Instructor Resource
Venkataraman, *Operations Management, 1e*
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Solutions Manual

Chapter 2: Operations and Supply Chain Strategies

1. Corporate strategy addresses improving economic performance of the firm and value creation for the shareholders. It can be argued that the triple bottom line takes a longer term and more inclusive perspective of value that is not as easily quantified but no less impactful than traditional measures.
Cognitive Domain: Knowledge
Difficulty Level: Easy

2. Adidas includes among its guiding principles, “We are a global organisation that is socially and environmentally responsible, that embraces creativity and diversity and is financially rewarding for our employees and shareholders.” Adidas’s other four principles address strengthening their brand, providing continuous improvement for the customer, helping athletes achieve peak performance, and delivering outstanding financial results. These goals appear to be well considered and in no need of modification at this time.
Cognitive Domain: Analysis
Difficulty Level: Medium

3. Boeing’s customers include airlines and the flying public. Their core competencies include designing and customizing aircraft and multisourcing. Boeing’s operational critical success factors are flexibility (each plane is a snowflake) and coordination of a complex international supply chain. Their product factors recognize that they are dealing with a mature, high-tech product for which traceability is mandated by regulatory agencies. This product must deliver value to industry customers that have historically had thin margins.
Cognitive Domain: Analysis
Difficulty Level: Medium

4. The extra revenue potential from an early start to the Christmas shopping season must be balanced against the disruption in workers’ lives as they are scheduled to work on a traditional holiday. Exposure on social media may drive some customers to the store and drive others away.
Cognitive Domain: Analysis
Difficulty Level: Medium

5. These answers are from the perspective of a U.S. company: a) might impact choices for outsourcing services; b) could delay implementation of green/sustainability initiatives; c) imports may be cheaper so increased outsourcing a possibility; d) could accelerate green/sustainability initiatives; e) could delay implementation of system requiring extensive training or social media components; f) for companies just over the 50-worker level, there might be an incentive to downsize via outsourcing or automation.
Cognitive Domain: Analysis
Difficulty Level: Medium

6. Examples include the following: employees' ability to rapidly design and program; company's ability to partner with streaming services; rollout of super-high-speed Internet in select metropolitan areas; accessibility of broadband in more rural areas; acceptance and adoption of near-universal gaming platform and/or operating system.
Cognitive Domain: Application
Difficulty Level: Medium

7a. In Week 7, labor productivity is 54/2 = 27 tiles/worker.
7b. The floors may have different layouts that require trimming many or very few tiles; some jobs may require patterns rather than just one color tile; accessibility of power, water, or other on-site considerations may facilitate installation in some cases.
Cognitive Domain: Application
Difficulty Level: Medium

8.

$$Birthday\ Party = \frac{150 \times \$10}{\$450 + 50 \times \$10} = \$1.58\ ;\ Wedding\ Reception = \frac{200 \times \$40}{\$2400 + 80 \times \$10} = \$2.50\ ;$$

$$Graduation\ Party = \frac{120 \times \$12}{\$720 + 40 \times \$10} = \$1.29$$

$$Anniversary\ Celebration = \frac{140 \times \$15}{\$140 + 50 \times \$10} = \$1.11$$

Udupi charges the wedding reception client significantly more per plate. On a number-of-meals-served-per-labor-hour basis, the wedding reception is actually the least productive service. For the other three events, the material cost is the factor that makes them more productive or less productive.
Cognitive Domain: Application
Difficulty Level: Medium

9a.

$$US\ Labor = \frac{\$2,500,000}{\$300,000} = 8.33;\ India\ Labor = \frac{\$1,800,000}{\$350,000} = 5.14$$

$$US\ Materials = \frac{\$2,500,000}{\$170,000} = 14.71;\ India\ Materials = \frac{\$1,800,000}{\$120,000} = 15.00$$

$$US\ Equipment = \frac{\$2,500,000}{\$360,000} = 3.01;\ India\ Equipment = \frac{\$1,800,000}{\$200,000} = 2.69$$

Material productivity is nearly identical, but U.S. labor productivity is almost 40% higher, while Indian equipment productivity is 30% higher. Labor productivity may be driven by workforce skill or education, and equipment productivity may be a result of plant modernization, plant layout, or the general level of prices in each country.
9b.

$$US\ Multifactor = \frac{\$2,500,000}{\$300,000 + \$170,000 + \$360,000} = 3.01$$

$$India\ Multifactor = \frac{\$1,800,000}{\$350,000 + \$120,000 + \$200,000} = 2.69$$

Multifactor productivity gives a complete picture and compensates for substitution effects of labor versus capital.
Cognitive Domain: Application
Difficulty Level: Medium

10.

$$August = \frac{\$50,000}{4 \times (10 \times 40 + 6 \times 15)} = \$25.51$$

$$September = \frac{\$62,000}{4 \times (8 \times 40 + 8 \times 10)} = \$32.29$$

$$Productivity\ Increase = \frac{\$32.29 - \$25.51}{\$25.51} = 26.58\%$$

Cognitive Domain: Application
Difficulty Level: Medium

11.

$$Labor\ Productivity = \frac{output}{labor\ hours} = \frac{42}{120 \times workers}$$

$$0.24 = \frac{42}{120 \times workers}$$

$$workers = \frac{42}{120 \times 0.24} = 1.46$$

Cognitive Domain: Application
Difficulty Level: Medium

12.

$$Labor\ Productivity = \frac{output}{labor\ hours} = \frac{280,000\ tiles\ /\ year}{12\ mo\ /\ yr \times 160\ hr\ /\ mo \times workers}$$

$$0.08\ tiles\ /\ hr = \frac{280{,}000\ tiles\ /\ yr}{12\ mo\ /\ yr \times 160\ hr\ /\ mo \times workers}$$

$$workers = \frac{280,000}{12 \times 160 \times 0.08} = 1823$$

Cognitive Domain: Application
Difficulty Level: Medium

13.

Partial Labor Productivity: $\frac{150,000 \text{ units}}{12,000 \text{ hours}} = 12.5 \text{ units/hr}$

Partial Machine Productivity: $\frac{150,000 \text{ units}}{6,000 \text{ hours}} = 25 \text{ units/hr}$

Multifactor Productivity: $\frac{150,000 \text{ units}}{12,000 \times \$20 + 6,000 \times \$15 + \$50,000 + \$18,000 \text{ hours}} = .38 \text{ units/\$}$

Cognitive Domain: Application
Difficulty Level: Medium

14abc.

	Chennai	*Shanghai*	*Brussels*	*Sharjah*
Finished goods in units	15,000	11,000	5,000	8,000
Work-in-process in units	1,500	2,000	700	1800
Labor costs	$10,000	$12,000	$7000	$8000
Material costs	$45,000	$50,000	$60,000	$64, 000
Energy costs	$7,000	$9,000	$10,000	$5,000
Transportation costs	$5,000	$7,500	$11,000	$6,000
Overhead costs	$4,000	$5,500	$8,000	$6,500
Labor Productivity (units/$)	*1.5*	*0.92*	*0.71*	*1.00*
Multifactor Productivity (units/$)	*0.21*	*0.13*	*0.05*	*0.31*

Brussels has the lowest levels of both labor and multifactor productivity.
Cognitive Domain: Application
Difficulty Level: Medium

15.

	2013	*2014*	
Number of units produced	10,000	11,000	
Labor hours used	3000	2900	
Machine hours used	1,000	1,200	
Materials used (pounds)	500	450	
Energy (BTU)	40,000	29,000	*% Improvement*
Labor productivity (units/labor hour)	*3.33*	*3.79*	*13.79%*
Machine productivity (units/machine hour)	*10.00*	*9.17*	*-8.33%*
Material productivity (units/pound)	*20.00*	*24.44*	*22.22%*
Energy productivity (units/BTU)	*0.25*	*0.38*	*51.72%*

Energy productivity shows the greatest percentage improvement.
Cognitive Domain: Application
Difficulty Level: Medium

16.

2013: $\frac{10{,}000 \text{ units}}{3{,}000\times\$12+1{,}000\times\$8+500\times\$6+40{,}000\times\$0.6}=0.141\text{units}/\$$

2014: $\frac{11{,}000 \text{ units}}{2{,}900\times\$12+1{,}200\times\$8+450\times\$6+29{,}000\times\$0.6}=0.171\text{units}/\$$

The percentage change in productivity = $\frac{0.17-0.14}{0.14}$ = 21.43%

Cognitive Domain: Application
Difficulty Level: Medium

17.

$$\frac{\$5\times100+\$3\times50}{40\times10}=1.625\ \$/hour\ \ -or-\ \ \frac{\$5\times100+\$3\times50}{40\times10\times\$15}=0.11\ \$/\$$$

Cognitive Domain: Application
Difficulty Level: Medium

18a. For May: $hours=\frac{output}{workers\times labor\ productivity}=\frac{5000}{250\times.08}=250$

18b. For June: $hours=\frac{output}{workers\times labor\ productivity}=\frac{5000}{250\times.10}=200$

Cognitive Domain: Application
Difficulty Level: Medium

Solutions Manual

Module B: The Transportation Models

1.

To / From	*A*	*B*	*C*	*Capacity*
1	30			30
2	40			40
3	30	30	20	80
Demand	100	30	20	150

The northwest corner rule is optimal at $1,020.
Cognitive Domain: Knowledge
Difficulty Level: Easy

2.

To / From	*A*	*B*	*C*	*Capacity*
1	0	0	14	14
2	1	15	0	16
3	11	0	7	18
Demand	12	15	21	

The total cost is $146.
Cognitive Domain: Knowledge
Difficulty Level: Easy

3.

To	*A*	*B*	*C*	*Capacity*

From				
1	1	0	26	27
2	0	25	0	25
3	23	0	0	23
Demand	24	25	26	75

The total cost is $9,170.
Cognitive Domain: Knowledge
Difficulty Level: Easy

4a.

To / *From*	*X*	*Y*	*Z*	*Capacity*
A	280	20		300
B		200	60	260
C			190	190
Warehouse Demand	280	220	250	750

Northwest corner rule = $9,850

4b.

To / *From*	*X*	*Y*	*Z*	*Capacity*

A	50		250	300
B	40	220		260
C	190			190
Warehouse Demand	280	220	250	750

Matrix least-cost method = $10,310

4c.

To / *From*	*X*	*Y*	*Z*	*Capacity*
A	240	0	60	300
B	40	220	0	260
C	0	0	190	190
Warehouse Demand	280	220	250	750

Optimal solution = $9,170
Cognitive Domain: Comprehension
Difficulty Level: Medium

5a.

To / *From*	*Chennai*	*New Delhi*	*Chandigarh*	*Mill Capacity (in tons)*
Jodhpur	30			30
Bhopal	5	35	5	45

Nagpur			35	35
Warehouse Demand (in tons)	35	35	40	110

Northwest corner rule = $520

5b.

To / *From*	*Chennai*	*New Delhi*	*Chandigarh*	*Mill Capacity (in tons)*
Jodhpur	0	0	30	30
Bhopal	35	0	10	45
Nagpur	0	35	0	35
Warehouse Demand (in tons)	35	35	40	110

Matrix least-cost method = $520

5c.

To / *From*	*Chennai*	*New Delhi*	*Chandigarh*	*Mill Capacity (in tons)*
Jodhpur	0	0	30	30
Bhopal	0	35	10	45
Nagpur	35	0	0	35
Warehouse Demand (in tons)	35	35	40	110

Optimal solution = $485
Cognitive Domain: Comprehension
Difficulty Level: Medium

6a.

To / *From*	*X*	*Y*	*Z*	*Capacity (in truck loads)*
A	40			40
B	10	35		45
C		5	30	35
Demand (in truckloads)	50	40	30	120

Northwest corner rule = $1,910

6b.

To / *From*	*X*	*Y*	*Z*	*Capacity (in truck loads)*
A	15	25		40
B		15	30	45
C	35			35
Demand (in truckloads)	50	40	30	120

Matrix least-cost method = $1,670

6c.

To / *From*	*X*	*Y*	*Z*	*Capacity (in truck loads)*

A	35	5	0	40
B	15	0	30	45
C	0	35	0	35
Demand (in truckloads)	50	40	30	120

Optimal solution = $1,525
Cognitive Domain: Comprehension
Difficulty Level: Medium

7.

To / *From*	*Dallas*	*Erie*	*Fargo*	*Capacity*
Cleveland	$10 400	$4	$12	400
Calgary	$18	$12 700	$8	700
Tucson	$12 100	$10	$14 • 800	• 900
• Demand	• 500	• 700	• 800	• 2000

Tucson to Dallas: +$12 + $12 – $18 – $10 = -$4. Shift 100 units from the Calgary-to-Dallas allocation to the Tucson-to-Dallas route, and move 100 units from the Tucson-to-Erie allocation to the Calgary-to-Erie route. This reduces the cost by $400.
Cognitive Domain: Comprehension
Difficulty Level: Medium

8.

• *To* / *From*	*W*	*X*	*Y*	*Z*	*Capacity*

1	$8 200	$3	$2	$5	200
2	$10 200	$7 200	$6 200	$8	600
3	$9	$4	$4 100	$7 200	300
Demand	400	200	300	200	1,100

Allocating a shipment from 3 to X results in +$4 + $6 – $4 – $7 = -$1, which is an improvement. Shift 100 units from the 3Y allocation to the 3X path, and shift 100 units from the 2X route to the 2Y path. The improvement is $100, from $8,000 to $7,900.
Cognitive Domain: Comprehension
Difficulty Level: Medium

9.

$$Min\ Cost = \$5DL + \$4DCl + \$3DCh + \$8ML + \$4MCl + \$3MCh + \$9CoL + \$7CoCl + \$5CoCh$$

subject to:

$$DL + DCl + DCh = 1000$$

$$ML + MCL + MCh = 3000$$

$$CoL + CoCl + CoCh = 3000$$

$$DL + ML + CoL = 3000$$

$$DCl + MCl + CoCl = 2000$$

$$DCh + MCh + CoCh = 2000$$

All variables ≥ 0
Cognitive Domain: Analysis
Difficulty Level: Medium

10.

$$Min\ Cost = \$5JCe + \$5JNd + \$4JCa + \$6BCe + \$4BNd + \$5BCa + \$5NaCe + \$4NaNd + \$5NaCa$$

$$subject\ to:$$

$$JCe + JNd + JCa = 30$$

$$BCe + BNd + BCa = 45$$

$$NaCe + NaNd + NaCa = 35$$

$$JCe + BCe + NaCe = 35$$

$$JNd + BNd + NaNd = 35$$

$$JCa + BCa + NaCa = 40$$

$$all\ variables \geq 0$$

Cognitive Domain: Analysis
Difficulty Level: Medium

11. A Cleveland plant has an optimal system cost of $37,400.

	Warehouse				
Plant	*Boston*	*Tucson*	*Denver*	*Dummy*	*Capacity*
Chicago	0	0	190	10	200
Baton Rouge	0	110	0	40	150
Cleveland	160	140	0	0	300
Demand	160	250	190	50	

An Atlanta plant has an optimal system cost of $43,600; Hari should choose Cleveland.

	Warehouse				
Plant	*Boston*	*Tucson*	*Denver*	*Dummy*	*Capacity*
Chicago	0	0	190	10	200
Baton Rouge	0	110	0	40	150

Atlanta	160	140	0	0	300
Demand	160	250	190	50	

Cognitive Domain: Analysis
Difficulty Level: Medium

12.

To / *From*	*Erie*	*Franklin*	*Venango*	*Supply Available*
Energy efficient			400	400
Northeast gas		350		350
Western gas	500			500
Dummy gas		50		50
Demand	500	400	400	

A dummy supply source is needed to balance supply and demand. The total cost is $20,850.
Cognitive Domain: Comprehension
Difficulty Level: Medium

13.

To / *From*	*Buffalo*	*Atlanta*	*New Orleans*	*Seattle*	*Capacity*
Colorado Springs	1,500	2,500		500	4,500
Dayton		1,500	3,500		5,000

Dummy Springs				1,500	1,500
Demand	1,500	4,000	3,500	2,000	

A dummy supply source is required to balance the model; the optimal cost is $386,000.
Cognitive Domain: Comprehension
Difficulty Level: Medium

14.

To / *From*	*Cleveland*	*Orlando*	*Denver*	*San Diego*	*New York*	*Mill Capacity (in tons)*
San Jose	0	0	25	20	0	45
Dayton	25	20	5	0	0	50
Boston	0	0	5	0	30	35
Demand (in tons)	25	20	35	20	30	130

The optimal cost is $1,065.
Cognitive Domain: Comprehension
Difficulty Level: Medium

15.

$$Min\ Cost = \$15SjCl + \$21SjOr + \$13SjDe + \$10SjSd + \$22SjNy +$$
$$\$3DaCl + \$11DaOr + \$9DaDe + \$21DaSd + \$7DaNy +$$
$$\$4BoCl + \$12BoOr + \$10BoDe + \$25BoSd + \$5BoNy$$
$$subject\ to:$$
$$SjCl + SjOr + SjDe + SjSd + SjNy = 45$$
$$DaCl + DaOr + DaDe + DaSd + DaNy = 50$$
$$BoCl + BoOr + BoDe + BoSd + BoNy = 50$$
$$SjCl + DaCl + BoCl = 25$$
$$SjOr + DaOr + BoOr = 20$$
$$SjDe + DaDe + BoDe = 35$$
$$SjSd + DaSd + BoSd = 20$$
$$SjNy + DaNy + BoNy = 30$$
$$all\ variables \geq 0$$

Cognitive Domain: Analysis
Difficulty Level: Medium

16.

	Destinations			
Existing Plants	*Miami*	*Seattle*	*Houston*	*Capacity*
Raleigh	60	290	0	350
Akron	0	0	250	250
Cedar Rapids	50	0	150	200
Atlanta	200	0	0	
Demand	310	290	400	

The optimal cost is $22,730.

	Destinations			
Existing Plants	*Miami*	*Seattle*	*Houston*	*Capacity*

Raleigh	60	290	0	350
Akron	0	0	250	250
Cedar Rapids	50	0	150	200
Mobile	200	0	0	200
Demand	310	290	400	

The optimal cost is $23,130.
Add the plant in Atlanta.
Cognitive Domain: Analysis
Difficulty Level: Medium

17. The condition is degeneracy, and it can be overcome by creating an artificially occupied cell that allows a complete path to be traced. Placing a negligible amount in the Calgary-to-Dallas route permits application of the stepping stone method.

To / *From*	*Dallas*	*Erie*	*Fargo*	*Capacity*
Cleveland	$9 400	$6	$10	400
Calgary	$20 **0**	$10 700	$8 200	900
Tucson	$14	$16	$15 600	600
Demand	400	700	800	2,000

The optimal solution costs $18,600.

To / *From*	*Dallas*	*Erie*	*Fargo*	*Capacity*

Cleveland	$9 0	$6 400	$10 0	400
Calgary	$20 0	$10 100	$8 800	900
Tucson	$14 400	$16 200	$15 0	600
Demand	400	700	800	2,000

Cognitive Domain: Analysis
Difficulty Level: Hard

18.

To / *From*	*W*	*X*	*Y*	*Z*	*Capacity*
1	$7 200	$4	$3	$6	200
2	$9 200	$8 200	$5	$7	400
3	$8 **0**	$5	$4 300	$6 200	500
Demand	400	200	300	200	1,100

Add a negligible amount to the 3W shipping route to permit completion of the stepping stone analysis. One improvement would be to divert a shipment to the 1X cell, which improves the solution by $400.

To / From	W	X	Y	Z	Capacity
1	$7 0	$4 200	$3	$6	200
2	$9 400	$8 0	$5	$7	400
3	$8 **0**	$5	$4 300	$6 200	500
Demand	400	200	300	200	1,100

Cognitive Domain: Analysis
Difficulty Level: Hard

19a. The matrix is unbalanced, so a dummy source must be added as Plant 6 with a capacity of 200.

To / From	Warehouse					Capacity
	A	B	C	D	E	
Plant-1	400	400	400			1,200
Plant-2	1000			500		1,500
Plant-3				900		900
Plant-4		200			900	1,100

Plant-5			1300			1,300
Plant-6		200				200
Demand	1400	800	1700	1400	900	6,000 6,200

19b.The minimum cost solution is $37,800.

To / *From*	*Warehouse*					
	A	*B*	*C*	*D*	*E*	*Capacity*
Plant-1	400				800	1,200
Plant-2	100			1,400		1,500
Plant-3	900					900
Plant-4		800	200		100	1,100
Plant-5			1,300			1,300
Plant-6		200	200			200
Demand	1,400	800	1700	1400	900	6,000 6,200

Cognitive Domain: Analysis
Difficulty Level: Hard

20.

$$Min\ Cost = \$10A1 + \$9B1 + \$12C1 + \$8D1 + \$6E1 +$$
$$\$7A2 + \$12B2 + \$9C2 + \$5D2 + \$7E2 +$$
$$\$6A3 + \$5B3 + \$8C3 + \$4D3 + \$9E3 +$$
$$\$13A4 + \$7B4 + \$10C4 + \$8D4 + \$5E4 +$$
$$\$8A5 + \$11B5 + \$6C5 + \$10D5 + \$12E5 +$$
$$\$0A6 + \$0B6 + \$0C6 + \$0D6 + \$0E6$$

subject to:

$$A1 + B1 + C1 + D1 + E1 = 1200$$
$$A2 + B2 + C2 + D2 + E2 = 1500$$
$$A3 + B3 + C3 + D3 + E3 = 900$$
$$A4 + B4 + C4 + D4 + E4 = 1100$$
$$A5 + B5 + C5 + D5 + E5 = 1300$$
$$A6 + B6 + C6 + D6 + E6 = 200$$
$$A1 + A2 + A3 + A4 + A5 + A6 = 1400$$
$$B1 + B2 + B3 + B4 + B5 + B6 = 800$$
$$C1 + C2 + C3 + C4 + C5 + C6 = 1700$$
$$D1 + D2 + D3 + D4 + D5 + D6 = 1400$$
$$E1 + E2 + E3 + E4 + E5 + E6 = 900$$
$$all\ variables \geq 0$$

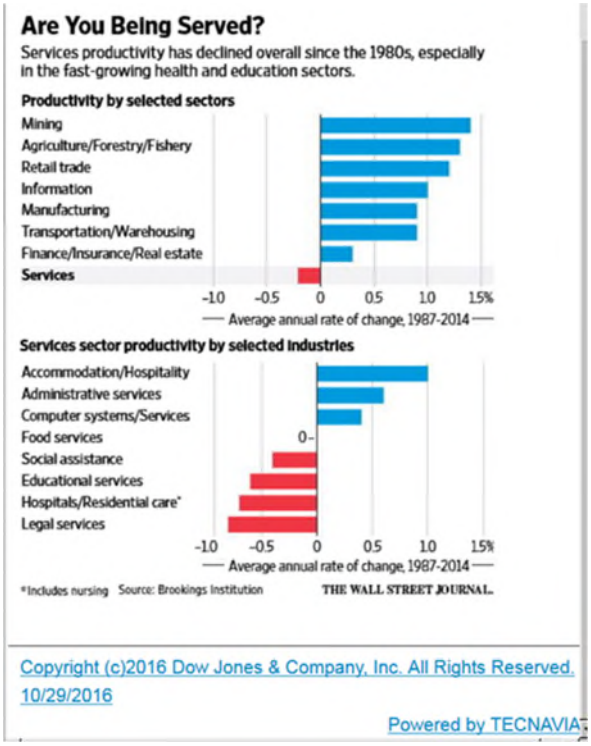
Cognitive Domain: Analysis
Difficulty Level: Hard

Class Activities

Chapter 2: Operations and Supply Chain Strategies

Activity 1: Small Group Activity
Learning Objective: Compare the different types of productivity measurements and explain how firms use them strategically

Have each student find two other classmates to form a group. Provide each group a copy of the charts below. Discuss among each other in the group what does the decline in services productivity mean to them personally and professionally. Brainstorm with each other in the group on specific operations and supply chain strategies that may reverse the declining trend, especially in the health and education sectors. Report the work of the group to the whole class.



Activity 2: Individual Exercise
Learning Objective: Identify the key capabilities firms need to formulate and implement global operations and supply chain strategies and manage the risks related to them.

Have each student find a company he/she likes. Discuss to what extent the company is successful in pursuing one or more of the five competitive priorities. Select several students to share their work with the rest of the class.

Activity 3: Online Activity
Learning Objective: Describe how both manufacturers and service organizations formulate and evaluate their supply chain strategies

Have students watch the video, "Inside Amazon: Drones at Your Doorstep" (https://youtu.be/ZxrzIXkPycs). Write about the operations and supply chain strategies that account for Amazon's success. Post the writing as an entry in the discussion board. Each student will make comments on three other students' posting afterwards.

Lecture Notes

Chapter 2: Operations And Supply Chain Strategies

Learning Objectives

- Compare the different levels of strategic planning and identify the performance measures in each.
- Define operations strategy and describe how it is formulated and evaluated.
- Contrast the formulation and evaluation of operating strategies for service organization with those for manufacturing organizations.
- Compare the different types of productivity measurements and explain how firms use them strategically.
- Describe how both manufacturers and service organizations formulate and evaluate their supply chain strategies.
- Identify the key capabilities firms need to formulate and implement global operations and supply chain strategies and manage the risks related to them.
- Describe what companies are doing to incorporate sustainability into their supply chain strategy and the problems they face in doing so.

Operations Profile: Pfizer's Revamped Supply Chain Strategy Saves The Company Millions

- Pfizer set up a centralized procurement department and a team to examine the services the firm buys.
- Called the Knowledge Management Services (KMS) Group, it saved Pfizer a whopping $370 million between 2007 and 2010.
- The KMS team concentrated on consulting services and legal services.
- To develop a disciplined approach to using consulting services at Pfizer, the team created a process to review, classify, and approve outside consultants.

Strategic Planning Levels

- See Figure 2.1: Strategic Planning Levels

Corporate Strategy

- A corporate strategy attempts to address the fundamental question of what industries and markets the organization should enter and compete in.
- Corporate strategic planning is the broadest in scope (highest level in the hierarchy), has a long-term time horizon and establishes the overall goals and directions for the corporation as a whole.
- Decisions made at this level include what businesses to acquire or divest, whether or not to acquire suppliers or distributors, and how to allocate resources between the different units.

Sustainability

- Companies are increasingly considering sustainability when in their corporate strategies.
- There are three performance targets that measure sustainability, i.e. triple bottom line.
- A firm's triple bottom line includes not only the economic value it provides its shareholders, but the environmental and social value the company creates.
- Three overlapping components of sustainability are economic, environmental, and social value.

The Triple Bottom Line

- See Figure 2.2: The Triple Bottom Line

Business-Unit Strategies

- For corporations that own a portfolio of businesses, each needs a business-unit strategy.
- Each of these businesses is typically referred to as a Strategic Business Unit, or SBU.
- A business-unit strategy establishes how each business unit should compete within its particular industry or market.
- The core competencies of the SBUs refer to the activities they excel at, or strive to excel at.

Functional Strategies

- Functional strategies should coordinate and integrate the activities and resources within each functional area, e.g. marketing, operations, finance, and accounting.

- Functional strategies are developed and implemented at a lower level in the corporate hierarchy, have shorter time horizons, and are more specific and detailed in terms of their action plans than the higher-level business strategies.

Formulating And Evaluating Operations Strategies

- The purpose of a firm's operations strategy is to use the company's operational resources effectively to help it achieve a competitive advantage.
- An operations strategy, which provides the roadmap for all of the decisions managers of the firm's operations function make, is usually formulated in terms of the competitive priorities or core competencies of the firm, such as its ability to compete on prices and costs, quality, flexibility, time (speed), and innovation.

Critical Elements Of An Operations Strategy

- An operations strategy has four critical elements: customers, operational capabilities or critical success factors (CSFs), product factors, and core competencies that can enable a company to achieve competitive advantage.
- Operations can come up with product-related features that customers most value or production technologies and processes that competition can't easily imitate.

The Four Elements Of An Operations Strategy

- See Figure 2.3: The Four Elements of an Operations Strategy

Product Factors

- Product factors include the nature of the product, its stage in the product life cycle, and the process used to produce that product.
- The nature of the product refers to the distinctive features or characteristics that identify the good or service.
- Products that are in the mature stages of their life cycles require different core competencies.
- Streamline the processes enables a firm to make the delivery of the products more efficient.

Customers

- The ultimate aim of operations and supply chain strategies is to produce and deliver those products or services that not only satisfy, but actually delight customers, the people and groups who consume a firm's products or services.
- Each downstream partner of that firm in the supply chain is also a customer.
- For example, you may be the end-user of the Crest toothpaste produced by Proctor & Gamble (P&G), but a retail store such as Walmart is also an intermediate customer.

Critical Success Factors

- Every industry has some unique strategic factors, such as resources or capabilities, which affect a company's ability to successfully compete.
- These elements are called critical success factors (CSFs).
- Each firm should determine its own CSFs based on what's important to the customers in the target market.
- CSFs can originate from superior technology, operations and processes, logistics and distribution capabilities, marketing channels, etc.

Core Competencies

- Core competencies are skills or key areas of expertise that a company has developed over time that distinguish the company from its competitors on the satisfaction of the costumer's needs.
- There are five core competencies: price, quality, time, innovation, and flexibility.
- A company cannot excel in all five core competencies. Therefore, a company has to identify a subset of these core competencies that it can be good at, and develop and nurture it.

Two Ways To Compete Based On The Price

- One is to produce the product at a lower cost than the company's competitors.
- For commodity products the firm can try to achieve economies of scale that drive the production down.
- If the product offering is not a commodity, then the firm should try lowering the cost of raw materials or labor.
- The second way a firm can compete on price is to be willing to accept a smaller profit margin.

- Wal-Mart, for example, operates with lower profit margins by selling its products at low prices.

Quality

- Quality describes product's fitness for use depending upon the price the customer is willing to pay for it.
- The eight most common characteristics of quality are: performance, conformance, features, durability, reliability, serviceability, aesthetics, and perceived quality.
- Competing simultaneously on the basis of all eight quality dimensions would be very expensive and difficult.
- The nature of the product might force the company to make trade-offs among them.

Time

- Time as a core competency has three attributes:
- Product development cycle time: the time it takes to conceptualize a new good or service, produce it, and make it available to customers.

- 2. On-time delivery: firm's ability to deliver the products to its customers on or before the promised delivery date.
- 3. Delivery speed: the ability to deliver the product or service faster than the rest of the competition that can be a competitive advantage.

Innovation

- Innovation is the process of implementing new ideas or changes that create value for customers.
- Product innovation is the development and introduction of a brand new product or service or the improvement of an existing product or service through design changes or through the use of new components and materials.
- Process innovation refers to the changes in the way in which product is produced or a service is delivered within the firm or across a supply chain.

Flexibility

- Flexibility is a firm's ability to produce a range of different products or services or to respond efficiently to changes in demand.

- An order winner is a competitive criterion (core competence) of a product that causes a customer to choose it instead of a competitor's product.
- An order qualifier is a competitive criterion that must be present in a product for it to be a viable competitor in the marketplace.

Relationship Between Structural And Infrastructural Decisions

- See Figure 2.4: An Operations Strategy Framework

Evaluating The Performance Of An Operations Strategy

- The Strategic Profit Model (SPM or DuPont model) provides a visual representation of an organization's financial performance.
- The Balanced Scorecard includes strategic nonfinancial performance measures in addition to the traditional financial metrics.
- Balanced Scorecard focuses on four critical areas:
- Learning and Growth
- Business Processes
- Customer
- Financial

Strategic Framework For Service Operations

- See Figure 2.6: Strategic Framework for Service Operations

2.3 Formulating And Evaluating Strategies For Service Organizations

- Strategic Positioning: Identifying the target market
- Formulating the Service Operations Strategy
- The Service Design
- 2. The Service Operations System
- 3.The Service Delivery System
- Tactical Execution: the day-to-day activities required to support the service strategy.

Continuous Service Improvement

- Plan, Do, Check, Act (PDCA):

- Plan: Recognize an opportunity for improvement and plan for a change.
- Do: Test the change by implementing a small-scale pilot study.
- Check: Review and analyze the results of the test and identifying the lessons learned.
- Act: Take action based on what was learned from the previous step.

2.4 Measuring Productivity As Part Of Strategic Planning

- In the context of operations, productivity is the ratio of outputs (goods and services) produced to the inputs used.
- The single-factor productivity measure uses a single input in the ratio.
- Multifactor productivity is a productivity measure that uses all of the relevant inputs used to make the product or provide the service.
- In the context of operations, productivity is the ratio of outputs (goods and services) produced to the inputs used.
- The single-factor productivity measure uses a single input in the ratio.
- Multifactor productivity is a productivity measure that uses all of the relevant inputs used to make the product or provide the service.

Formulating Supply Chain Strategies

- What is the nature and number of operating facilities needed?
- What suppliers and how many are needed?
- What work should be outsourced or offshored?
- What type of relationships should the firm have with its suppliers?
- What should the distribution network be and how should it be managed?

A Decision Framework For Formulating A Supply Chain Strategy

- See Figure 2.7: A Decision Framework for Formulating a Supply Chain Strategy

The Supply Chain Operations Reference (SCOR) Model

- See Figure 2.8: The Supply Chain Operations Reference (SCOR) model

2.6 Global Operations And Supply Chain Strategies

- An effective global, integrated sales and operations planning process for key markets

- A procurement, manufacturing, distribution, and research and development network
- Tight links with their customers and suppliers so that they can better predict the demand for their products
- Logistics partnerships to ensure the firm's efforts to source products to low-cost markets
- The ability to effectively recruit low-cost suppliers
- A "go-to-market" strategy, which is a firm's plan to provide value to its customers

Integrating Operations And Supply Chain Strategies

- Companies that have experienced greater success integrating their operations and supply chains globally have developed three capabilities:
- Supply chain adaptability, which is the ability of the supply chain to respond to changes
- Financial-engineering capabilities, which is the ability to create new financial instruments
- Risk anticipation and mitigation capabilities, which refers to anticipating events that could disrupt global operations

Risk Management Strategies

- Many unforeseen events can disrupt operational and supply chain activities
- A firm's operations should have a risk management program that can anticipate uncontrollable events
- Corporations are working closely with their suppliers to safeguard their supply chains against future breakdowns.
- Businesses should also be concerned about disruptions to operations and supply chains from safety and security problems

Chapter 2: Operations And Supply Chain Strategies

Practice Problems

Multiple Choice

1. Edward entered an oyster shucking contest. He shucked 360 oysters in four hours. What was his productivity?
a. 180 oysters/hour
b. 360 oysters/hour
c. 90 oysters/hour
d. 75 oysters/hour
Ans: C
Difficulty Level: Easy

2. Elena entered an oyster shucking contest and she shucked 320 oysters in three hours and fifteen minutes. What was her productivity?
a. 106.7 oysters/hour
b. 101.6 oysters/hour
c. 98.5 oysters/hour
d. 91.4 oysters/hour
Ans: C
Difficulty Level: Easy

NARRBEGIN: 1
Use the following information to answer questions 3-4.

Jenken's Hardware maintains a large inventory. The manager wants to see if providing a rest break would be more productive for workers who stack inventory. She runs an experiment with a worker. She has a worker stack boxes for four hours straight on one day. The next day the same worker stacked boxes for the same four hour period, but took a half-hour break. In the first case, the worker stacked 650 boxes while on the second day the worker stacked 640 boxes.
NARREND

3. What was the productivity on the first day?
a. 150.0 boxes/hour
b. 156.3 boxes/hour
c. 162.5 boxes/hour
d. 182.9 boxes/hour
Ans: C
Difficulty Level: Easy
NAR: 1

4. What was the productivity on the second day?
a. 150.0 boxes/hour
b. 156.3 boxes/hour
c. 162.5 boxes/hour
d. 182.9 boxes/hour
Ans: D
Difficulty Level: Easy

NARRBEGIN: 2
Use the following information to answer questions 5-6.

A freight delivery service is looking at the impact of allowing overtime in their packing-sorting department. For a week they measured the average number of packages sorted during a regular eight hour shift. The next week they measured the average number of packages sorted during a regular shift with two hours of overtime. During the first week (just regular time), the average number of packages sorted was 1,250. During the second week (regular time with overtime), the average number of packages sorted was 1,500.
NARREND

5. What was the productivity during the first week?
a. 125.0 packages/hour
b. 150.0 packages/hour
c. 156.3 packages/hour
d. 187.5 packages/hour
Ans: C
Difficulty Level: Easy
NAR: 2

6. What was the productivity during the second week?
a. 125.0 packages/hour
b. 150.0 packages/hour
c. 156.3 packages/hour
d. 187.5 packages/hour
Ans: B
Difficulty Level: Easy

NARRBEGIN: 3
Use the following information to answer questions 7-11.

Rocket Fuel Energy Drink is sponsoring local push-up contests. They look at the maximum number of push-ups a contestant can do. They also measure how long it takes the contestant to do their maximum number of push-ups. Winners are decided by the number of push-ups per minute. Four teenagers entered the contest: Jake did 75 push-ups in 9 minutes, Bill did 82 push-ups in 9.5 minutes, Alice did 101 push-ups in 10 minutes and 12 seconds, and Ivan did 125 push-ups in 12 minutes.
NARREND

7. What was Jake's score?
a. 8.33 push-ups/minute
b. 8.63 push-ups/minute
c. 9.90 push-ups/minute
d. 10.42 push-ups/minute
Ans: A
Difficulty Level: Easy
NAR: 3

8. What was Bill's score?
a. 8.33 push-ups/minute
b. 8.63 push-ups/minute
c. 9.90 push-ups/minute
d. 10.42 push-ups/minute
Ans: B
Difficulty Level: Easy

9. What was Alice's score?
a. 8.33 push-ups/minute
b. 8.63 push-ups/minute
c. 9.90 push-ups/minute

d. 10.42 push-ups/minute
Ans: C
Difficulty Level: Easy

10. What was Ivan's score ?
a. 8.33 push-ups/minute
b. 8.63 push-ups/minute
c. 9.90 push-ups/minute
d. 10.42 push-ups/minute
Ans: D
Difficulty Level: Easy

11. Who won the contest?
a. Alice
b. Bill
c. Ivan
d. Jake
Ans: C
Difficulty Level: Medium

12. Louise Bragan has a sideline business of carving candlestick holders. She began by hand carving them with simple tools. On average it costs $150 in materials, and miscellaneous costs ran $50 to produce 1,300 candlestick holders. She estimates that her labor cost was $200. What was her multifactor productivity to produce candlestick holders?
a. 3.00 holders/$
b. 3.15 holders/$
c. 3.25 holders/$
d. 3.42 holders/$
Ans: C
Difficulty Level: Medium

13. Louise Bragan has a sideline business of carving candlestick holders. She began by hand carving them with simple tools. Now, in order to improve productivity, she has purchased a professional dremel to assist with the carving. On average it now costs her $150 in materials, and miscellaneous costs run $50 to produce 2,400 candlestick holders. She estimates that her labor cost was $200 and that the capital cost of using the new dremel was $300. What was her multifactor productivity to produce candlestick holders?
a. 3.00 holders/$
b. 3.15 holders/$
c. 3.25 holders/$
d. 3.42 holders/$
Ans: D
Difficulty Level: Medium

NARRBEGIN: 4
Use the following information to answer questions 14-16.

NASA is supporting a program to develop an electric power small personal aircraft. They put out a Request for Proposal to several electric engine manufacturers. Three companies submitted proposals. The Cyclone engine produces 100 horsepower with a 25 kilowatt power pack. The Tornado engine produces 120 horsepower with a 40 kilowatt power pack. The Typhoon engine produces 150 horsepower with a 45 kilowatt power pack.
NARREND

14. What was the productivity of the Cyclone engine?
a.0.75 hp/kw

b. 3.00 hp/kw
c. 3.33 hp/kw
d. 4.00 hp/kw
Ans: D
Difficulty Level: Easy
NAR: 4

15. What was the productivity of the Tornado engine?
a. 0.75 hp/kw
b. 3.00 hp/kw
c. 3.33 hp/kw
d. 4.00 hp/kw
Ans: B
Difficulty Level: Easy

16. What was the productivity of the Typhoon engine?
a.0.75 hp/kw
b. 3.00 hp/kw
c. 3.33 hp/kw
d. 4.00 hp/kw
Ans: C
Difficulty Level: Easy

NARRBEGIN: 5
Use the following information to answer questions 17-20.

Decorative Designs produces architectural moldings. Their most popular moldings come in either plastic or plaster. Plastic moldings are made in batches of 600 units, while the batch size of plaster moldings is only 500. The costs for producing batches of the molding are given below:

	Labor	Materials	Energy	Capital	Miscellaneous
Plastic	**$10**	**$30**	**$25**	**$40**	**$15**
Plaster	**$45**	**$15**	**$20**	**$20**	**$10**

NARREND

17. What is the productivity for Plastic moldings?
a. 3.5 units/$
b. 4.0 units/$
c. 4.5 units/$
d. 5.0 units/$
Ans: D
Difficulty Level: Medium
NAR: 5

18. What is the productivity for Plaster moldings?
a. 3.5 units/$
b. 4.0 units/$
c. 4.5 units/$
d. 5.0 units/$
Ans: C
Difficulty Level: Medium

19. Decorative Designs sells the plastic moldings for $5.00 a piece and the Plaster moldings for $6.25 a piece. What is the revenue productivity for the plastic moldings?

a. 17.63 $ revenue/$ cost

b. 23.42 $ revenue/$ cost
c. 25.00 $ revenue/$ cost
d. 28.41 $ revenue/$ cost
Ans: C
Difficulty Level: Medium

20. Decorative Designs sells the plastic moldings for $5.00 a piece and the Plaster moldings for $6.25 a piece. What is the revenue productivity for the plaster moldings?

a. 17.63 $ revenue/$ cost
b. 23.42 $ revenue/$ cost
c. 25.00 $ revenue/$ cost
d. 28.41 $ revenue/$ cost
Ans: D
Difficulty Level: Medium

NARRBEGIN: 6
Use the following information to answer questions 21-25.

Sporting Life Clothing is looking at building a new facility to produce heavy-duty ski jackets. They have four possible locations. One proposal calls for building a highly automated facility in the United States. A second proposal involves working with a Chinese contractor to renovate an existing facility. The two other options involve building facilities in either Mexico or Vietnam. Sporting Life Clothing has some estimates of the costs associated with each facility, which is provided below:

	Materials	Labor $/hr.	Labor hr.	Energy	Capital	Miscellaneous
USA	**$5,000**	**$35**	**60**	**$1,000**	**$4,000**	**$250**
China	**$3,500**	**$10**	**400**	**$ 200**	**$2,500**	**$100**
Mexico	**$4,000**	**$15**	**300**	**$ 600**	**$3,000**	**$150**
Vietnam	**$3,000**	**$ 7**	**500**	**$ 300**	**$1,750**	**$ 50**

It is further estimated that production volumes per shift will vary among the four possible choices. It is estimated that during an eight hour shift, the U.S.A. plant could produce 1,200 jackets, the Chinese plant 900 jackets, the Mexican plant 1,100 jackets, and the Vietnamese plant 700 jackets.
NARREND

21. Based on these numbers what would be the productivity of the U.S.A. plant?
a. .097 jacket/$
b. .087 jacket/$
c. .090 jacket/$
d. .081 jacket/$
Ans: A
Difficulty Level: Medium
NAR: 6

22. Based on these numbers what would be the productivity of the Chinese plant?
a. .097 jacket/$
b. .087 jacket/$
c. .090 jacket/$
d. .081 jacket/$
Ans: B
Difficulty Level: Medium

23. Based on these numbers what would be the productivity of the Mexican plant?
a. .097 jacket/$
b. .087 jacket/$

c. .090 jacket/$
d. .081 jacket/$
Ans: C
Difficulty Level: Medium

24. Based on these numbers what would be the productivity of the Vietnamese plant?
a. .097 jacket/$
b. .087 jacket/$
c. .090 jacket/$
d. .081 jacket/$
Ans: D
Difficulty Level: Medium

25. Based on these numbers what would the ranking of the plants based on productivity (measured by # of jackets per dollar of cost)?
a. China, Mexico, U.S.A., Vietnam
b. Mexico, China, Vietnam, U.S.A.
c. U.S.A., Mexico, China, Vietnam
d. Vietnam, China, Mexico, U.S.A.
Ans: C
Difficulty Level: Hard

NARRBEGIN: 7
Use the following information to answer questions 26-27.

Edward's Pottery is looking into purchasing a simple robot to help form clay to turn into vases. They believe that such a machine would greatly improve productivity. Last month, Edward's spent $300 on materials, $400 on labor and their energy costs were $50. In that month they produced 1,500 vases. With the robot, they expect the following costs: materials—$250, labor—$150, energy—$150, and capital—$450.
NARREND

26. What was the productivity of the older system?
a. 0.75 vases/$
b. 1.50 vases/$
c. 2.00 vases/$
d. 2.50 vases/$
Ans: C
Difficulty Level: Medium
NAR: 7

27. How many vases would the new system have to produce in order to equal the old system?
a. 1,500 vases
b. 1,750 vases
c. 2,000 vases
d. 2,225 vases
Ans: C
Difficulty Level: Medium

NARRBEGIN: 8
Use the following information to answer questions 28-31.

Altman Freight builds containers that handle a variety of cargos. One type of container is designed to be used on trucks, rails, and ships. They are reviewing the welding component of the production of these containers. They summarized the data by quarter. The results are given below:

	Welding Hours	Containers
Fall	**1200**	**16,000**
Winter	**1050**	**14,500**
Spring	**1350**	**18,000**
Summer	**1275**	**17,500**

NARREND

28. What was the welding productivity in the Fall?
a. 13.00
b. 13.33
c. 13.73
d. 13.81
Ans: B
Difficulty Level: Easy
NAR: 8

29 What was the welding productivity in Winter?
a. 13.00
b. 13.33
c. 13.73
d. 13.81
Ans: D
Difficulty Level: Easy

30. What was the welding productivity in the Spring?
a. 13.00
b. 13.33
c. 13.73
d. 13.81
Ans: B
Difficulty Level: Easy

31. What was the welding productivity in the Summer?
a. 13.00
b. 13.33
c. 13.73
d. 13.81
Ans: C
Difficulty Level: Easy

NARRBEGIN: 9
Use the following information to answer questions 32-35.

Shelton Aviation specializes in maintaining and painting private and commercial aircrafts. Their paint shop wants to plan for the upcoming quarter. Painting varies based on the type of aircraft. Shelton operates four separate painting operations. Each line has its own crew and operates for 520 hours per quarter. Productivity measures for the four lines are given below:

Aircraft	Number to be Painted	Painting Productivity
Private	**14**	**0.00091 planes/man hour**
Commuter	**9**	**0.00065 planes/man hour**
Single aisle	**6**	**0.00051 planes/man hour**
Twin Aisle	**4**	**0.00032 planes/man hour**

NARREND

32. How many workers do they need to hire on the Private aircraft line (use appropriate rounding)?
a. 30
b. 27
c. 24
d. 23
Ans: A
Difficulty Level: Medium
NAR: 9

33. How many workers do they need to hire on the Commuter aircraft line (use appropriate rounding)?
a. 30
b. 27
c. 24
d. 23
Ans: B
Difficulty Level: Medium

34. How many workers do they need to hire on the Single Aisle aircraft line (use appropriate rounding)?
a. 30
b. 27
c. 24
d. 23
Ans: D
Difficulty Level: Medium

35. How many workers do they need to hire on the Twin Aisle aircraft line (use appropriate rounding)?
a. 30
b. 27
c. 24
d. 23
Ans: C
Difficulty Level: Medium

NARRBEGIN: 10
Use the information below to answer questions 36-38.

Illinois Institute of Technology is planning on hosting an international conference on nanotechnology. Due to a failure in planning, they had a three-week push to put together the mailing packages. During the first week, they had four full-time employees each working 40 hours and two part-time employees each of whom worked 10 hours. In the first week, they put together 3,500 mailing packages. During the second week they had five full-time employees each working 40 hours and five part-time employees each of whom worked 10 hours. In the second week, they put together 4,500 mailing packages. During the third week, they had five full-time employees each working 40 hours and five part-time employees each of whom worked 15 hours. In the third week they put together 7,000 mailing packages.
NARREND

36. What was the package/hours productivity during the first week?
a. 16.4
b. 19.4
c. 22.7
d. 25.0
Ans: B
Difficulty Level: Medium
NAR: 10

37. What was the package/hours productivity during the second week?

a. 16.4
b. 17.6
c. 18.0
d. 20.0
Ans: C
Difficulty Level: Medium

38. What was the package/hours productivity during the third week?
a. 18.0
b. 19.5
c. 20.8
d. 25.5
Ans: D
Difficulty Level: Medium

NARRBEGIN: 11
Use the following information to answer questions 39-41.

Nature Best Bakery sells goods to supermarkets. They are planning their next week's production for their three major lines. The data they put together is given below:

	Pastries	**Breads**	**Cakes**
Projected Volume	**1,200**	**4,000**	**600**
Productivity/Person	**21.7 units/hr.**	**24.1 units/hr.**	**20.8 units/hr.**

NARREND

39. How many people will be needed on the pastry line (use appropriate rounding) assuming an eight hour shift?
a. 4
b. 5
c. 7
d. 9
Ans: C
Difficulty Level: Easy
NAR: 11

40. How many people will be needed on the bread line (use appropriate rounding) assuming an eight hour shift?
a. 7
b. 11
c. 21
d. 60
Ans: C
Difficulty Level: Easy

41. How many people will be needed on the cake line (use appropriate rounding) assuming an eight hour shift?
a. 4
b. 7
c. 12
d. 24
Ans: A
Difficulty Level: Easy

NARRBEGIN: 12
Use the information below to answer questions 42-45.

Mohan's Machinery is reviewing its pump production line. They gathered data for the years 2014 and 2015. In 2015, Mohan's Machinery initiated a Lean Six Sigma program and hoped that it would produce significant savings. Data on the use of labor hours, machine hours, materials, and energy for the production of the pumps during the two years are provided in the table below.

	2014	2015
Labor hours	3,000	3,950
Machinery Use hours	1,200	1,425
Material Use	1,500	1,780
Energy Use (BTUs)	60,000	75,000
Units Produced	20,000	27,000

They computed the amount of resources required to produce one unit in both 2014 and 2015.
NARREND

42. What was the percent change for labor hours per unit between the two years?
a. 2.47%
b. 1.67%
c. -2.47%
d. -3.45%
Ans: C
Difficulty Level: Medium
NAR: 12

43. What was the percent change for Machinery Use hours per unit between the two years?
a. 5.28%
b. 6.00%
c. 12.04%
d. -12.04%
Ans: D
Difficulty Level: Medium

44. What was the percent change for Material Use hours per unit between the two years?
a. -12.10%
b. 6.49%
c. 7.50%
d. 13.40%
Ans: A
Difficulty Level: Medium

45. What was the percent change for Energy Use per unit between the two years?
a. -9.25%
b. -7.41%
c. 6.21%
d. 7.87%
Ans: B
Difficulty Level: Medium

NARRBEGIN: 13

Use the information below to answer questions 46-47.

English Knickknacks produces a variety of porcelain products. They are taking a look at the production of two types of porcelain products:the hand-painted teapot and a hand-painted tea set. Data for last month's production is provided below:

	Teapots	Tea Sets
Accepted Units	105	72
Minor Flaw Units	20	28
Selling Price for Accepted Units	70	250
Selling Price for Minor Flaw Units	40	130
Manufacturing Hours	450	400

NARREND

46. What was the productivity ($/hr.) for the teapot line?
a. $17.98/hr.
b. $18.11/hr.
c. $20.90/hr.
d. $23.14/hr.
Ans: B
Difficulty Level: Medium
NAR: 13

47. What was the productivity ($/hr.) for the tea set line?
a. $44.66/hr.
b. $50.14/hr.
c. $54.10/hr.
d. $60.23/hr.
Ans: C
Difficulty Level: Medium

NARRBEGIN: 14
Use the information below to answer questions 48-50

Argus technologies produces advanced sensor technologies for the military. As such, the productions run on a monthly level are relatively small. Since Argus is in competition with other firms, it is making every effort to be as efficient as possible. Below you'll find some data on the final assembly for three of the most advanced sensor products produced by Argus.

	Workers	Worker Productivity units/hour	Required Production
LLTV	9	0.07	120
IR	13	0.10	200
LIDAR	10	0.08	140

NARREND

48. What is the required number of hours for the LLTV line in order to meet the production quota?
a. 175
b. 191
c. 207
d. 300
Ans: B
Difficulty Level: Easy

NAR: 14

49. What is the required number of hours for the IR line in order to meet the production quota?
a. 121
b. 134
c. 154
d. 191
Ans: C
Difficulty Level: Easy

50. What is the required number of hours for the LIDAR line in order to meet the production quota?
a. 175
b. 191
c. 201
d. 223
Ans: A
Difficulty Level: Easy

Sample Answers to In-Text Questions

Chapter 2: Operations and Supply Chain Strategies

Discussion Questions

1. In what ways does the triple bottom line affect how the strategies for a firm's operations function are formulated and implemented?
Answer: It means that a corporation must take into consideration the 3 overlapping strategies in Figure 2.2, Environmental, Economic, and Social strategies to get a balance of value from the three.

2. FedEx's core competency is embedded in its slogan: *"When it absolutely, positively has to be there overnight."* Identify that core competency.
Answer: Core competencies are Quality of on-time commitment, and Speed of Delivery

3. Describe why an operations strategy is critical to a firm.
Answer: It is critical that the operations function have a good strategy to help the firm achieve a competitive advantage. You need to balance costs, quality, speed, and innovation to satisfy the goals of the corporate and business units/ strategies.

4. Why is it important to maintain a strategic fit among the four elements of an operations strategy? How can a company resolve any mismatches among them that result from changing markets trends or customers' order-winning criteria?
Answer: The four elements must balance with the corporate goals in the most optimal way. They must be continually evaluated with the goal of staying in balance with the changing markets, and trends, products and processes.

5. What do you think the order-winning and order-qualifying criteria for the furniture retailer IKEA is?
Answer: An order qualifying criteria might be its reputation for quality or its broad selection, or the convenience of the store. The Order winners might be something like the actual quality of the product, how easy the assembly is, the service reputation, etc.

6. Suppose that you own a lawn mowing and snowplowing service and are planning to provide these services to homeowners in a wealthy neighborhood. How would you use the concepts of order winners and order qualifiers to formulate and implement your service operations strategy? You must know what level of services this customer set requires, and provide it with a high reputation to be in the qualifier set. The Order winner might be from references, proper sales approach, and general image of the company better than the competition, etc.

7. From an operations strategy perspective, how can the balanced scorecard be used as a performance measurement system?
   Answer: The balanced scorecard measures the financial success, which is affected by prices, and repeat business. The Customer area is measured by satisfied customers with respect to the product quality and availability in distribution, and delivery. The Learning and growth success is measured by things like customer service, and quality improvement and learning from mistakes. The Process success is measured by the efficiency and effectiveness of all of the operations processes in each area of the supply chain.

8. Develop a balanced scorecard for a regional airlines company.
   All the financial health measurements
   All of the Customer satisfaction metrics, on time, lost luggage, etc.
   Learning metrics such as not repeating mistakes, and complaint satisfaction
   Honing the internal processes to a high degree, such as airside opns, customer opns, maintenance opns, etc.

9. Compare the operations strategies for goods versus service firms?
   Answer: Operations strategies for goods center around production, quality, inventory, capacity, etc. The service firm usually concentrates more on location, training of personnel, flexibility to handle any customer problem, location and interplay of front stage, back stage, and support operations, etc.

10. A key supply chain strategy decision is to determine the structure of a firm's supply chain. How do you think the supply chains for Wal-Mart and IKEA are structured?
    Answer: This might be centered on location, selection of merchandise, delivery strategies, number of warehouses, capabilities, etc.

11. What are the distinguishing features of companies that lead the way with sustainable supply chain strategies?
    Answer: this might include the carbon footprint, the end-to end sustainability, recycling, reduction of packaging, etc.

12. What are the six capabilities needed for an integrated global operations and supply chain strategy?
    Answer: things like integrated sales and operations, an effective network to deliver quality and speed, better collaboration with supply chain partners, logistics partners no navigate the complexities of global trade, effectively find low cost, quality suppliers, and a market strategy to best utilize the company's core competencies and external resources.

13. Define productivity. What is the difference between productivity and efficiency?

Answer: Productivity is the ratio of Output divided by input. Efficiency tells us how economically our resources are used, and Productivity tells us the output of those resources. Productivity is a combination of efficiency and effectiveness.

14. Define single-factor, multifactor, and total productivity measures
    Answer: Productivity can be expressed by the output of a single resource, or by the output of a combination of resources.

15. A multinational company has two manufacturing plants, one in Germany and the other in China. Both plants produce the same product, which is sold in their respective countries. Using a partial productivity measure for labor, an analyst for the company finds that the productivities of these two plants are significantly different.
    a) Explain the some of the possible reasons for the difference.
       Answer: The output of Labor hours might be effected by many factors such as different processes, equipment, technology, environment, etc. The price of labor hours would affect the output per labor dollars.
    b) Why might a comparison of the two plants' productivity using a single factor be misleading?
       Answer: Some resource factors might be more efficiently used than the other factory. Which factor is used might favor one over the other.
    c) Can you think of another productivity measure that would be more meaningful?
       Answer: multifactor measures might give a better picture.

16. What are some of the inherent problems in measuring productivity in the service sector?
    Answer: The services might not be of the same content or difficulty. The productivity of a surgeon might not be just how many operations does she perform?

17. Outline the factors that affect productivity.
    Answer: This is listed in table 2.4

18. What are the steps that you would take to improve productivity in a manufacturing organization? in a service organization?
    Answer: Improve meaningful measurements, benchmark with similar industries and competitors, treat employees as valued assets, and empower them to suggest improvements, improve trust and communications, etc.

Critical Thinking Exercise

This article discusses how Nestlé coped with the volatility in food and raw material costs. The company crafted a strategy that doesn't depend on commodity prices falling. This strategy relied on the efficiency of the operations function to reduce costs, while producing

and launching premium, higher-margin products in which raw material costs account for a smaller percentage of the retail price.

Read the article titled "Nestlé's Recipe for Juggling Volatile Commodity Costs" and answer the questions that follow it. You can access this article by clicking on the link: https://resourcecenter.businessweek.com/page.asp?prmID=207&prmPID=6629

Discussion Questions

1. Why is the information presented in this article important from an operations strategy perspective?
   Answer: It is an innovative way to look at cost controls, and price jumps, and not tie your price and quality to a volatile market.

2. Based on this article, what in your opinion are Nestlé's distinctive competencies?
   Answer: Boosting crop yields, driving internal savings, reducing raw materials, etc.
   How can a low-cost strategy be good for operations management? Can it be bad? If so, how?

3. Answer: A low cost strategy depends on low costs from suppliers, and some markets are more volatile. It is usually a great challenge to be lean in every respect. A low cost strategy is rarely good for operations, unless you are able to use it to squeeze out lower costs of materials from your supplier. (You know we can't pay that much!), etc. and the supplier will comply.

Sample Answers to In-Text Questions

Module B: Transportation Models

Discussion Questions

1. Why are transportation models treated as a special case of linear Programming models?
   Answer: The transportation model is a special case of linear programming problems in which the objective is to minimize the total cost of transporting goods from the various supply origins to the different demand destinations. It is a pervasive problem that all companies have, and the implications of the decision are very important.

2. What are the three pieces of information required to formulate a transportation model?
   Answer:
   1. All supply locations, and production capabilities per period;
   2. All demand locations and their requirements per period;
   3. The distribution or transportation cost of shipping one unit from each origin to each destination.

3. What are the five major assumptions required for transportation modeling?
   Answer:
   Capacity at each supply location or origin is limited.
   a. The demand requirements at each destination are known.
   b. Regardless of their origin or destination, the items shipped are the same (homogeneous).
   c. Regardless of the number of units shipped, the shipping cost per unit remains the same.

4. Between each origin and destination, the mode of transportation being used does not change, and there is only one route used.

5. What is the difference between a balanced and an unbalanced transportation problem?
   Answer: In a balanced problem, the total number of units demanded is equal to the number of units available. In an unbalanced problem, the number of units of supply and demand are different.

6. List the four “steps” of the northwest corner rule.

a. Answer: Begin at the top left-hand or northwest corner of the transportation matrix and allocate as many units to this cell as possible until either the supply is exhausted or the demand requirements are met.
    i. Exhaust the capacity from each supply location (row) before moving down to the next supply location.
    ii. Exhaust the requirements from each demand location (column) before moving right to the next demand location.
    iii. Repeat steps 2 and 3 until all available supply capacity is exhausted and demand requirements are met.

7. List the four "steps" of the matrix least cost method.
   Answer:
   a. Begin with the cell in the transportation matrix that has the lowest per unit cost. In case of any ties among cells for the lowest cost, break the ties arbitrarily.
   b. Allocate to this cost cell the maximum number of units allowable given available capacity or demand requirements. Eliminate the row or column that exhausts the supply or meets the demand requirements by this allocation from further consideration.
   c. From the remaining available cells in the matrix, choose the one that has the next lowest per unit cost and repeat step 2.
   d. Repeat step 3 until all units have been allocated.

8. Why does the matrix least cost method gives a better initial solution than the northwest corner rule does?
   Answer: As the overall objective is to minimize total cost, this method is intuitively more appealing and has better rationale than the northwest corner rule. As a result, this method reduces the number of computations and the time required to determine the optimal solution.

9. What is the implication of getting a negative value of improvement index for a closed path?
   Answer: You would need to select the cell with a minus sign that has the smallest shipment quantity, and then add that to all the cells with a + sign on the closed path.

10. For a balanced transportation problem, what are the two criteria for a nondegenerate optimum solution?
    Answer:
    1) All supply should be exhausted and all demand requirements must be met.
    2) The number of cells with positive allocations should be equal to R + C – 1, where R is the number of rows and C is the number of columns in the transportation matrix.

11. What does the term *degeneracy* mean in the context of transportation modeling, and what problems does it create in applying the stepping stone method?
    Answer: Degeneracy occurs when too few shipping routes are used, when one of the occupied routes (cells) fully exhausts the supply from a source and meets the demand requirements for a destination. When you apply the stepping stone method, it is impossible to trace a closed path for one or more of the unoccupied cells or routes. To overcome the problem of degeneracy, we need to create an artificially occupied cell.

12. Can the structure of transportation models be applied to other operations management situations? If the answer is "yes," provide some examples.
    Answer: Answers may vary.

13. In the stepping stone method, what is the rationale for placing alternate + and – signs around the closed path?
    Answer: Because you will need to calculate an improvement index: a value obtained to see if there is an improvement in cost by choosing another route. This value is calculated by first summing up the unit costs in the cells with a plus sign, and then from the resulting total, subtract the sum obtained by adding the unit costs in cells containing a minus sign.

14. Why do we create dummy supply sources or dummy demand destinations in transportation modeling problems?
    Answer: To model and solve an unbalanced transportation problem, we need to convert the unbalanced problem to a balanced one.

Instructor Resource
Ray Venkataraman and Jeffrey Pinto
Operations Management: Managing Global Supply Chains, 1e
SAGE Publishing, 2018

Case Notes

Chapter 2: Operations And Supply Chain Strategies

Supply Chain Strategies and Disaster Planning

Case Summary

This case explains the importance for organizations to develop a risk management plan for its supply chain to achieve agility.

Case Analysis

This case illustrates how firms should formulate and implement global operations and supply chain strategies for risk management to alleviate disruptions to their operations and supply chains from natural disasters or safety and security problems. The fact that only 10% of businesses have contingency plans in place to cope with operations and supply chain disruptions despite the likelihood of disasters means disaster planning/risk management should be an essential part of their supply chain strategy.

Sample Answers to Case Questions

1. Take a position either for or against the following statement: "In order to prepare for disasters, you should stockpile inventory, other critical supplies, and raw materials."

Stockpiling inventory, other critical supplies, and raw materials is not the way to prepare for disasters. Doing so only adds costs without adequately addressing disruptions brought on by disasters. In particular, there is no way to determine the exact amount of resources to stockpile as the magnitude and timing of disasters are difficult, if not impossible, to predict. In addition, stockpiling resources leads to hoarding of valuable resources that complicate disaster relief efforts as needed resources cannot be delivered in time to those who need them most.

2. Think of Heinz Corporation's production of consumer goods and food products. How might you develop a risk management and disaster response for the company's supply chain?

First, get a detailed picture of their first-tier and most distant suppliers. Second, build a wide network of suppliers to reduce the risk of purchasing goods and services from a single supplier. Third, continually update and reconsider risk management strategies in light of changes in the global economy and the corporation's operations.

3. Because it is impossible to plan for every disaster, how might you develop a method for identifying the most likely and serious risks your organization faces?

It requires the consideration of an organization's supply chain agility. First, diversify the supplier base wherever possible. Second, create an organization that can react quickly to whatever happens including equipping and training individuals for emergency-response.

4. In your opinion, how much risk planning is sufficient? Why? Defend your answer.

A risk planning should balance the likelihood of disasters with a contingency plan that provides an organization with the agility to cope with disruptions in its major operations and supply chain. Most importantly, the contingency plan needs to be updated continually with regular individual training for emergency response.

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OPERATIONS MANAGEMENT

Managing Global Supply Chains

Chapter 2: Operations and Supply Chain Strategies

Learning Objectives

- Compare the different levels of strategic planning and identify the performance measures in each.
- Define operations strategy and describe how it is formulated and evaluated.
- Contrast the formulation and evaluation of operating strategies for service organization with those for manufacturing organizations.
- Compare the different types of productivity measurements and explain how firms use them strategically.

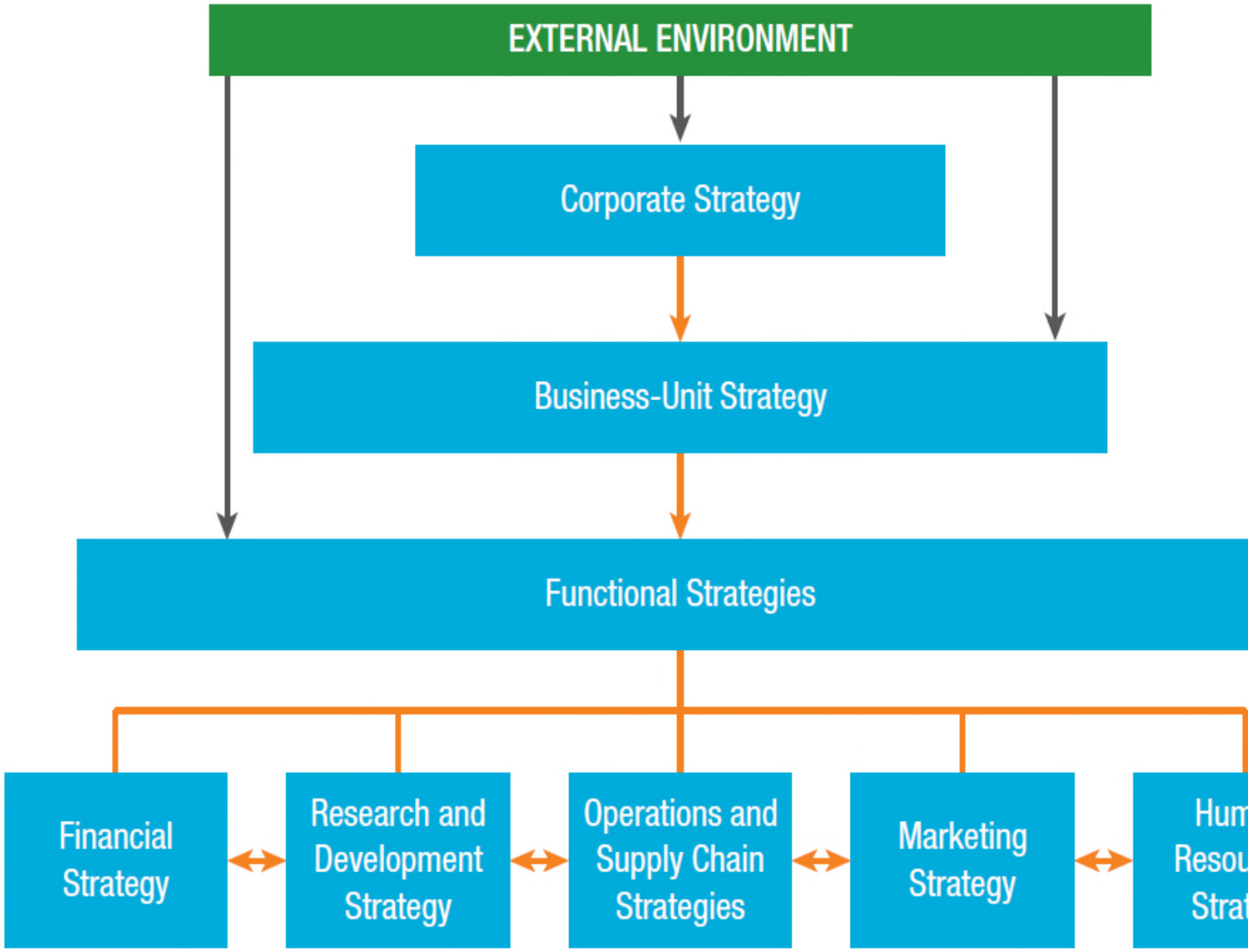
Learning Objectives (Cont'd)

- Describe how both manufacturers and service organizations formulate and evaluate their supply chain strategies.
- Identify the key capabilities firms need to formulate and implement global operations and supply chain strategies and manage the risks related to them.
- Describe what companies are doing to incorporate sustainability into their supply chain strategy and th problems they face in doing so.

Operations Profile: Pfizer's Revamped Supply Chain Strategy Saves the Company Millions

- Pfizer set up a centralized procurement department and a team to examine the services the firm buys.
- Called the Knowledge Management Services (KMS) Group, it saved Pfizer a whopping $370 million between 2007 and 2010.
- The KMS team concentrated on consulting services and legal services.
- To develop a disciplined approach to using consulting services at Pfizer, the team created a process to review, classify, and approve outside consultants.

FIGURE 2.1: Strategic Planning Levels



Venkataraman & Pinto, Operations Management, 1e. SAGE, 2018.

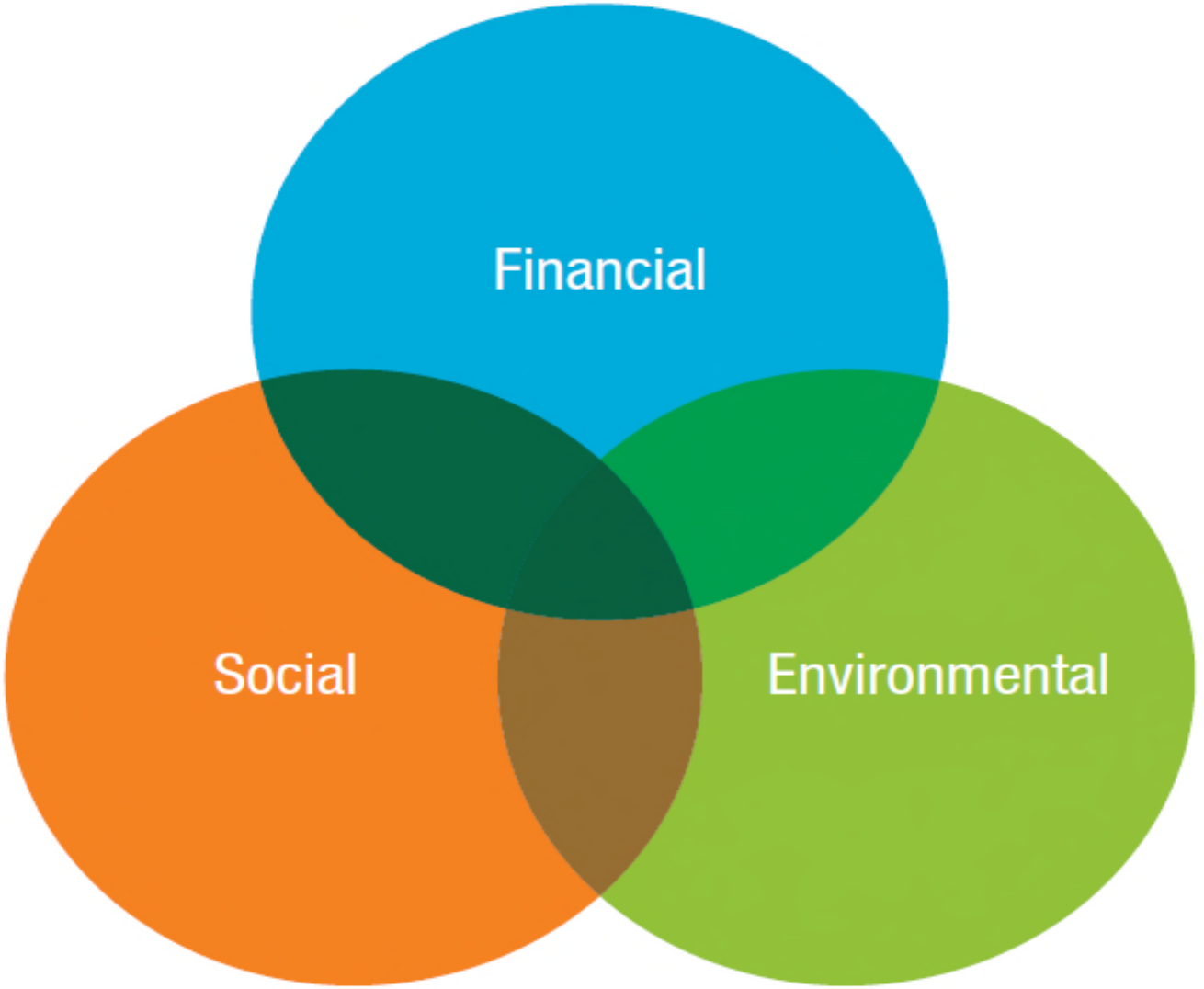
Corporate Strategy

- A corporate strategy attempts to address the fundamental question of what industries and marke the organization should enter and compete in.
- Corporate strategic planning is the broadest in scop (highest level in the hierarchy), has a long-term tim horizon, and establishes the overall goals and directions for the corporation as a whole.
- Decisions made at this level include what businesses to acquire or divest, whether or not to acquire suppliers or distributors, and how to allocat resources between the different units.

Sustainability

- Companies are increasingly considering sustainability when in their corporate strategies.
- There are three performance targets that measure sustainability, i.e. triple bottom line.
- A firm's triple bottom line not only includes the economic value it provides its shareholders, but the environmental and social value the company creates.
- Three overlapping components of sustainability are economic, environmental, and social value.

FIGURE 2.2: Triple Bottom Line



SOURCE: Reprinted from van den Berg, W. (n.d.). Does being wealthy mean being healthy? Olive Leaf Foundation. Retrieved from http://www.olf.org.za/article/does-wealth--health/

Business-Unit Strategies

- For corporations that own a portfolio of businesses, each needs a business-unit strategy.
- Each of these businesses is typically referred to as Strategic Business Unit, or SBU.
- A business-unit strategy establishes how each business unit should compete within its particular industry or market.
- The core competencies of the SBUs refer to the activities they excel at, or strive to excel at.

Functional Strategies

- Functional strategies should coordinate and integrate the activities and resources within each functional area, e.g. marketing, operations, finance, and accounting.
- Functional strategies are developed and implemented at a lower level in the corporate hierarchy, have shorter time horizons, and are more specific and detailed in terms of their action plans than the higher level business strategies.

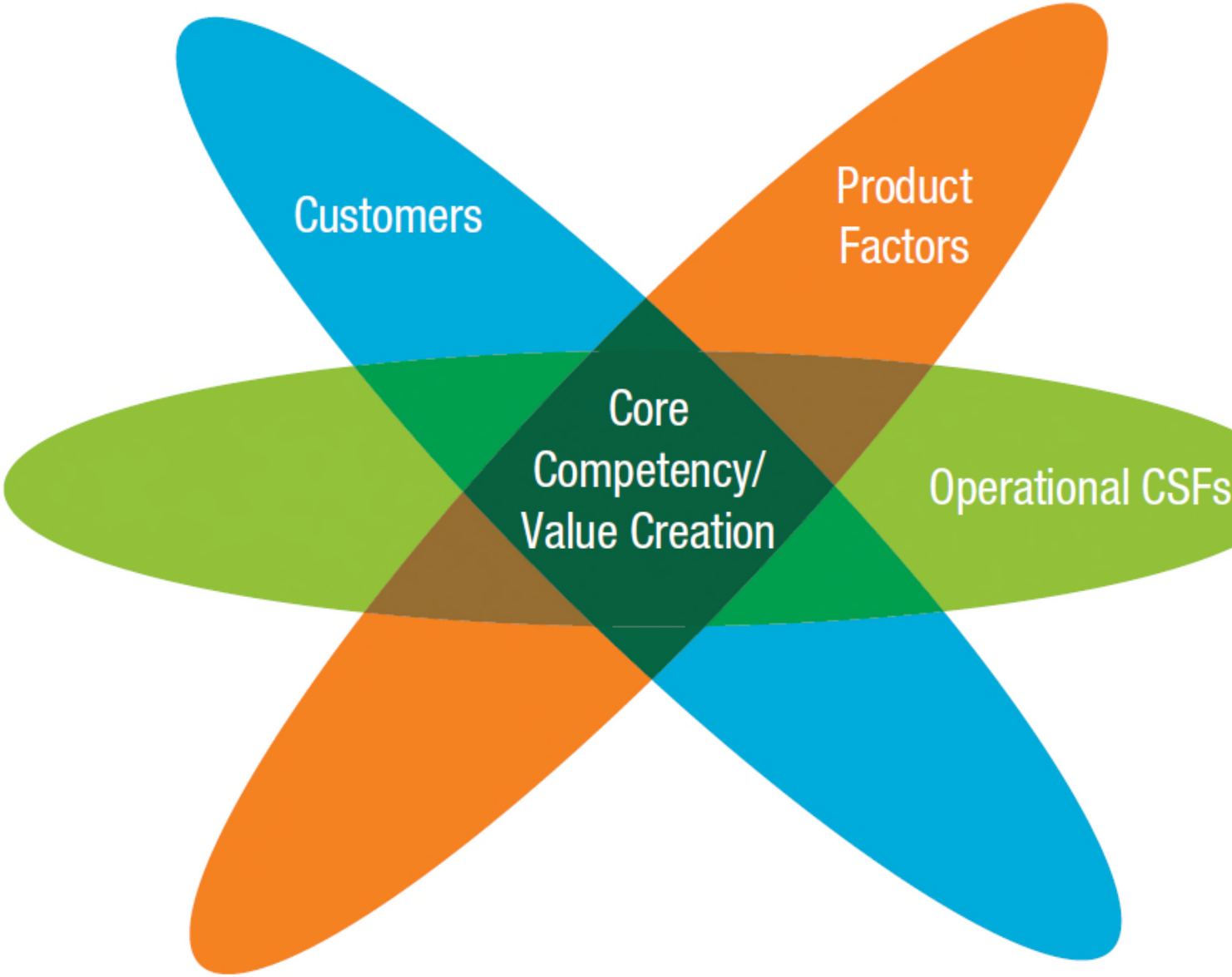
Formulating and Evaluating Operations Strategies

- The purpose of a firm's operations strategy is to use the company's operational resources effectively to help it achieve a competitive advantage.
- An operations strategy, which provides the roadmap for all of the decisions managers of the firm's operations function make, is usually formulated in terms of the competitive priorities or core competencies of the firm, such as its ability to compete on prices and costs, quality, flexibility, time (speed), and innovation.

Critical Elements of an Operations Strategy

- An operations strategy has four critical elements: customers, operational capabilities or critical success factors (CSFs), product factors, and core competencies that can enable a company to achiev competitive advantage.
- Operations can come up with product-related features that customers most value or production technologies and processes that competition canno easily imitate.

FIGURE 2.3: Four Elements of an Operations Strategy



Venkataraman & Pinto, Operations Management, 1e. SAGE, 2018.

Product Factors

- Product factors include the nature of the product, its stage in the product life cycle, and the process used to produce that product.
- The nature of the product refers to the distinctive features or characteristics that identify the good or service.
- Products that are in the mature stages of their life cycles require different core competencies.
- Streamline the processes enables a firm to make the delivery of the products more efficient.

Customers

- The ultimate aim of operations and supply chain strategies is to produce and deliver those products or services that not only satisfy, but actually delight customers, the people, and groups who consume a firm’s products or services.
- Each downstream partner of that firm in the supply chain is also a customer.
- For example, you may be the end-user of the Crest toothpaste produced by Proctor & Gamble (P&G), but a retail store such as Walmart is also an intermediate customer.

Critical Success Factors

- Every industry has some unique strategic factors, such as resources or capabilities, which affect a company's ability to successfully compete.
- These elements are called critical success factors (CSFs).
- Each firm should determine its own CSFs based on what is important to the customers in the target market.
- CSFs can originate from superior technology, operations and processes, logistics and distribution capabilities, marketing channels, etc.

Core Competencies

- Core competencies are skills or key areas of expertise that a company has developed over time which distinguish the company from its competitors on the satisfaction of the costumer’s needs.
- There are five core competencies: price, quality, time, innovation, and flexibility.
- A company cannot excel in all five core competencies. Therefore, a company has to identify a subset of these core competencies that it can be good at, and develop and nurture it.

Two Ways to Compete Based on the Price

- One is to produce the product at a lower cost than the company's competitors.
- For commodity products the firm can try to achieve economies of scale that drive the production down.
- If the product offering is not a commodity, then the firm should try lowering the cost of raw materials or labor.
- The second way a firm can compete on price is to b willing to accept a smaller profit margin.
- Wal-Mart, for example, operates with lower profit margins by selling its products at low prices.

Quality

- Quality describes product's fitness for use dependir upon the price the customer is willing to pay for it.
- The eight most common characteristics of quality are: performance, conformance, features, durability reliability, serviceability, aesthetics, and perceived quality.
- Competing simultaneously on the basis of all eight quality dimensions would be very expensive and difficult.
- The nature of the product might force the company to make trade-offs among them.

Time

- Time as a core competency has three attributes:
  1. Product development cycle time: the time it takes to conceptualize a new good or service, produce it, and mak it available to customers.
  2. On-time delivery: firm's ability to deliver the products to its customers on or before the promised delivery date.
  3. Delivery speed: the ability to deliver the product or service faster than the rest of the competition that can be a competitive advantage.

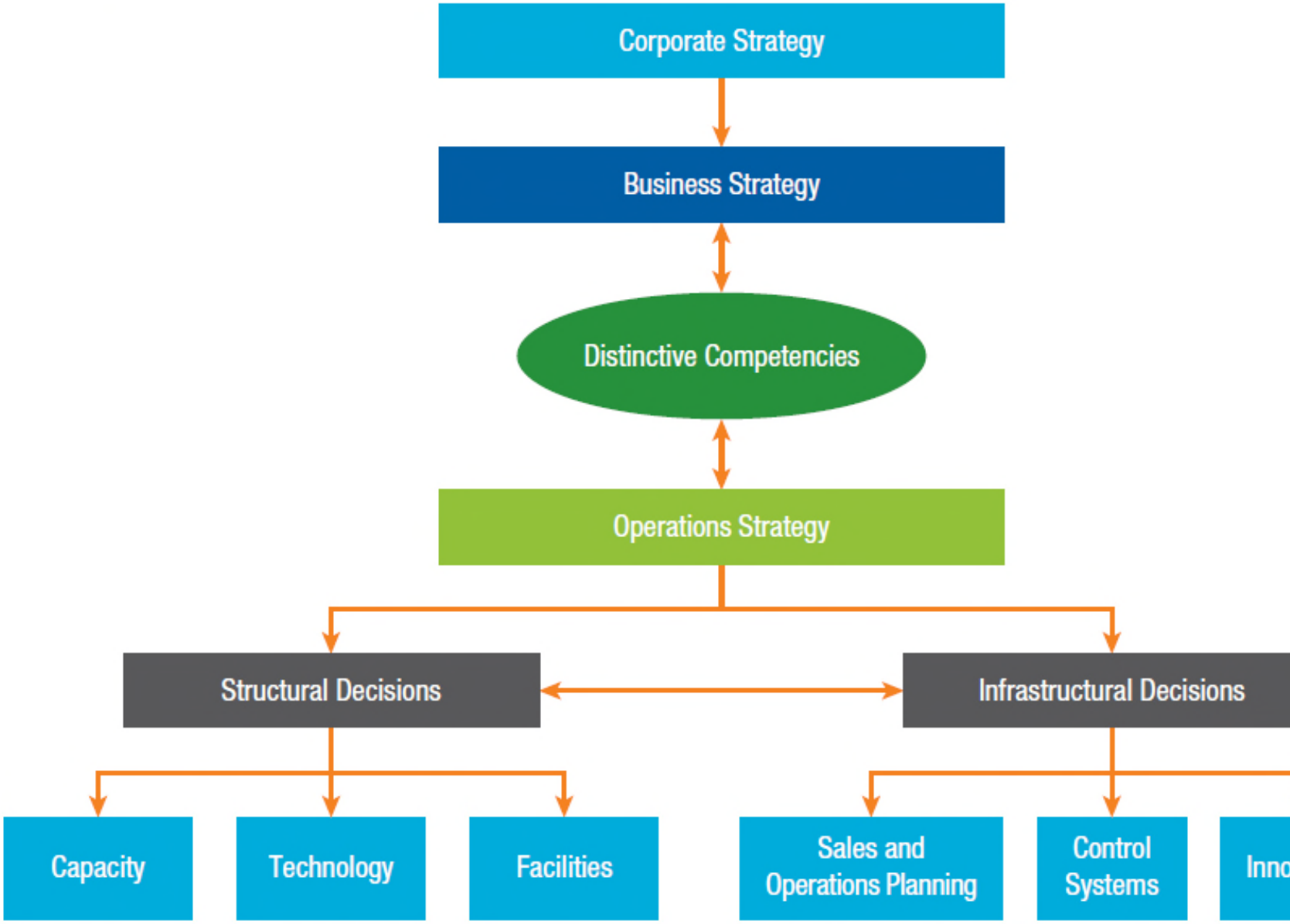
Innovation

- Innovation is the process of implementing new idea or changes that create value for customers.
- Product innovation is the development and introduction of a brand new product or service or th improvement of an existing product or service through design changes or through the use of new components and materials.
- Process innovation refers to the changes in the way in which product is produced or a service is delivere within the firm or across a supply chain.

Flexibility

- Flexibility is a firm's ability to produce a range of different products or services or to respond efficient to changes in demand.
- An **order winner** is a competitive criterion (core competence) of a product that causes a customer t choose it instead of a competitor's product.
- An **order qualifier** is a competitive criterion that must be present in a product for it to be a viable competitor in the marketplace.

FIGURE 2.4: Operations Strategy Framework



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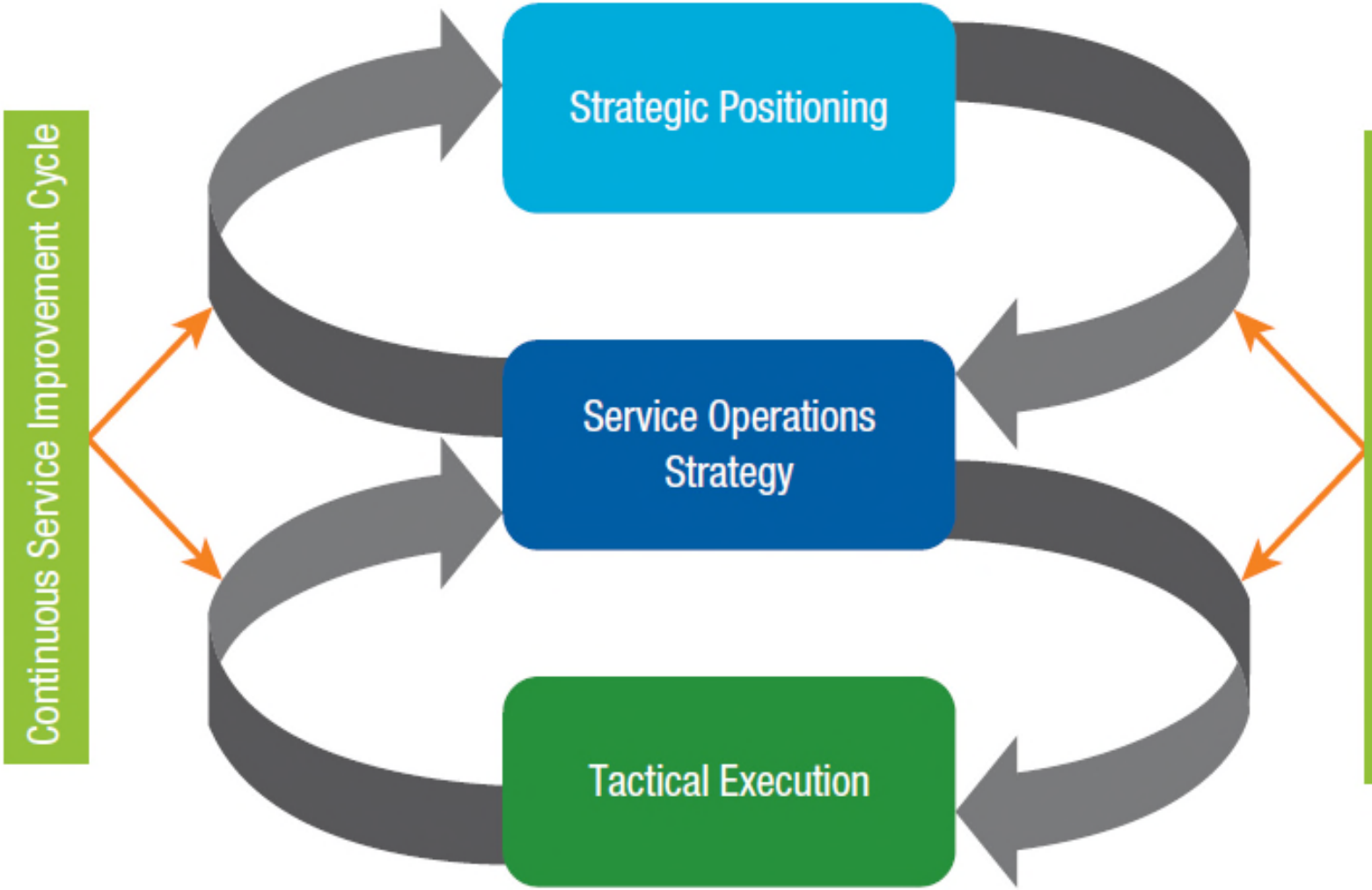
Evaluating the Performance of an Operations Strateg

- The Strategic Profit Model (SPM or DuPont model) provides a visual representation of an organization's financial performance.
- The Balanced Scorecard includes strategic nonfinancial performance measures in addition to the traditional financial metrics.
- Balanced Scorecard focuses on four critical areas:
  - Learning and Growth
  - Business Processes
  - Customer
  - Financial

FIGURE 2.6: Strategic Framework for Service Operations



Venkataraman & Pinto, Operations Management, 1e. SAGE, 2018.

2.3 Formulating and Evaluating Strategies for Service Organizations

- Strategic Positioning: Identifying the target market
- Formulating the Service Operations Strategy
  1. The Service Design
  2. The Service Operations System
  3. The Service Delivery System
- Tactical Execution: the day-to-day activities required to support the service strategy.

Continuous Service Improvement

- Plan, Do, Check, Act (PDCA):
- Plan: Recognize an opportunity for improvement ar plan for a change.
- Do: Test the change by implementing a small-scale pilot study.
- Check: Review and analyze the results of the test and identifying the lessons learned.
- Act: Take action based on what was learned from th previous step.

2.4 Measuring Productivity as Part of Strategic Planning

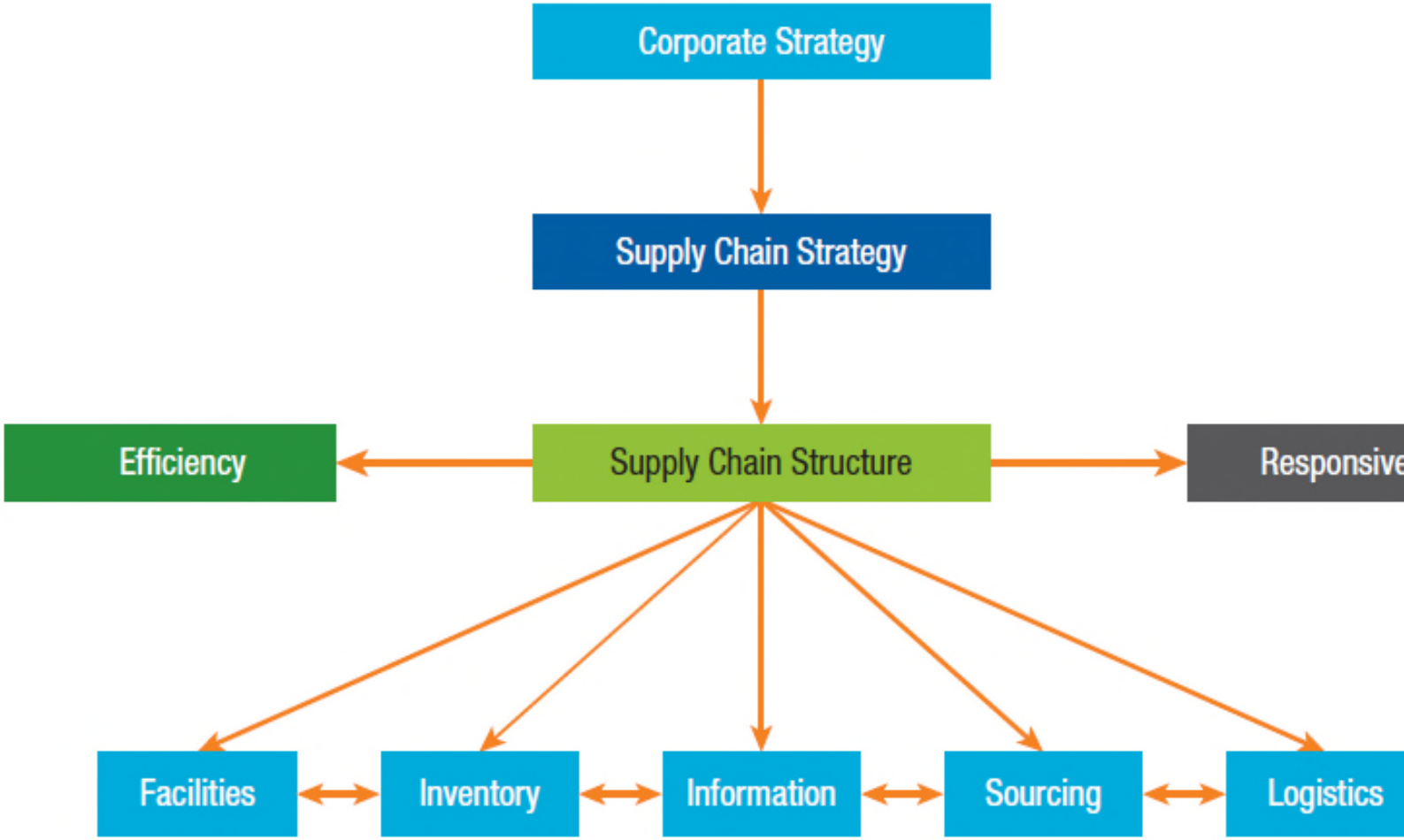
- In the context of operations, productivity is the ratio of outputs (goods and services) produced to the inputs used.
- The single-factor productivity measure uses a single input in the ratio.
- Multifactor productivity is a productivity measure that uses all of the relevant inputs used to make the product or provide the service.

Formulating Supply Chain Strategies

- What is the nature and number of operating facilitie needed?
- What suppliers and how many are needed?
- What work should be outsourced or offshored?
- What type of relationships should the firm have with its suppliers?
- What should the distribution network be and how should it be managed?

Supply Chain Strategy

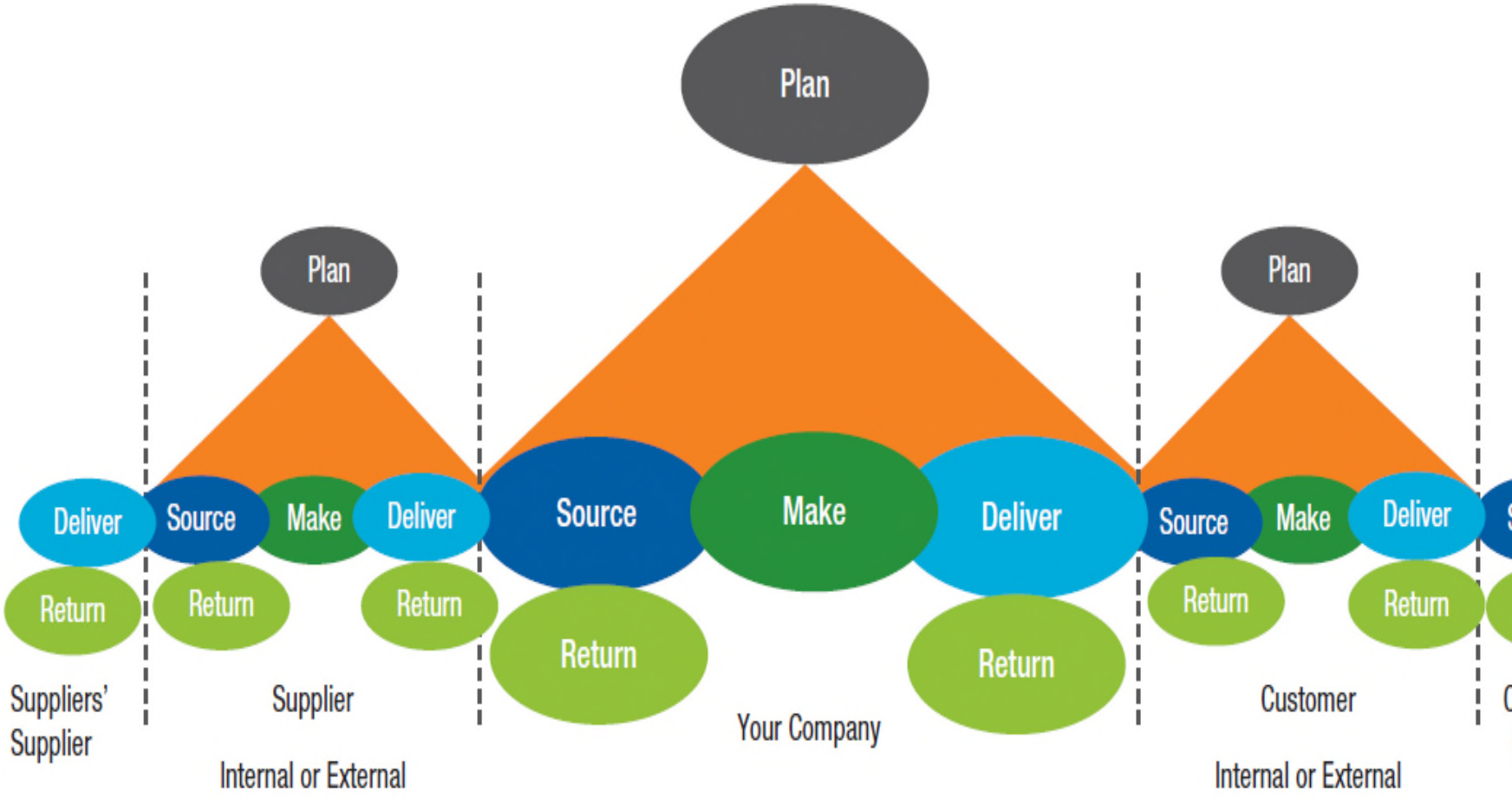
FIGURE 2.7: Decision Framework for Formulating a Supply Chain Strategy



SOURCE: Adapted from p. 47 of Chopra, S., & Meindl, P. (2007). Supply chain management (3rd ed.). New York, NY: Pearson-Prentice-Hall.

(SCOR) Model

FIGURE 2.8: Supply Chain Operations Reference (SCOR) Model



SOURCE: http://www.supply-chain.org.

2.0 Global Operations and Supply Chain Strategies

- An effective global, integrated sales and operations planning process for key markets.
- A procurement, manufacturing, distribution, and research and development network.
- Tight links with their customers and suppliers so tha they can better predict the demand for their product
- Logistics partnerships to ensure the firm's efforts to source products to low-cost markets.
- The ability to effectively recruit low-cost suppliers.
- A "go-to-market" strategy, which is a firm's plan to provide value to its customers.

Integrating Operations and Supply Chain Strategies

- Companies that have experienced greater success integrating their operations and supply chains. globally have developed three capabilities:
  - Supply chain adaptability, which is the ability of the supply chain to respond to changes
  - Financial-engineering capabilities, which is the ability to create new financial instruments
  - Risk anticipation and mitigation capabilities, which refers t anticipating events that could disrupt global operations

Risk Management Strategies

- Many unforeseen events can disrupt operational an supply chain activities.
- A firm's operations should have a risk management program that can anticipate uncontrollable events.
- Corporations are working closely with their supplier to safeguard their supply chains against future breakdowns.
- Businesses should also be concerned about disruptions to operations and supply chains from safety and security problems.

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OPERATIONS MANAGEMENT

Managing Global Supply Chains

Module B: The Transportation Models

Learning Objectives

- Formulate and solve the transportation problems using both manual methods and the Excel Solver and interpret the solutions.
- Apply transportation modeling to other situations.

Tesla and the Challenge of Locating a Battery Factory

- Tesla Motors, developer of the iconic Model S electric sports car, unveiled plans to create a “gigafactory” in order to produce batteries to power their automobiles.
- With the promise of such a massive factory and the thousands of jobs the project would bring, several western states were actively competing to be the host site for the structure.
- By using the transportation model, Tesla can identify the best location for its new factory, which will enable the company to minimize both inbound and outbound distribution costs of its batteries.

Formulating and Solving the Transportation Problem

- Many companies have multiple plants or sources of supply (origins) and multiple demand locations (destinations) for their goods and services.
- The transportation model is a special case of linear programming problems in which the objective is to minimize the total cost of transporting goods from the various supply origins to the different demand destinations.
- To solve transportation problems, we should first set up the problem as a transportation matrix.

The Northwest Corner Rule

1. Begin at the top left-hand or northwest corner of the transportation matrix and allocate as many units to this cell as possible until either the supply is exhausted or the demand requirements are met.
2. Exhaust the capacity from each supply location (row) before moving down to the next supply location.
3. Exhaust the requirements from each demand location (column) before moving right to the next demand location.
4. Repeat steps 2 and 3 until all available supply capacity is exhausted and demand requirements are met.

Matrix Least Cost Method

1. Begin with the cell in the transportation matrix that has the lowest per unit cost. In case of any ties, break the ties arbitrarily.
2. Allocate to this cost cell the maximum number of units allowable given available capacity or demand requirements. Eliminate the row or column that exhausts the supply or meets the demand requirements by this allocation.
3. From the remaining available cells in the matrix, choose the one that has the next lowest per unit cost and repeat step II.
4. Repeat step 3 until all units have been allocated.

Stepping Stone Method

1. Select an empty cell in the initial basic feasible solution (Figure B.3 or B.4) to be evaluated.
2. Beginning at this empty cell, draw a closed path back to that cell using only horizontal and vertical moves, ensuring that turning corners occur only on occupied cells. Stepping over any occupied or unoccupied cell is allowed.
3. Beginning with a plus (+) sign for the empty cell being evaluated, place alternating minus (–) and plus (+) signs on the corner cells of this closed path.

Stepping Stone Method (Cont'd)

4. Calculate an improvement index which is a value obtained to determine if there is an improvement in cost by choosing another route. It is calculated by first summing up the unit costs in the cells with a plus sign, and then from the resulting total, subtract the sum obtained by adding the unit costs in cells containing a minus sign.
5. Repeat steps 1 through 4 to calculate an improvement index for all unoccupied cells. If all the improvement indices have values greater than or equal to zero, then the current solution is optimal. If not, the current solution can be improved and the total transportation costs can be decreased further.

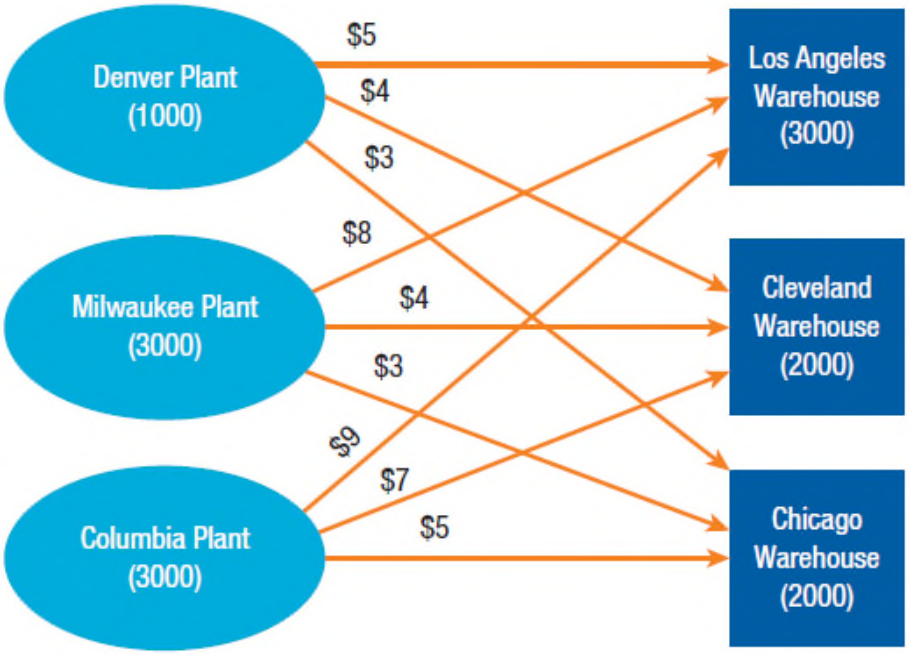
Stepping Stone Method (Cont'd)

6. In any of the improvement indices has a negative value, refer to the closed path that produced the negative improvement index. Select the cell with a minus sign that has the smallest shipment quantity.
7. Add the smallest quantity found in step 6 to all the cells with a + sign in the closed path. Subtract the same quantity from all the cells with a - sign.
8. This new improved solution may or may not be optimum. Steps 1 through 5 should be repeated to test each unoccupied cell in the new solution matrix. The process stops when all improvement indices computed are greater than or equal to zero.

Example B.1

- Orion has three supply locations with respective production capacities of an electronic component (Denver, Milwaukee, and Columbia) and three demand locations with their demand requirements for that electronic component.
- Given the various alternatives of possible allocation of shipments from the three supply locations to the three demand locations, the transportation model will help us to determine the optimal distribution plan that will minimize the total shipment or transportation costs.

FIGURE B.1: Structure of the Transportation Problem



Example B.1 (Cont'd)

- Step 1: Using the information available on capacities and demand requirements for the various origins and destinations, and the shipping cost per unit for each route, set up a transportation table or matrix.

FIGURE B.2: Transportation Matrix for Orion Electronics

TO / FROM	LOS ANGELES	CLEVELAND	CHICAGO	PRODUCTION CAPACITY
Denver	$4	$3	$2	1,000
Milwaukee	$7	$3	$2	3,000
Columbia	$8	$6	$4	3,000
Demand Requirement	3,000	2,000	2,000	7,000

Example B.1 (Cont'd)

- Step 2: Develop an initial basic feasible solution

FIGURE B.3: Transportation Matrix With an Initial Feasible Solution for Orion Electronics Using the Northwest Corner Rule

TO / FROM	LOS ANGELES	CLEVELAND	NEW YORK	PRODUCTION CAPACITY
Denver	$4 1,000	$3	$2	1,000
Milwaukee	$7 2,000	$3 1,000	$2	3,000
Columbia	$8	$6 1,000	$4 2,000	3,000
Demand Requirement	3,000	2,000	2,000	**7,000**

TABLE B.1: Transportation Cost for the Initial Shipping Allocation Using the Northwest Corner Rule

FROM	TO	UNITS SHIPPED	COST PER UNIT	TOTAL COST
Denver	Los Angeles	1,000	$4	$4,000
Milwaukee	Los Angeles	2,000	$7	$14,000
Milwaukee	Cleveland	1,000	$3	$3,000
Columbia	Cleveland	1,000	$6	$6,000
Columbia	Chicago	2,000	$4	$8,000
Total				$35,000

Example B.1 (Cont'd)

FIGURE B.4: Transportation Matrix With an Initial Basic Feasible Solution for Orion Electronics Using the Matrix Least Cost Method

TO / FROM	LOS ANGELES	CLEVELAND	CHICAGO	PRODUCTION CAPACITY
Denver	$4	$3 1,000	$2	1,000
Milwaukee	$7	$3 1,000	$2 2,000	3,000
Columbia	$8 3,000	$6	$4	3,000
Demand Requirement	3,000	2,000	2,000	**7,000**

TABLE B.2: Transportation Cost for the Initial Shipping Allocation Using the Matrix Least Cost Method

FROM	TO	UNITS SHIPPED	COST PER UNIT	TOTAL COST
Denver	Cleveland	1,000	$3	$3,000
Milwaukee	Chicago	2,000	$2	$4,000
Milwaukee	Cleveland	1,000	$3	$3,000
Columbia	Los Angeles	3,000	$8	$24,000
Total				$34,000

Example B.1 (Cont'd)

- Step 3: Beginning with a + sign for the empty cell being evaluated (Cleveland in this case), place alternating – and + signs on the corner cells of this closed path.

FIGURE B.5: Evaluation of the Denver–Cleveland Cell

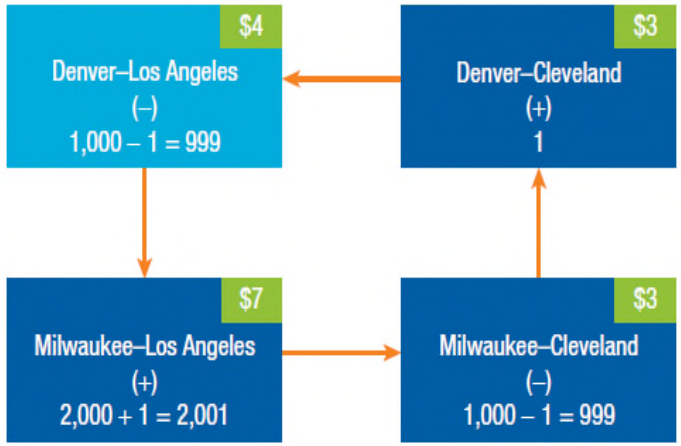


FIGURE B.6: Transportation Matrix for the Evaluation of the Denver–Cleveland Route for Orion Electronics Using the Stepping Stone Method

TO / FROM	LOS ANGELES	CLEVELAND	CHICAGO	PRODUCTION CAPACITY
Denver	$4 1,000–	$3 +	$2	1,000
Milwaukee	$7 2,000+	$3 –1,000	$2	3,000
Columbia	$8	$6 1,000	$4 2,000	3,000
Demand Requirement	3,000	2,000	2,000	**7,000**

Example B.1 (Cont'd)

- Step 4: We calculate an improvement index for the Denver-Cleveland cell (route) by first summing the unit costs in the cells with a plus sign in the closed path, and from the resulting sum, subtracting the sum obtained by adding the unit costs in cells containing a minus sign.
- The results are: (3 + 7) – (3 + 4) = +3
- The result of +3 tells us that for every additional unit shipped in the Denver-Cleveland route, the total transportation cost will increase by $3 from the current level of $35,000.
- Since the improvement index has a positive value, we go to Step 5.

Example B.1 (Cont'd)

- Step 5: Because the improvement index for the Denver-Cleveland route was positive, we will conduct a second iteration and repeat steps 1 through 4 to calculate an improvement index for another unoccupied cell of the initial solution matrix obtained using the northwest corner rule.

FIGURE B.7: Transportation Matrix for the Evaluation of the Denver–Chicago Route for Orion Electronics Using the Stepping Stone Method

TO / FROM	LOS ANGELES (L)	CLEVELAND (CL)	CHICAGO (C)	PRODUCTION CAPACITY
Denver (D)	$4 1,000–	$3	$2 +	1,000
Milwaukee (M)	$7 2,000+	$3 –1,000	$2	3,000
Columbia (CO)	$8	$6 +1,000	$4 –2,000	3,000
Demand Requirement	3,000	2,000	2,000	**7,000**

Example B.1 (Cont'd)

- Step 6: From the closed path for Columbia–Los Angeles route, select the cell with a minus sign and the smallest shipment quantity, which is the 1,000 units in the Columbia–Cleveland route. Therefore, we select the Columbia–Cleveland cell.

FIGURE B.8: Transportation Matrix for the Columbia–Los Angeles Route

TO / FROM	LOS ANGELES (L)	CLEVELAND (CL)	CHICAGO (C)	PRODUCTION CAPACITY
Denver (D)	$4 1,000	$3	$2	1,000
Milwaukee (M)	$7 2,000–	$3 +1,000	$2	3,000
Columbia (CO)	$8 +	$6 –1,000	$4 2,000	3,000
Demand Requirement	3,000	2,000	2,000	**7,000**

Example B.1 (Cont'd)

- Step 7: To obtain an improved solution, we will add the smallest quantity of 1000 units found in the previous step to all the cells with a + sign in the closed path and subtract the same quantity from all the cells with a - sign. All other cells are left unchanged.

FIGURE B.9: Transportation Matrix With an Improved Solution in the Second Iteration of the Stepping Stone Method

TO / FROM	LOS ANGELES (L)	CLEVELAND (CL)	CHICAGO (C)	PRODUCTION CAPACITY
Denver (D)	$4 1,000	$3	$2	1,000
Milwaukee (M)	$7 1,000	$3 2,000	$2	3,000
Columbia (CO)	$8 1,000	$6	$4 2,000	3,000
Demand Requirement	3,000	2,000	2,000	**7,000**

Example B.1 (Cont'd)

- Step 8: This new improved solution may or may not be optimum. Steps 1 through 5 should be repeated to test each unoccupied cell in the new solution matrix.

FIGURE B.10: Transportation Matrix for the Milwaukee–Chicago Route

TO / FROM	LOS ANGELES (L)	CLEVELAND (CL)	CHICAGO (C)	PRODUCTION CAPACITY
Denver (D)	$4 1,000	$3	$2	1,000
Milwaukee (M)	$7 1,000–	$3 2,000	$2 +	3,000
Columbia (CO)	$8 1,000+	$6	$4 2,000–	3,000
Demand Requirement	3,000	2,000	2,000	**7,000**

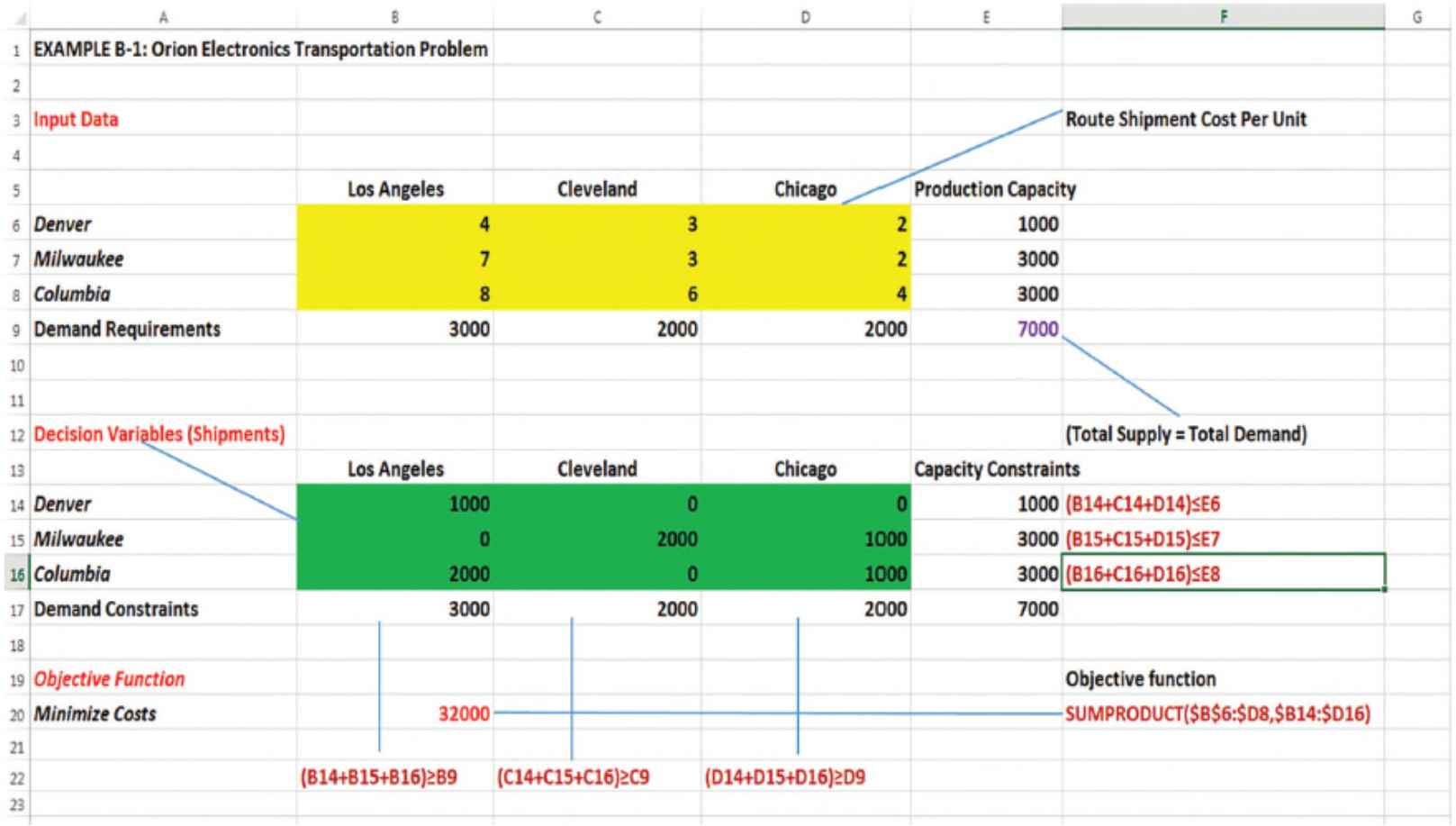
Example B.1 (Cont'd)

FIGURE B.11: Transportation Matrix With an Improved Solution in the Third Iteration of the Stepping Stone Method

TO / FROM	LOS ANGELES (L)	CLEVELAND (CL)	CHICAGO (C)	PRODUCTION CAPACITY
Denver (D)	$4 1,000	$3	$2	1,000
Milwaukee (M)	$7	$3 2,000	$2 1,000	3,000
Columbia (CO)	$8 2,000	$6	$4 1,000	3,000
Demand Requirement	3,000	2,000	2,000	**7,000**

Example B.1 (Cont'd)

SCREENSHOT B.1: Orion Electronics Company Transportation Model Formulation and Solution in Excel



	A	B	C	D	E	F
1	EXAMPLE B-1: Orion Electronics Transportation Problem					
2						
3	Input Data					Route Shipment Cost Per Unit
4						
5		Los Angeles	Cleveland	Chicago	Production Capacity	
6	*Denver*	4	3	2	1000	
7	*Milwaukee*	7	3	2	3000	
8	*Columbia*	8	6	4	3000	
9	Demand Requirements	3000	2000	2000	7000	
10						
11						
12	Decision Variables (Shipments)					(Total Supply = Total Demand)
13		Los Angeles	Cleveland	Chicago	Capacity Constraints	
14	*Denver*	1000	0	0	1000	(B14+C14+D14)≤E6
15	*Milwaukee*	0	2000	1000	3000	(B15+C15+D15)≤E7
16	*Columbia*	2000	0	1000	3000	(B16+C16+D16)≤E8
17	Demand Constraints	3000	2000	2000	7000	
18						
19	*Objective Function*					Objective function
20	*Minimize Costs*	32000				SUMPRODUCT($B$6:$D8,$B14:$D16)
21						
22		(B14+B15+B16)≥B9	(C14+C15+C16)≥C9	(D14+D15+D16)≥D9		
23						

Unequal Supply and Demand (Example B.2)

- Orion Electronics has decided to increase its production capacity from 1000 units to 2500 units. Reformulate the transportation problem in Example B.1 and solve the problem using Excel Solver.

FIGURE B.12: Revised Transportation Matrix for Orion Electronics With a Dummy Destination

TO / FROM	LOS ANGELES	CLEVELAND	CHICAGO	DUMMY DESTINATION	PRODUCTION CAPACITY
Denver	$4	$3	$2	$0	**2,500**
Milwaukee	$7	$3	$2	$0	3,000
Columbia	$8	$6	$4	$0	3,000
Demand Requirement	3,000	2,000	2,000	**1,500**	**8,500**

Unequal Supply and Demand (Example B.2) (Cont'd)

FIGURE B.13: Transportation Matrix With an Initial Feasible Solution Using the Northwest Corner Rule for the Revised Transportation Problem of Orion Electronics

TO / FROM	LOS ANGELES	CLEVELAND	CHICAGO	DUMMY DESTINATION	PRODUCTION CAPACITY
Denver	$4 2,500	$3	$2	$0	**2,500**
Milwaukee	$7 500	$3 2,000	$2 500	$0	3,000
Columbia	$8	$6	$4 1,500	$0 1,500	3,000
Demand Requirement	3,000	2,000	2,000	**1,500**	**8,500**

Unequal Supply and Demand (Example B.2) (Cont'd)

SCREENSHOT B.2: Optimum Solution to the Orion Electronics Transportation Problem With a Dummy Destination

	A	B	C	D	E	F	G
1	EXAMPLE B-2: Revised Orion Electronics Transportation Problem						
2	Input Data						Route Shipment Cost Per Unit
3							
4		Los Angeles	Cleveland	Chicago	Dummy Destination	Production Capacity	
5	*Denver*	4	3	2	0	2500	
6	*Milwaukee*	7	3	2	0	3000	
7	*Columbia*	8	6	4	0	3000	
8	Demand Requirements	3000	2000	2000	1500	8500	
9							
10							
11	Decision Variables (Shipments)						(Total Supply = Total Demand)
12		Los Angeles	Cleveland	Chicago	Dummy Destination	Capacity Constraints	
13	*Denver*	2500	0	0	0	2500	(B13+C13+D13+E13)≤F5
14	*Milwaukee*	0	2000	1000	0	3000	(B14+C14+D14+E14)≤F6
15	*Columbia*	500	0	1000	1500	3000	(B15+C15+D15+E15)≤F7
16	Demand Constraints	3000	2000	2000	1500		
17							
18	*Objective Function*						Objective function
19	*Minimize Costs*	26000					SUMPRODUCT($B$5:$E7,$B13:$E15)
20							
21		(B13+B14+B15)≥B8	(C13+C14+C15)≥C8	(D13+D14+D15)≥D8	(E13+E14+E15)≥E8		
22							

Degeneracy

- Degeneracy is a condition that occurs when the solution to a transportation problem has occupied routes (cells) that are less than the (number of origins + the number of destinations - 1).

FIGURE B.14: Transportation Matrix With a Degenerate Initial Solution for the Orion Electronics Company Problem Using the Matrix Least Cost Method

FROM \ TO	LOS ANGELES	CLEVELAND	CHICAGO	PRODUCTION CAPACITY
Denver	$4	$3 1,000	$2	1,000
Milwaukee	$7	$3 1,000	$2 2,000	3,000
Columbia	$8 3,000	$6	$4	3,000
Demand Requirement	3,000	2,000	2,000	**7,000**

Degeneracy (Cont'd)

FIGURE B.15: Transportation Matrix by Creating an Artificially Occupied Cell to Overcome Degeneracy

TO / FROM	LOS ANGELES	CLEVELAND	CHICAGO	PRODUCTION CAPACITY
Denver	$4	$3 1,000	$2	1,000
Milwaukee	$7 0	$3 1,000	$2 2,000	3,000
Columbia	$8 3,000	$6	$4	3,000
Demand Requirement	3,000	2,000	2,000	**7,000**