B Appendix

ANSWERS TO SELECTED PROBLEMS

Chapter 2

1. a. 16.67%.
   b. 2.09 times.
   c. 34.78%.
   d. $23,000,000.

Chapter 3

7. a. 70 minutes.
   b. The desired waiting time is 30 minutes; yet, the actual expected waiting time is 70 minutes, which is greater than the desired 30 minutes. To bring the actual and promised waiting times into agreement, we can do the following:

      - Reduce the processing time for jobs from 6 to less than 2.6 minutes.
      - Reduce either of the coefficients of variation.
      - Reduce the utilization from 70 to 50 percent by increasing the staffing levels in the health center.

9. a. 2.86, rounded to 3.
   b. 42.
   c. 70.
   d. If we were to set the resources to the levels indicated in the preceding calculations, then we should not have any bottlenecks. However, in reviewing the numbers, where the potential bottleneck emerges can be identified based on how sensitive the calculations are to violations in the assumptions. With that perspective, we can see if we were to have 3 cash registers, we are assuming that each order will have 4 people on the order. If this assumption is violated (e.g., we have a number of checks where there are less than 4 people per check), then this becomes the bottleneck.

11. a. 32 jobs per day.
    b. 10 days.
    c. 6.25 days.
    d. Process A (less labor).
    e. Process B (15 minutes per job compared to 24 minutes per job under Process A).

13. a. If we have an inventory of $200 and daily sales of $400, then the flow rate of 1 day could not be supported.
    b. To keep the flow times constant, we have to increase the inventory.

Chapter 3S

3. a.

Process Flow Chart

Page ____ of ____

Overall Description of Process Charted:

Date Charted: _____ Charted by: _____

Check appropriate box: Current Process: (x) Proposed Process: ( )

Dist FT Meters	Time (avg.)	Symbol	Pers Invol.	Value Code V/W/N/?[1]	Description of Activity (indicate outcome)
		O ➡ □ D ∇		?	Transport in the raw materials
		O ⇒ □ D ▼		N	Store the raw materials
		O ⇒ ■ D ∇		?	Inspect the material
		O ⇒ □ D ▼		N	Put the raw materials in storage
		O ➡ □ D ∇		W	Move the materials to the area where mixed
	60 min	● ⇒ □ D ∇		V	Mix the items, place in pans
50 yds.		O ➡ □ D ∇			Move to shipping area
		O ⇒ □ D ∇			Put into inventory
		● ⇒ □ D ∇		V	Order, rearrange the number of bagels, match to an order
		O ➡ □ D ∇			Move to trucks
		O ⇒ □ ◗ ∇			Wait to be loaded into trucks
	20 min	● ⇒ □ D ∇			Place into trucks
	40 min	O ➡ □ D ∇			Transport (while allowing bagels to rise)
		O ⇒ □ ◗ ∇			Wait to be unloaded
		● ⇒ □ D ∇			Unload trucks
		O ➡ □ D ∇			Move to work areas
	40 min	● ⇒ □ D ∇		V	Mix, cook
		O ➡ □ D ∇			Move to cooling area
		● ⇒ □ D ∇		N	Allow bagels to cool
		O ➡ □ D ∇			Move to retail area displays
		O ⇒ □ D ▼		V	Sit in displays and wait to be sold
		6 8 1 2 4			

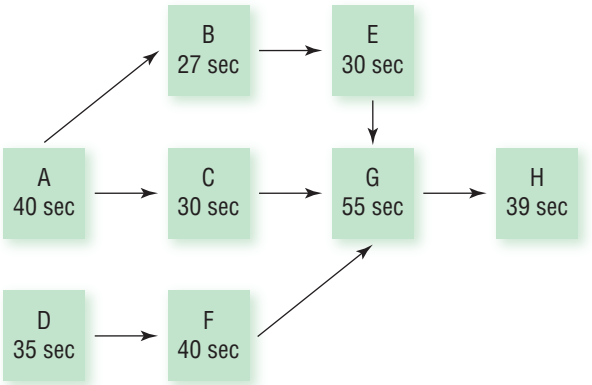
b. Value-adding activities are indicated in the preceding chart.

[1] The value code indicates the extent to which the activity is value-adding (V), waste-creating (W), not value-adding but necessary (N), or unknown (?).

Chapter 5

1. a. 50 seconds.
   b. 82.8%.
   c. 72 units per hour.
   d. 45 seconds per unit.
   e. The time at workstation 4 needs to be reduced by 5 seconds so that it does not exceed the TAKT time of 45 seconds.

3. a.



   b. 96 seconds per unit.
   c. 3.08, round up to 4 workstations.
   d.

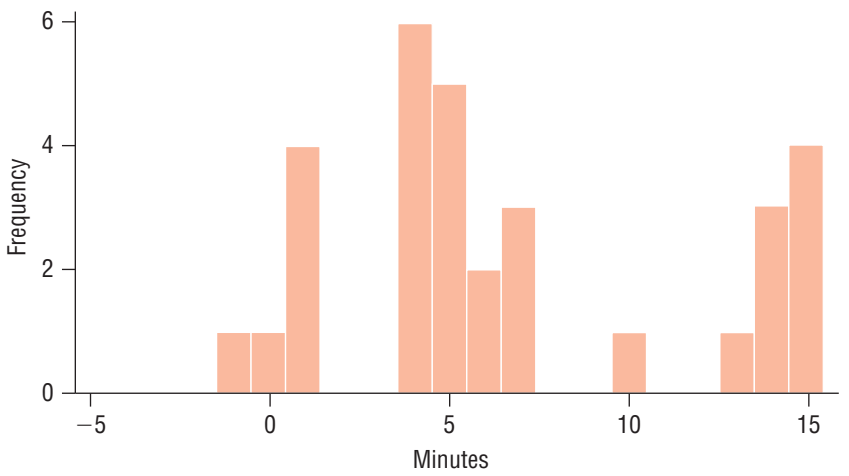
Workstation	Tasks in Order	Workstation Time (Seconds)	Idle Time (Seconds)
1	A, D	75	21
2	F, C	70	26
3	B, E	57	39
4	G, H	94	2

   e. 77.1%.

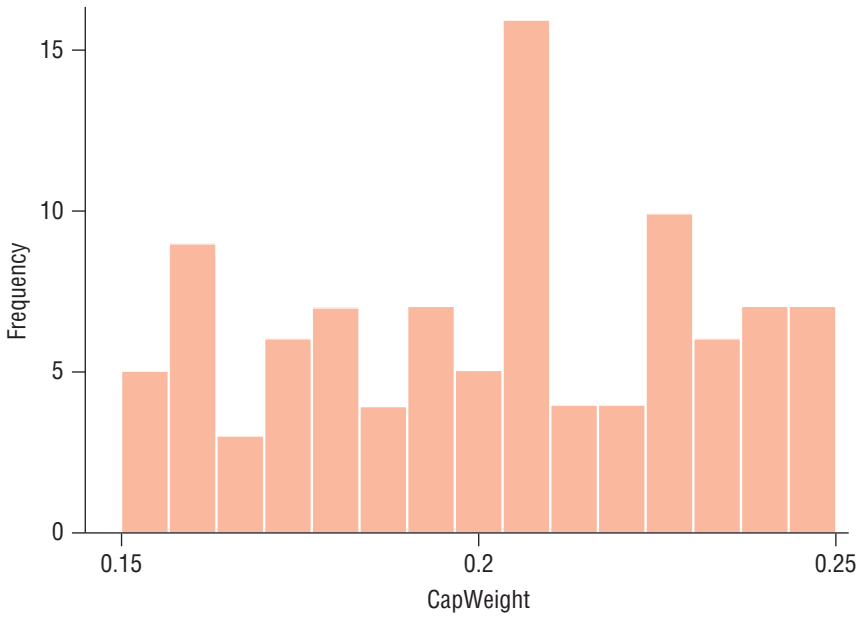
9. V = 2,667 claims.
   Use the newer, more automated process because the total cost will be lower because the volume of 3,500 claims per year exceeds the indifference point.

Chapter 6S

1.



2. Histogram



3. C_p = S/P = 1/.6 = 1.67
   C_{pk} = 1.64

13.

Data Points	*x*-bar Chart	*R*-bar Chart
Central line	12.94	1.35
Lower control limit (LCL)	12.14 − .58*1.35 = 11.36	0
Upper control limit (UCL)	12.14 + .58*1.35 = 12.92	2.12*1.35 = 2.86

14. For this table, we would construct a Pareto chart with the following information:

Reject Cause	Number
Contamination	15
Oxide defect	9
Misc	3
Corrosion	2
Metallization	2
Doping	1
Silicon defect	1

Focus on contamination and oxide defect. Tools to use here include:

- Cause-and-effect analysis.
- Checksheets.

15. Number of defects decreased from 33 to 19.
Significant decrease in oxide defects (from 9 → 1).
Significant decrease in contamination (from 15 → 8).
Increases in silicon defects.

Chapter 7

1. Inventory turnover rate: 7 times.
Inventory carrying cost: $150,000.

3. Item 1 = $607,500.
Item 2 = $540,000.
Item 3 = $81,900.
Item 4 = $333,000.
Item 5 = $9,900.
Total annual inventory carrying cost = $1,572,300.

6. a. EOQ = 1,789 cases.
Average inventory = 894.5 cases.
Inventory turnover = 223.6 times.
b. EOQ at $18 = 1,886 cases.
However, Foods Galore must order 10,000 cases to receive this price. Therefore, the calculated EOQ for the $18 price is not relevant.
TAC of ordering at the $20 price = $4,008,944.27.
TAC of ordering at the $18 price = $3,623,300.00.
Foods Galore should order 10,000 cases at a time because they would save $385,644.27.
c. Standard deviation of demand during lead time = 1,211.94 or 1,212 cases.
5% risk of stockout equals 1.65 deviations of safety stock = 2,000 cases.
Inventory carrying cost = $9,000.
1% risk of stockout = 2,824 cases.
Inventory carrying cost = $12,708.

8. Production order quantity 73.03 = 74 units.
Producing 74 units in a production run at a rate of 16 per day requires 74/16 = 4.625 days.

10. Standard deviation of demand during lead time = 204.27 = 205 units.
    SS = 339 units.
    EOQ = 707.11 = 708 units.
    TAC of ordering 708 units = $628,535.54.
    Average cycle stock = 354 units.
    Average inventory = 693 units.

Chapter 9

1. Unit fill rate = 95%.
   Line fill rate = 90%.
   Order fill rate = 80%.

3. 62.2%.

5. Unit fill rate = 96%.
   Line fill rate = 97.6%.
   Order fill rate = 96.6%.

Chapter 10

1. Supplier A's score is 2.7, Supplier B's is 3.15, Supplier C's 3.2. Judgment should be used to decide between Supplier B and Supplier C.
3. WebTex score is 3.25, CoolWeb is 2.6, Dazzling Designs is 4.05, and Major Marketing is 3.7. Dazzling Designs has the highest score and may be the best supplier to select.

Chapter 11

1. a. $99.66
   b. The 2-day shipment total cost = $109.86. The 2-day shipment is more expensive than the 5-day shipment. If the manager chose this option, the company would lose $10.20.

5. Air = $910.96
   Ground = $1,432.88
   Other considerations involved besides cost are the availability of these modes of transportation, customer desire for rapid delivery, and their dependability. If the customer wants the diamonds delivered as soon as possible and to ensure their safety, air is probably the best option. Although there are chances of delays, air transportation will probably deliver the diamonds more quickly with less handling and chances of damaging these expensive items.

8. Single shipments cost = $1,440.
   Consolidated shipment cost = $1,420.
   The consolidated shipment offer is the better choice. The company would save $20 by combining all 10 shipments into one.

10. X* = 47.647
    Y* = 32.647

Chapter 12

1. The weight put on one time period older than the most recent period is .24.
   Two periods older 0.096.

3. Forecast error = 3.
   F_{t+1} = 28.5, or 29 rounded up.

5. a.

Week	Demand	2-Week	Error	Absolute	4-week	Error	Absolute	6-week	Error	Absolute
1	232									
2	263									
3	271	247.5	23.5	23.5						
4	248	267	−19	19						
5	235	259.5	−24.5	24.5	253.5	−18.5	18.5			
6	261	241.5	19.5	19.5	254.3	6.8	6.8			
7	207	248	−41	41	253.8	−46.8	46.8	251.7	−44.7	44.7
8	243	234	9	9	237.8	5.3	5.3	247.5	−4.5	4.5
9	237	225	12	12	236.5	0.5	0.5	244.2	−7.2	7.2
10	293	240	53	53	237.0	56.0	56.0	238.5	54.5	54.5
11	243	265	−22	22	245.0	−2.0	2.0	246.0	−3.0	3.0
12	260	268	−8	8	254.0	6.0	6.0	247.3	12.7	12.7
13	253	251.5	1.5	1.5	258.3	−5.3	5.3	247.2	5.8	5.8
14	270	256.5	13.5	13.5	262.3	7.8	7.8	254.8	15.2	15.2
15	230	261.5	−31.5	31.5	256.5	−26.5	26.5	259.3	−29.3	29.3
16	253	250	3	3	253.3	−0.3	0.3	258.2	−5.2	5.2
17	238	241.5	−3.5	3.5	251.5	−13.5	13.5	251.5	−13.5	13.5
18	272	245.5	26.5	26.5	247.8	24.3	24.3	250.7	21.3	21.3
19	222	255	−33	33	248.3	−26.3	26.3	252.7	−30.7	30.7
20	243	247	−4	4	246.3	−3.3	3.3	247.5	−4.5	4.5
21	289	232.5	56.5	56.5	243.8	45.3	45.3	243.0	46.0	46.0
22	238	266	−28	28	256.5	−18.5	18.5	252.8	−14.8	14.8
23	262	263.5	−1.5	1.5	248.0	14.0	14.0	250.3	11.7	11.7
24	234	250	−16	16	258.0	−24.0	24.0	254.3	−20.3	20.3
			−14.0	20.5		−19.0	17.5		−10.5	19.2
			MFE	MAD		MFE	MAD		MFE	MAD

The four-week moving average has the lowest MAD. It also has the highest level of bias, in that the forecast tends to overestimate the demand. In this situation, it would be better to overforecast than to underforecast.

b. The alpha of 0.25 results in the lowest MFE value of 76.5. Although the MAD of 18 is not the lowest, it is very close to the lowest value. Thus, 0.25 is the best choice for the alpha value.

13. $FIT_7 = 69.3$.

15. $b = 7.8$, $a = 14.3$.

17. a. Sales (1000s) = 1.182 (PMI) + 71.99, $R^2 = 0.65$.
    b. Sales (1000s) = 1.73 (PMI) + 49.65, $R^2 = 0.91$.
    c. 133.

Chapter 13

1. Total level plan cost = $271,400.
   Total chase plan cost (adjust workforce) = $257,400.
   Total overtime plan cost = $288,480.
   Total subcontract cost = $260,640.
   Total hybrid cost = $269,640.

3. Total cost = $24,400,000.

5. a. 350 units per month.
   b. The maximum end-of-period inventory experienced would be 300 units.
      Total cost = $539,000.
   c. Total cost = $534,000.

7. Total level plan cost = $29,610,000.
   Total case with overtime cost = $30,500,000.
   Total Chase (Hiring/firing) Cost = $28,960,000

Chapter 14

1. Es are components in Bs and Ds. Start with the Bs. 20 As × 2 Bs for each A = 40 Bs. 40 Bs × 4 Es for each B = 160 Es. Then determine the Es needed for the Ds. 20 As × 2 Ds for each A = 40 Ds. 40 Ds × 2 Es for each D = 80 Es. The total number of Es = 160 + 80 = 240.

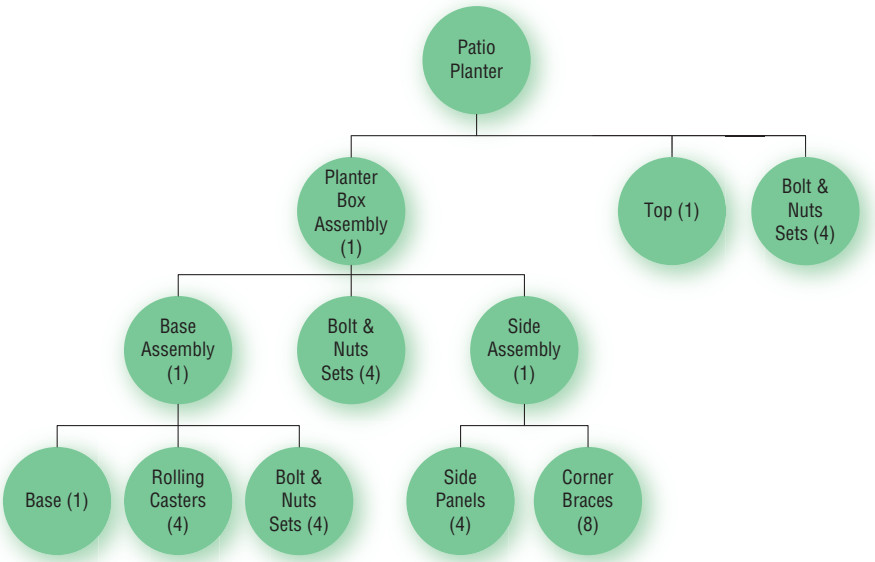
   Cs are used directly to make As and also are used to make Ds. 20 As × 1 C for each A = 20 Cs. 20 As × 2 Ds for each A = 40 Ds. 40 Ds × 1 C for each D = 40 Cs. The total number of Cs = 20 + 40 = 60.

4. Fs are used in component Ds and component Cs. 15 As × 1 B for each A = 15 Bs. 15 Bs × 2 Ds for each B = 30 Ds. 30 Ds × 4 Fs for each D = 120 Fs. 15 As × 4 Cs for each A = 60 Cs. 60 Cs × 1 F for each C = 60 Fs. 60Cs × 3 Ds for each C = 180 Ds. 180 Ds × 4 Fs for each D = 720 Fs. Total Fs = 120 + 60 + 720 = 900 Fs.

   If part D is purchased, the number of levels in the BOM will be reduced from four levels to three levels. The components that are used to make Ds (E and F) will not be shown in the BOM.

   If D is purchased, C is the only parent of F in the BOM. 15 As × 4 Cs for each A = 60 Cs. 60 Cs × 1 F for each C = 60 Fs. Only 60 Fs will be needed. The other Fs will be purchased and used by the supplier who provides component D.

10.



The total number of bolt and nuts sets = 32 + 32 + 32 = 96 sets.

11.

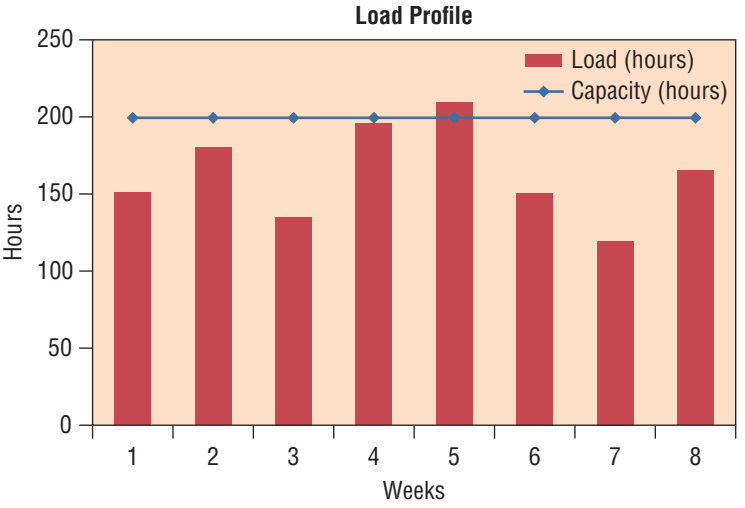
MRP Record Lead time = 2 weeks On hand = 0 Safety stock = 0 Order quantity: L4L	Part Name: Bicycle frame Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	70	50	80	80	70	60	80	80
Scheduled receipts	70	50						
Available inventory								
Net requirements			80	80	70	60	80	80
Planned order receipts			80	80	70	60	80	80
Planned order releases	80	80	70	60	80	80		

MRP Record Lead time = 2 weeks On hand = 0 Safety stock = 0 Order quantity: FOQ = 100	Part Name: Bicycle frame Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	70	50	80	80	70	60	80	80
Scheduled receipts	100	100						
Available inventory	30	80		20	50	90	10	30
Net requirements				80	50	10		70
Planned order receipts				100	100	100		100
Planned order releases		100	100	100		100		

Compared to the FOQ strategy, the L4L strategy orders more often (six times compared to four times) but has no inventory costs. The FOQ strategy has inventory costs. The L4L also provides a truer picture of actual demand to the supplier.

17.

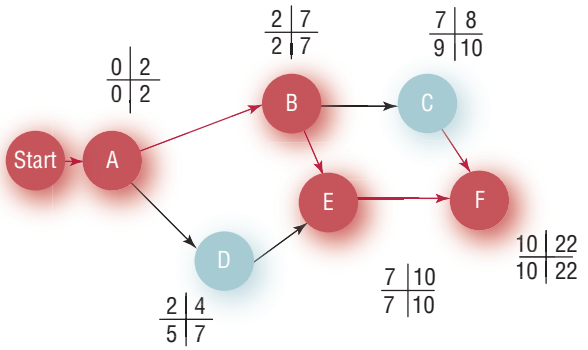
Processing time = 9 minutes	Part Name: Computer keyboard Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Planned order releases	1,000	1,200	900	1,300	1,400	1,000	800	1,100
Processing load (hours)	150.0	180.0	135.0	195.0	210.0	150.0	120.0	165.0
Available capacity (hours)	200	200	200	200	200	200	200	200



The load exceeds capacity in week 5, and there are significant levels of excess capacity in weeks 1, 3, 6, and 7. Perhaps product can be made in week 3 and held in inventory for week 5.

Chapter 15

6. a.



b. The critical path is A, B, E, F

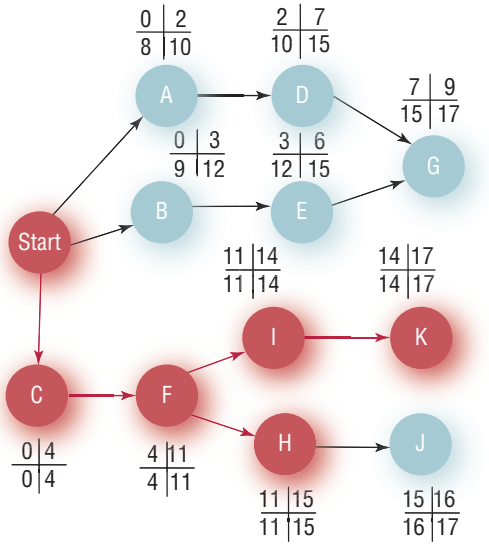
Task	Immediate Predecessors	Earliest Start (ES)	Earliest Completion (EC) = ES + task duration
A	None	0	2
B	A	2	7
C	B	7	8
D	A	2	4
E	B, D	7	10
F	C, E	10	22

Task	Immediate Successors	Latest completion	Latest Start (LS) = LC − task duration	Slack = LS − ES
F	None	22	10	10−10 = 0
E	F	10	7	7−7 = 0
D	E	7	5	5−2 = 3
C	None	10	9	9−8 = 1
B	E	7	2	2−2 = 0
A	B, D	2	0	0−0 = 0

c. The activities that the project manager should track most closely are A, B, E, and F. They are on the critical path.

d. Increasing the time required for D from 2 days to 6 days is an increase of 4 days. Activity D currently has 3 days of slack [LC − EC (7 − 4 days) or LS − ES (5 − 2 days)]. Thus, D will now be on the critical path and the overall project time will increase by 1 day and activity B is no longer on the critical path. The ES and LS time for activity E becomes 8 rather than 7 days.

8. The critical path tasks are C, F, H, I, K.



Task	Immediate Predecessors	Earliest Start (ES)	Earliest Completion (EC) = ES + task duration
A	None	0	2
B	None	0	3
C	None	0	4
D	A	2	7
E	B	3	6
F	C	4	11
G	D, E	7	9
H	F	11	15
I	F	11	14
J	H	15	16
K	I	14	17

Task	Immediate Successors	Latest Completion (LC)	Latest Start (LS) = LC − task duration	Slack = LS − ES
K	None	17	14	14−14 = 0
J	None	17	16	16−15 = 1
I	K	14	11	11−11 = 0
H	J	15	11	11−11 = 0
G	None	17	15	15−7 = 8
F	H, I	11	4	4−4 = 0
E	G	15	12	12−3 = 9
D	G	15	10	10−2 = 8
C	F	4	0	0−0 = 0
B	E	12	9	9−0 = 9
A	D	10	8	8−0 = 8

Chapter 15S

3. The project must be crashed by an additional two days. To do this, you must crash Prepare Documentation by 2 days at a cost of $400/day and Populate System Data by 1 day at a cost of $700. Thus, the total cost of crashing the project by 7 days is $4,600, which is more than the $4,000 bonus. The project could be shortened to 6 days by crashing Prepare Documentation by 1 day at a cost of $3,500.

5. The probability that the project will take less than 32 days is 53%, so the probability that the project will take more than 32 days is 47%.

7. a. 35 weeks.
   b. The likelihood that the critical path will be completed in 37 weeks is 75%.
   c. The likelihood that the project will be completed in 36 weeks is 63%.
   d. The likelihood that the project will be completed in 33 weeks is 37%.
   e. Because the two paths share several activities, it is difficult to estimate the likelihood that both paths will complete the project on time. However, because the duration of the "Code A" task is much shorter than the combined duration of tasks "Code B" and "Code C," we can be fairly sure that "Code A" will always be completed before both "Code B and "Code C" are completed. Using the expected durations, "Code A" has 6.66 days of slack. Therefore, we can be confident that the expected critical path will always dictate the actual length of the project, and we can be assured of the correctness of our estimates of project completion in parts a-d above that are based on the critical path alone.