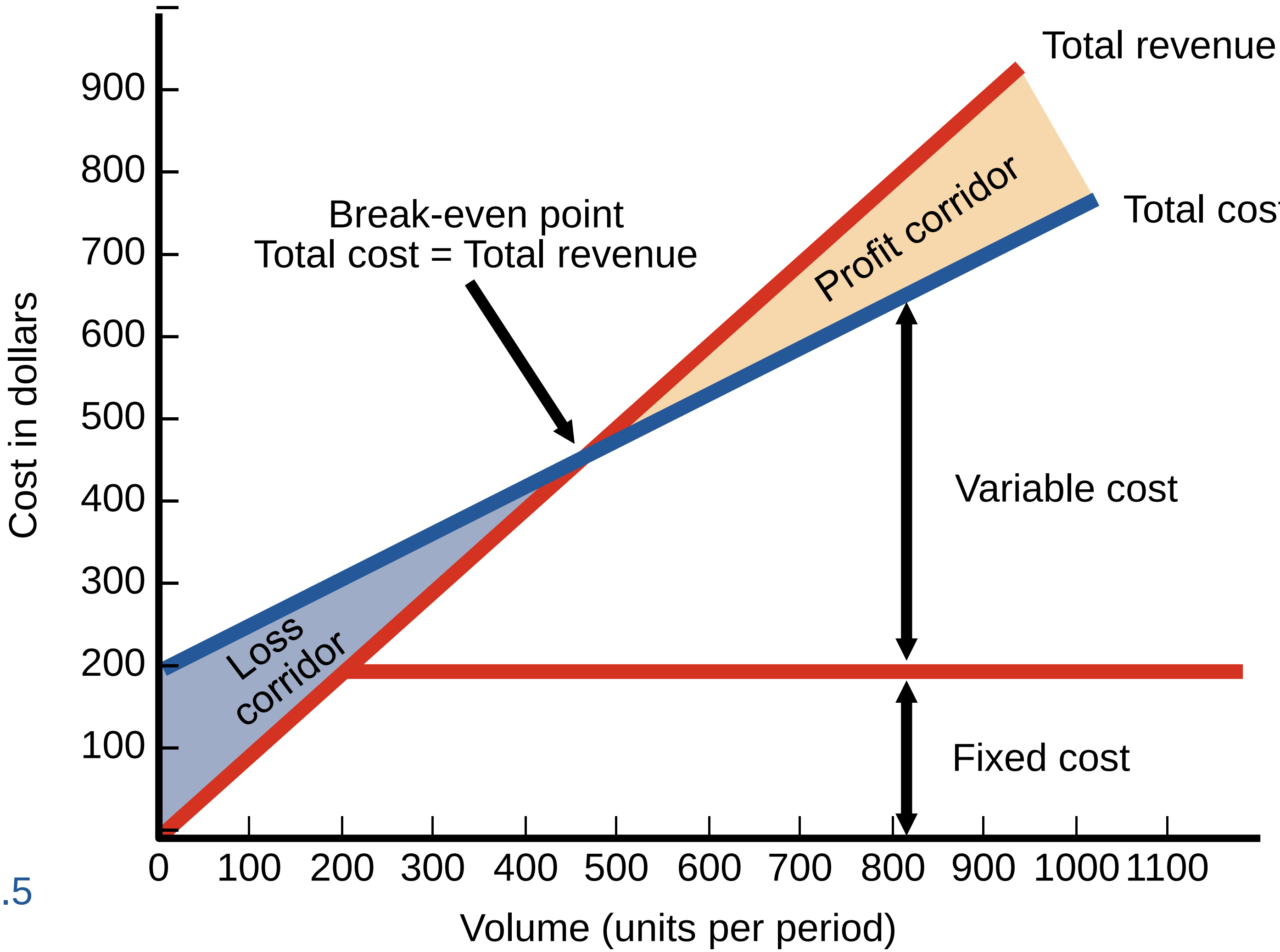


Figure S7.5

Break-Even Analysis

Assumptions

- Costs and revenue are linear functions
  - Generally not the case in the real world
- We actually know these costs
  - Very difficult to verify
- Time value of money is often ignored

Break-Even Analysis

BEP_x = break-even point in units

$BEP_\$$ = break-even point in dollars

P = price per unit (after all discounts)

x = number of units produced

TR = total revenue = Px

F = fixed costs

V = variable cost per unit

TC = total costs = $F + Vx$

Break-even point occurs when

$$TR = TC$$

or

$$Px = F + Vx$$

$$BEP_x = \frac{F}{P - V}$$

Break-Even Analysis

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$BEP_\$$ = break-even point in dollars

P = price per unit (after all discounts)

x = number of units produced

TR = total revenue = Px

F = fixed costs

V = variable cost per unit

TC = total costs = $F + Vx$

$$BEP_\$ = BEP_x P = \frac{F}{P - V} P$$

$$= \frac{F}{(P - V)/P}$$

$$= \frac{F}{1 - V/P}$$

$$\text{Profit} = TR - TC$$
$$= Px - (F + Vx)$$
$$= Px - F - Vx$$
$$= (P - V)x - F$$

Break-Even Example

Fixed costs = $10,000
Direct labor = $1.50/unit
Material = $.75/unit
Selling price = $4.00 per unit

$$BEP_\$ = \frac{F}{1 - (V/P)} = \frac{\$10,000}{1 - [(1.50 + .75)/(4.00)]}$$

$$= \frac{\$10,000}{.4375} = \$22,857.14$$

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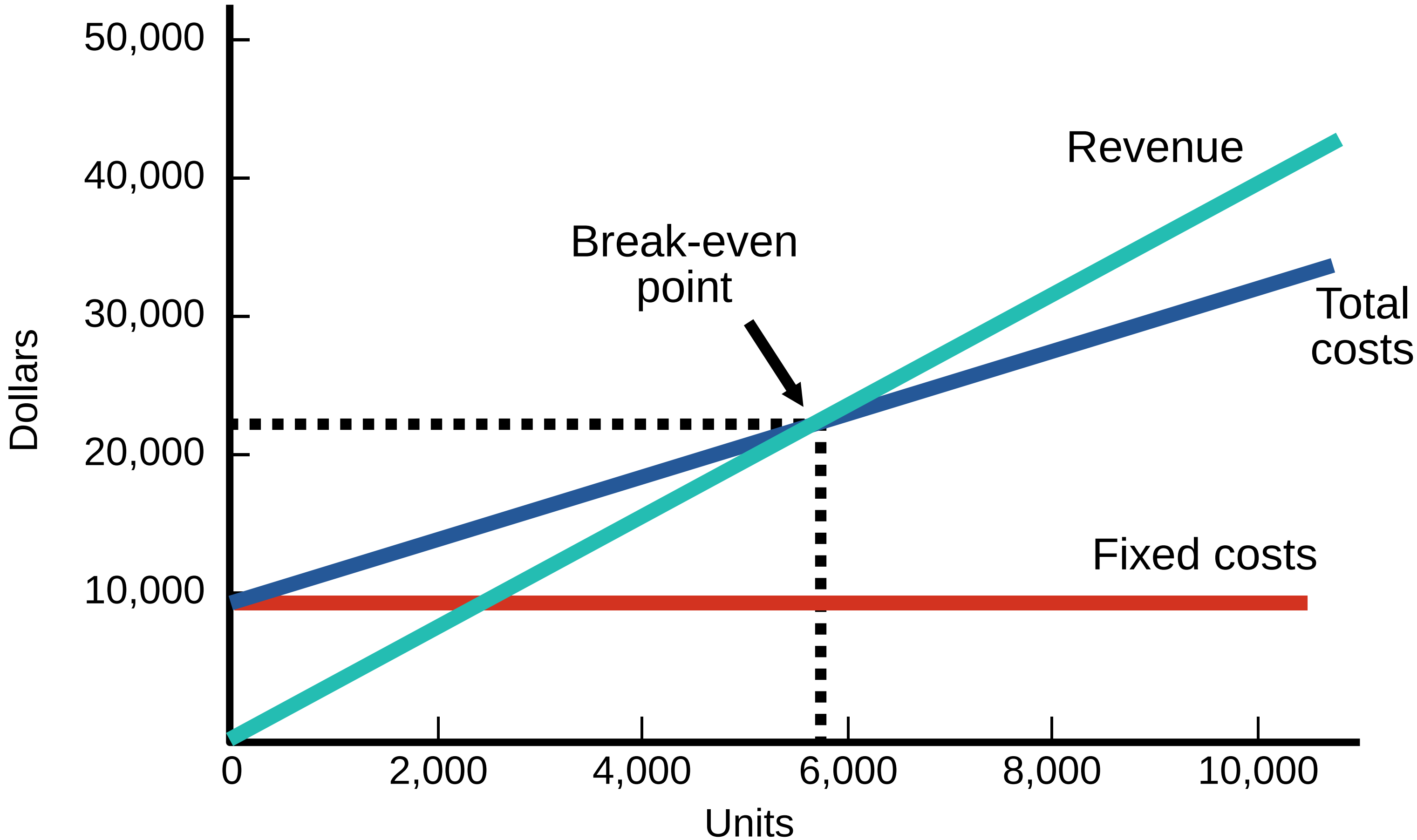
$$= \frac{\$10,000}{.4375} = \$22,857.14$$

$$BEP_x = \frac{F}{P - V} = \frac{\$10,000}{4.00 - (1.50 + .75)} = 5,714$$

Break-Even Example



Break-Even Example

Multiproduct Case

$$\text{Break-even point in dollars } (BEP_{\$}) = \frac{F}{\sum \left[\left(1 - \frac{V_i}{P_i} \right) \times (W_i) \right]}$$

where V = variable cost per unit
P = price per unit
F = fixed costs
W = percent each product is of total dollar sales expressed as a decimal
i = each product

Multiproduct Example

Fixed costs = $3,000 per month

ITEM	PRICE	COST	ANNUAL FORECASTED SALES UNITS
Sandwich	$5.00	$3.00	9,000
Drink	1.50	.50	9,000
Baked potato	2.00	1.00	7,000

1	2	3	4	5	6	7	8
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	$5.00	$3.00	.60	.40	$45,000	.621	.248
Drinks	1.50	0.50	.33	.67	13,500	.186	.125
Baked potato	2.00	1.00	.50	.50	14,000	.193	.097
					$72,500	1.000	.470

Multiprod

Fixed costs = $3,000 p

ITEM	PRICE	COST
Sandwich	$5.00	$3.00
Drink	1.50	.50
Baked potato	2.00	1.00

1	2	3	4				
ITEM (i)	SELLING PRICE (P)	VARIABLE COST (V)	(V/P)				
Sandwich	$5.00	$3.00	.60				
Drinks	1.50	0.50	.33				
Baked potato	2.00	1.00	.50	.50	14,000	.193	.097
					$72,500	1.000	.470

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

$$= \frac{\$3{,}000 \times 12}{.47} = \$76{,}596$$

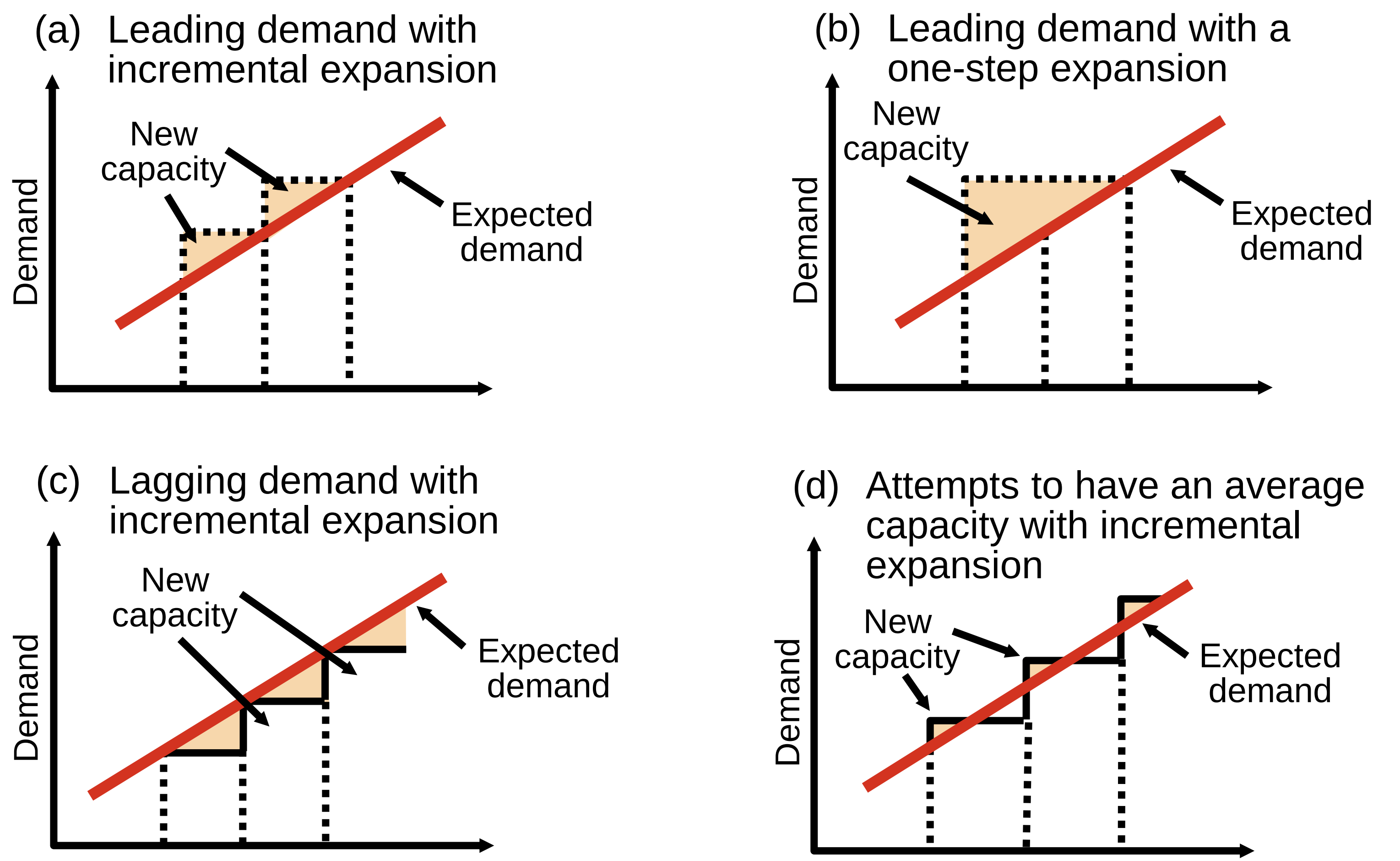
$$\text{Daily sales} = \frac{\$76{,}596}{312 \text{ days}} = \$245.50$$

$$\frac{.621 \times \$245.50}{\$5.00} = 30.5 \approx 31$$

Sandwiches each day

Reducing Risk with Incremental Changes

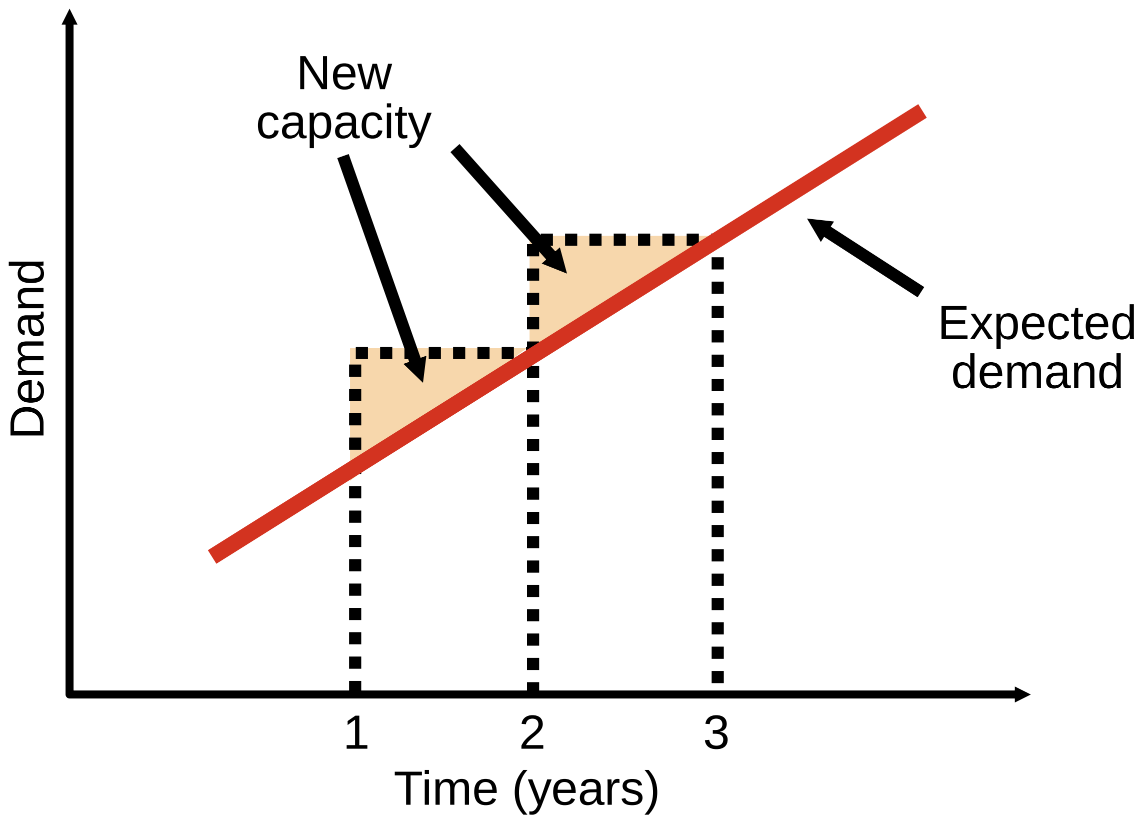
Figure S7.6



Reducing Risk with Incremental Changes

(a) Leading demand with incremental expansion

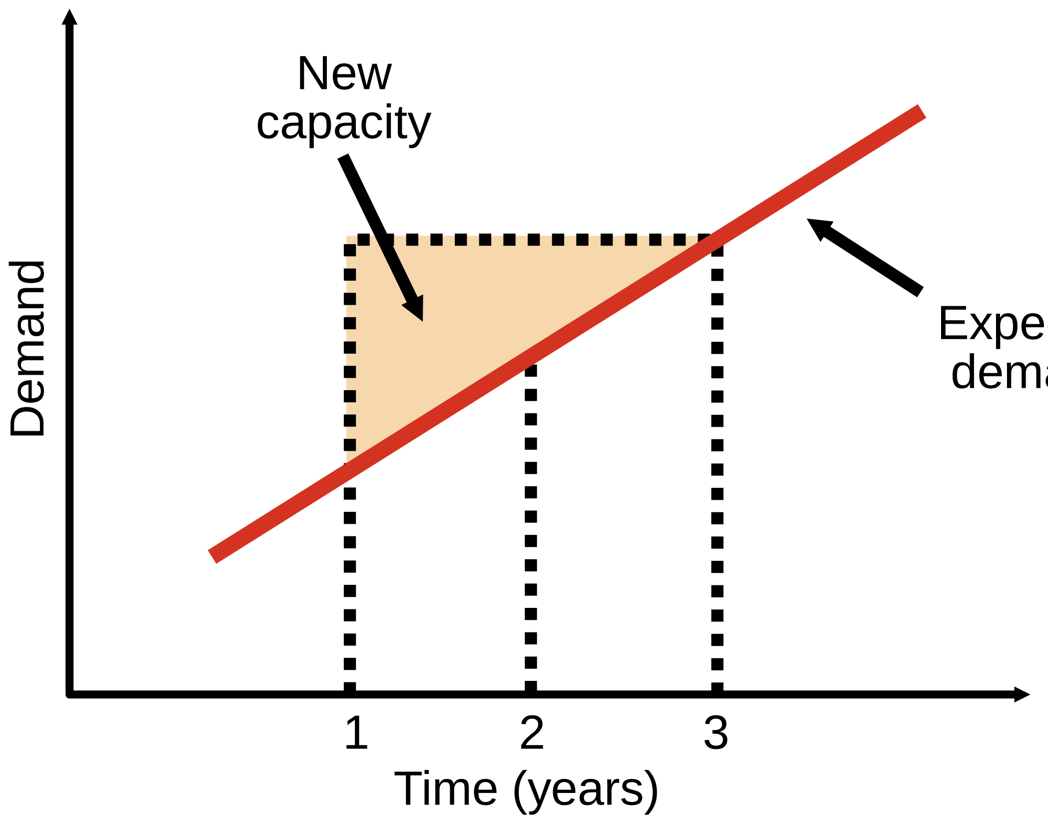
Figure S7.6



Reducing Risk with Incremental Changes

(b) Leading demand with a one-step expansion

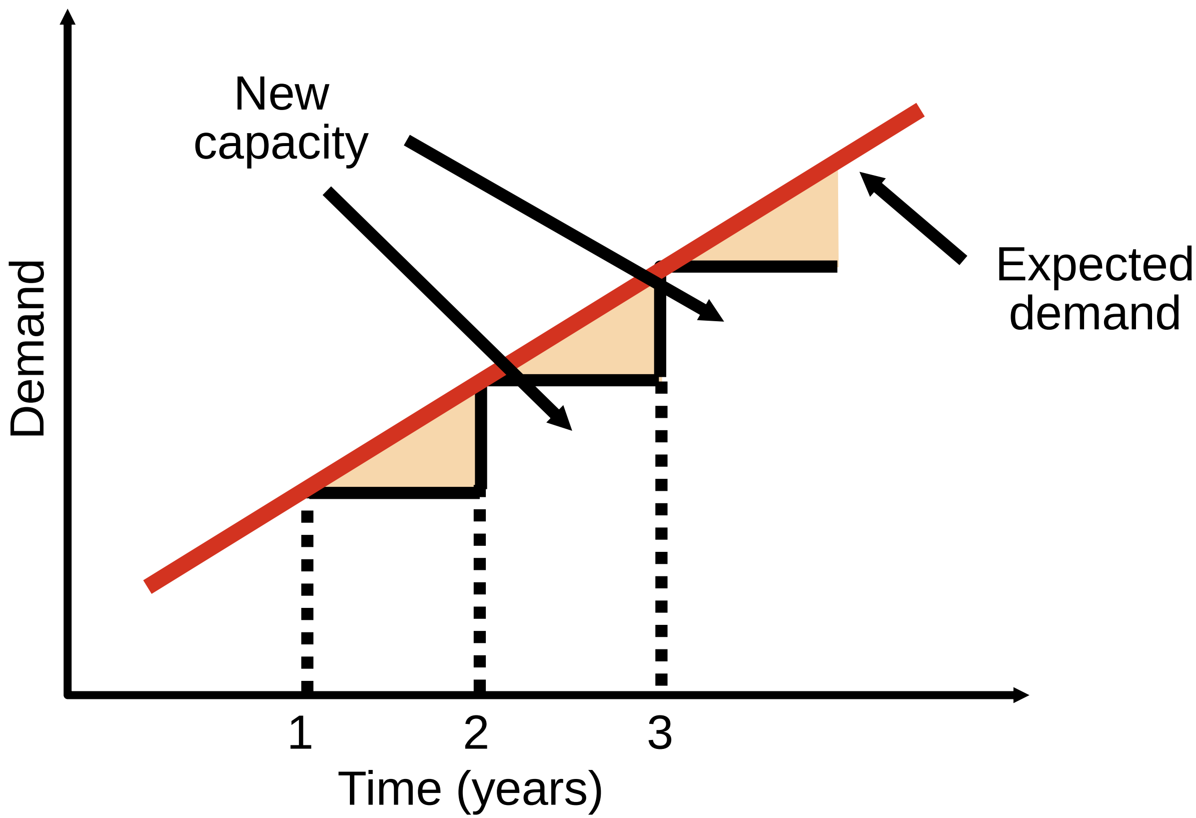
Figure S7.6



Reducing Risk with Incremental Changes

(c) Lagging demand with incremental expansion

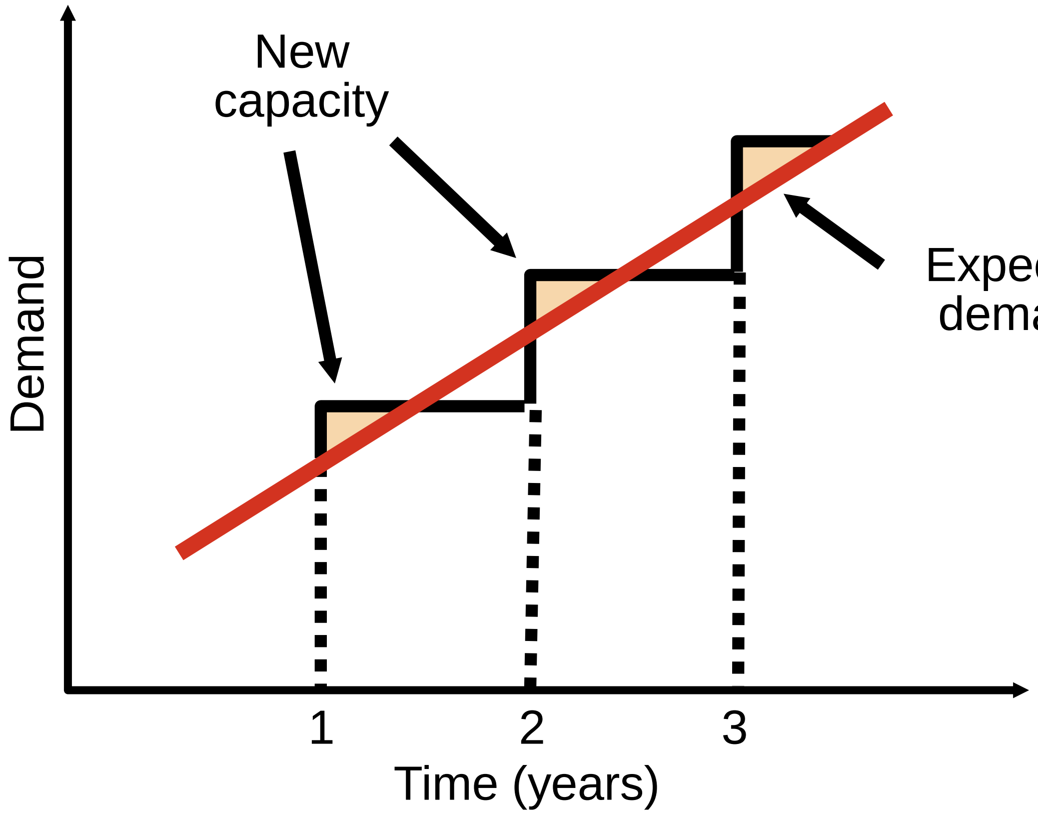
Figure S7.6



Reducing Risk with Incremental Changes

(d) Attempts to have an average capacity with incremental expansion

Figure S7.6



Applying Expected Monetary Value (EMV) and Capacity Decisions

- Determine states of nature
  - Future demand
  - Market favorability
- Assign probability values to states of nature to determine expected value

EMV Applied to Capacity Decision

- Southern Hospital Supplies capacity expansion

EMV (large plant) = (.4)($100,000) + (.6)(–$90,000)
= –$14,000

EMV (medium plant) = (.4)($60,000) + (.6)(–$10,000)
= +$18,000

EMV (small plant) = (.4)($40,000) + (.6)(–$5,000)
= +$13,000

EMV (do nothing) = $0

Strategy-Driven Investment

- Operations managers may have to decide among various financial options
- Analyzing capacity alternatives should include capital investment, variable cost, cash flows, and net present value

Net Present Value (NPV)

In general:

$$F = P(1 + i)^N$$

where

F = future value
P = present value
i = interest rate
N = number of years

Solving for P:

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

Net Present Value (NPV)

In general:

$$F = P(1 + i)^N$$

where F = fu
P = pr
i = in
N = nu

While this works fine, it is cumbersome for larger values of N

Solving for P:

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

NPV Using Factors

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

where X = a factor from Table S7.1 defined as $= 1/(1 + i)^N$ and F = future value

TABLE S7.1	Present Value of $1				
YEAR	**6%**	**8%**	**10%**	**12%**	**14%**
1	.943	.926	.909	.893	.877
2	.890	.857	.826	.797	.769
3	.840	.794	.751	.712	.675
4	.792	.735	.683	.636	.592
5	.747	.681	.621	.567	.519

Portion of Table S7.1

Present Value of an Annuity

An annuity is an investment which generates uniform equal payments

$$S = RX$$

where	X	=	factor from Table S7.2
	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

TABLE S7.2	Present Value of and Annuity of $1				
YEAR	**6%**	**8%**	**10%**	**12%**	**14%**
1	.943	.926	.909	.893	.877
2	1.833	1.783	1.736	1.690	1.647
3	2.676	2.577	2.487	2.402	2.322
4	3.465	3.312	3.170	3.037	2.914
5	4.212	3.993	3.791	3.605	3.433

Portion of
Table S7.2

Present Value of an Annuity

- River Road Medical Clinic equipment investment

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

From Table S7.2
$X = 4.212$

$S = RX$
$S = \$7{,}000(4.212) = \$29{,}484$

Limitations

1. Investments with the same NPV may have different projected lives and salvage values
2. Investments with the same NPV may have different cash flows
3. Assumes we know future interest rates
4. Payments are not always made at the end of a period