Solutions for Operations and Supply Chain Management for MBAs 7th Edition by Meredith

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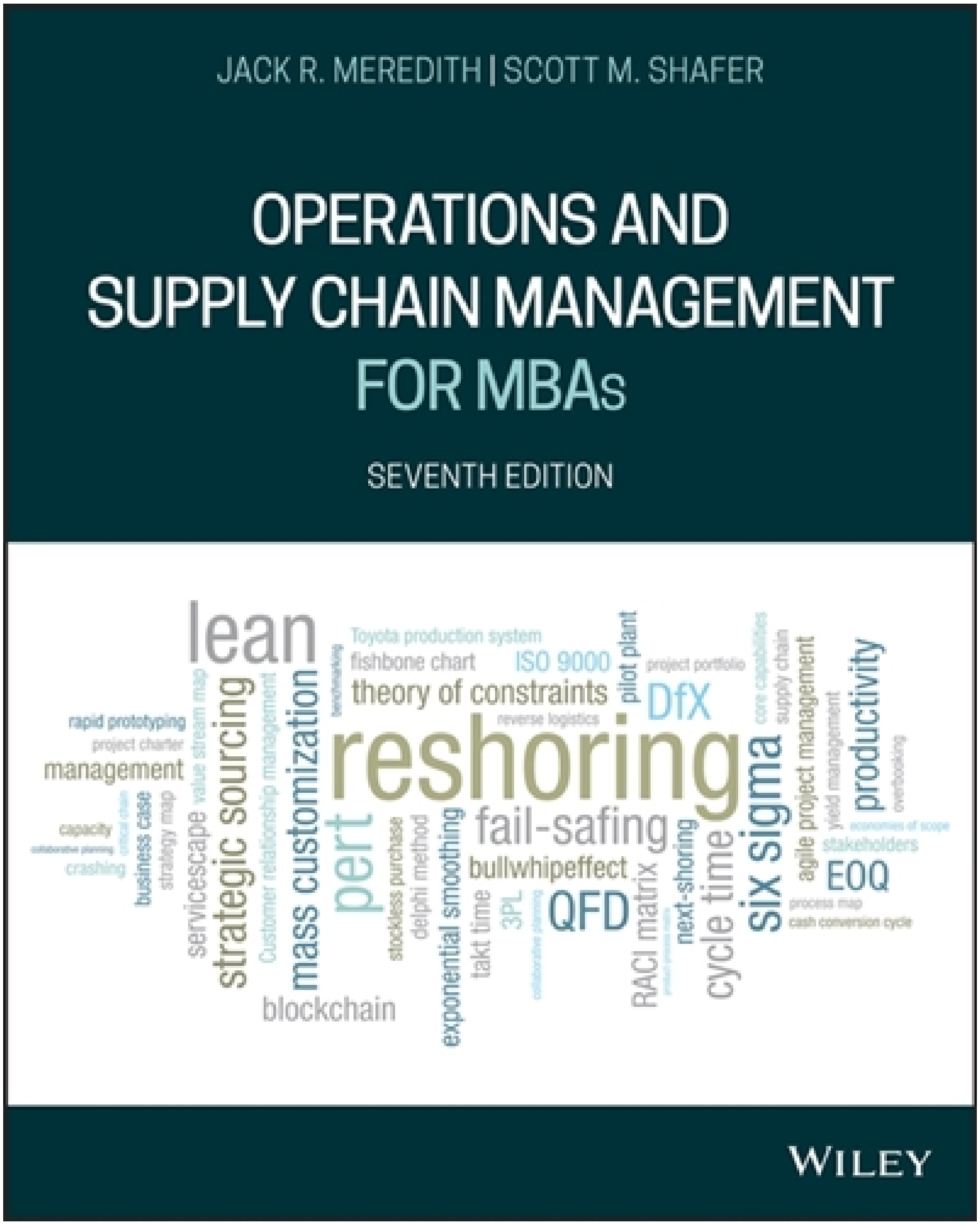


Solutions

Chapter 2
Executing Strategy: Project Management

Chapter Summary

After defining what a project is, the chapter continues with the crucial topic of project planning. Included in this section are discussions of the project portfolio, the project lifecycle, projects in the organizational structure, organizing the project team, project plans, and a new discussion on change management. We then move on to an explanation of some project scheduling techniques, showing some typical project management software printouts that are available to project managers. Also a new section on agile project management has been added. Next, another new section has been added on project crashing. Finally, the chapter concludes with a discussion of controlling project cost and performance, primarily through the use of "earned value."

Chapter Teaching Tips

One way to introduce this chapter is to focus on the growth of projects in our society. Another, and often more engaging, introduction is to devise a project with the class or with one person currently engaged in a project involving multiple people (e.g., a campus career day), lay out the work breakdown structure, estimate the activities and the times, and construct and solve the PERT network. Another engaging issue is to ask the class how they might track the progress of a project as it progresses. How would they actually measure the amount of progress attained—task-by-task or by looking at the overall project? Could they trust someone who says that their task, or the project, is 99% done? If not, what surrogate measures would be helpful for tracking project progress?

Illustrative Answers to the Expand Your Understanding Questions

1. This major strategic error is more common than any other mistake. It is important to realize that it is precisely because the tasks are defined so poorly that it is necessary to take longer to plan the work that must be done. Although we would want to avoid "analysis paralysis," the overwhelming tendency is to plan too little rather than too much.

2. The cost-schedule reconciliation charts are more straightforward but cannot easily be compared since the vertical axis is not the same in both charts. A project manager unfamiliar with the earned value concept might therefore prefer the reconciliation charts.

3. One simple way is to equate the value with the cost of materials and resources used to date, but this defeats the purpose. In reality, resources are usually brought in long before a task is complete and only a minor additional increase in cost (e.g., a day's wages) may represent the final attainment of a task with considerable value. It is the responsibility of the project manager to decide on what task completions, or even partial completions, represent value completed for

the sponsor. In practice, there are five commonly used ways (all with potential pitfalls) to measure earned value: 0-100% (i.e., no credit for the task budget [not actual spending] until a task is completely finished), 50-50% (half of the budget when the task starts, half when done), as a percentage of a scarce, critical resource used in proportion to progress (e.g., yards of concrete poured for a road or building), percent of budgeted time passed since start of the task, and percent of the budget spent since start of the task.

4. Because typically more things can go wrong than right, the optimistic times will probably be more accurate.

5. Of the reasons listed in the text for the growth in project operations, the need for quick response to customers' needs given today's increasingly intense competition is likely the primary driving force toward projects.

6. When activity times are uncertain, we cannot know ahead of time with certainty which path will take the longest to complete. We only know which path was critical after the project is completed.

7. If the paths have activities in common, which is quite likely, the paths are not truly independent. However, if a project has a sufficiently large number of activities, which most projects do, then the assumption of independence is usually acceptable.

8. The exponential form is probably more common than we have recognized in the past, particularly for projects where all the pieces have to come together at the end (as contrasted, say, to functional activities). Behavioral aspects and scheduling issues are also affected by the project form since conflicts commonly arise during the mid-term accelerated scheduling ramp-up of the stretched-S curve. With the exponential form this ramp-up occurs at the end of the project so we should expect personnel and scheduling conflicts later in the project compared to the stretched-S form.

9. At the beginning of the project it is unclear what project aspects should get top priority (and thus resources) because everyone involved usually thinks their area is most important. For much the same reasons, scheduling of still unclear activities is also a source of conflict. As the project progresses to the implementation stage, the actual execution of the challenging activities frequently encounters difficulties so technical and scheduling aspects become major sources of conflict. Toward the end of the project, the due date looms large and schedules to meet this final, all-important milestone generate severe anxiety and conflict.

10. One dangerous aspect of the wave of inexpensive but powerful software packages available these days is not understanding fully how the software is arriving at the results it shows and what assumptions lie behind those results. This can be highly misleading for project managers. Another possibly even more dangerous aspect is the natural tendency for a project manager to manage the software instead of the actual project, i.e., collecting information, inputting data to the program, rescheduling the tasks, inspecting the variances and earned values, and so on.

11. Simulation could also be used to model costs, resource use, interference between projects, scope changes, rework on a project, conditional looping, and a variety of other aspects of project management.

12. The earned value for a project is calculated by adding the earned value of all the projects tasks together. Each task's earned value is the percentage completion times the budgeted cost of that task. There is a variety of different ways for determining the percentage completion (see question 3).
13. The project portfolio illustrates the mix of projects in terms of their degree of both product and process change (and thus riskiness), and these different levels are divided into four categories of project types. The aggregate project plan is a map that can be used to illustrate different types of projects, different sizes, the history/evolution of projects, and most importantly, how all of these projects are arrayed against the four categories. Management can then see if there are too many in one category or if there is a gap among the categories or a trend over time, and so on.
14. Projects are much more complex these days and involve multiple organizations, more strategic issues, organizational restructurings, and billions of dollars at stake (called Megaprojects). Previously, projects typically consisted of constructing something such as a building or a road, or perhaps a ship, or even a computer. Hence, the need for someone to ensure that the desired benefits from our projects were realized.
15. We fairly well understand the risks to the budget, schedule, and scope of most projects and ways to deal with them, but risks to the benefits resulting from more complex projects can come from a range of unexpected directions, such as the citizens of a city not using a new metro line.
16. This largely depends on the personality of the student: technically oriented or socially/managerially oriented. It is interesting to observe how students perceive themselves in this regard.
17. The change manager is responsible for handling the people issues of the individuals and teams subject to the change whereas the project owner is responsible for obtaining the benefits of the change that those people will provide to the organization. The main difference is whether the change proceeds smoothly for the change manager versus whether the benefits are achieved for the project owner.
18. Multiplying the probabilities of each path taking longer than the specified time together yields the probability that all the paths simultaneously take longer than the specified time. For a project to take longer than the specified time, only one of the paths must take longer than the specified time, not all of them. Thus, the proper way calculate the probability of the project taking longer than a specified time is to first calculate the probability that the project finishes by the specified time and then subtracting this probability from one.
19. As is noted in the chapter, many of the tenants of APM can be easily incorporated in more traditional approaches to project management. For example, there is nothing that prevents increasing customer involvement in the traditional waterfall approach. Likewise, there is nothing inherent to traditional project management that prohibits greater experimentation. This suggests that nothing precludes a PM from adopting a subset of APM best practices.
20. Morgan et al. state "Effective strategy consists of choosing to do the right things. Effective execution means doing those things right." In Chapter 1 effectiveness was defined as doing the right thing which is exactly how Morgan et al. use the term effective strategy. Likewise, in Chapter 1 efficiency was defined as doing things right which is what Morgan et al. call effective execution.
21. The organization's strategy and its competitive position should be used to determine how to tradeoff one goal for another. For example, in the pharmaceutical industry it is often critical to

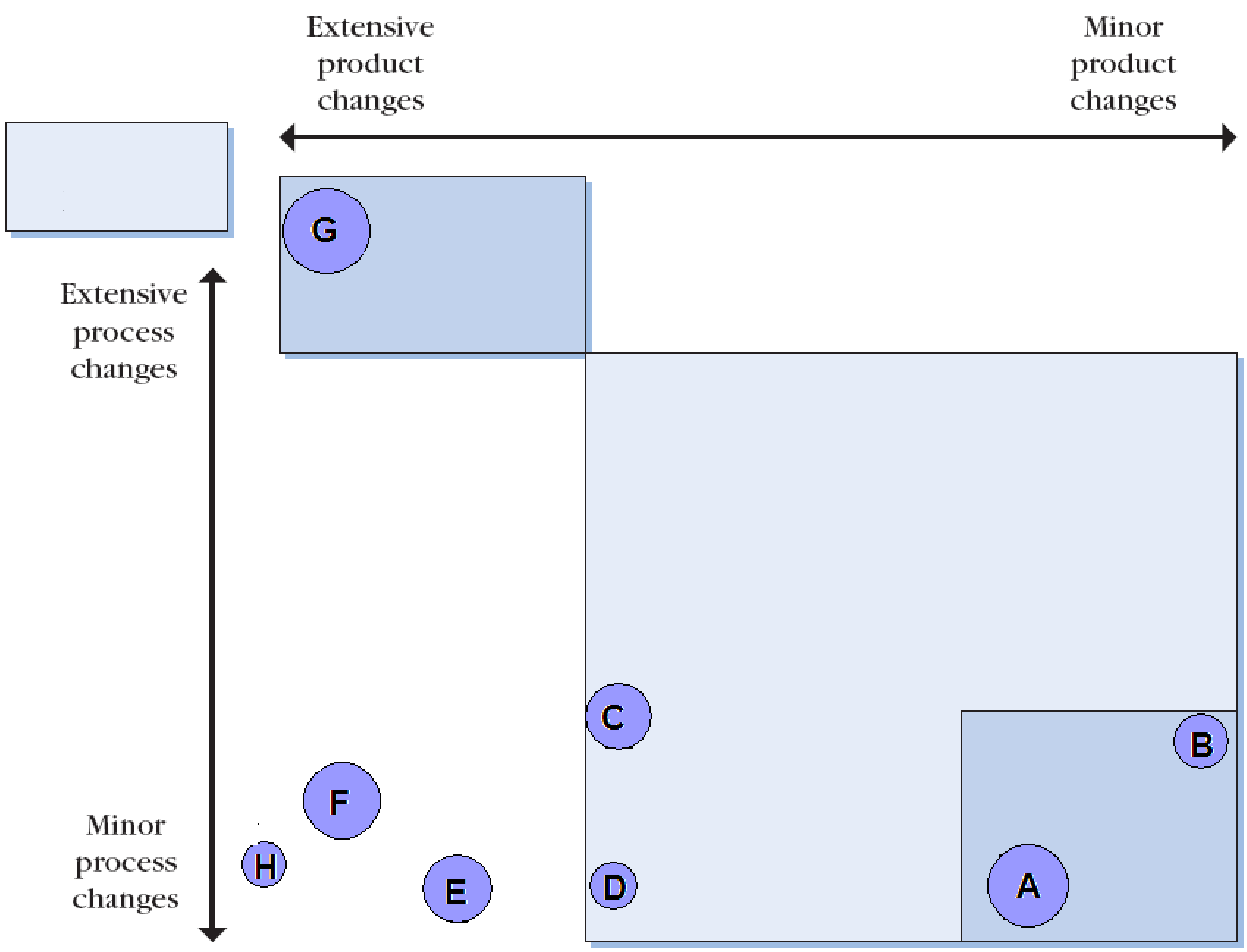
be first to market with a new drug. In this case, adding additional resources to get a new drug to market ahead of the competition would be appropriate. As another example, a non-profit may have to choose between delaying the completion of the project and/or lowering the performance of the project because additional financial resources are not available.

Apply Your Understanding: e-Razor, Incorporated

The purpose of this case is to reinforce student skills in regards to putting together an aggregate project plan. The case describes eight project and/or process modification projects and students are asked to put them into a aggregate project plan.

Answers to Questions

1. The diagram below represents one possible aggregate project plan. Note that students may make different assumptions and therefore place the bubbles in different locations. This is a good discussion area.



2. The answer to this question depends on the student's answer to the first question. Based on the diagram above, there is a wide variety of product change projects but relatively little process change projects. Since this is a fairly new company, a wide variety of product change projects is to be expected but one would also expect the process to be evolving as well.

3. The total cost of all the projects is $136,000 so the company will should be able to take on many of the projects. Like the second question, the answer to this question depends on the student's answer to the first question.

   Based on the diagram above, it makes sense to keep G as it is a potential breakthrough project. Eliminating E and F, which are minor changes on both axes reduces the cost to $97,000 which is within the budget.

Apply Your Understanding: Nutri-Sam

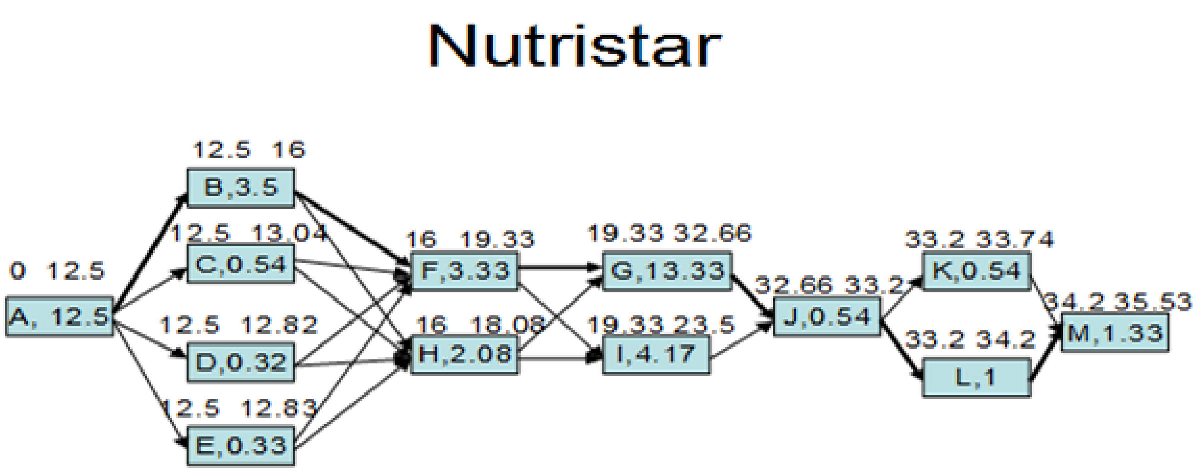
The purpose of this case is to reinforce students' skills in analyzing projects with probabilistic time estimates. The case also provides students with an opportunity to use spreadsheets to simulate the completion of the project and use the results of the simulation to perform standard probability calculations.

1. The following abbreviations will be used for the activities.

Activity Description	Abbreviation
Concept Development	A
Plan Development	
Define project scope	B
Develop broad schedule	C
Detailed cost estimates	D
Develop staffing plan	E
Design and Construction	
Detailed engineering	F
Facility construction	G
Mobilization of construction Employees	H
Procurement of equipment	I
Start-up and Turnover	
Pre-startup inspection	J
Recruiting and training	K
Solving start-up problems	L
Centerlining	M

Using these abbreviations and the information provided in the case, we could determine the answers to the case questions as shown below:

1. The network diagram is shown below:



To identify the four most critical paths, we can set up a table as shown below. The four most critical paths are shaded.

Path	Time	Path	Time
ABFGJKM	35.07	ADFGJKM	31.89
ABFGJLM	35.53	ADFGJLM	32.35
ABFIJKM	25.91	ADFIJKM	22.73
ABFIJLM	26.37	ADFIJLM	23.19
ABHGJKM	33.82	ADHGJKM	30.64
ABHGJLM	34.28	ADHGJLM	31.10
ABHIJKM	24.66	ADHIJKM	21.48
ABHIJLM	25.12	ADHIJLM	21.94
ACFGJKM	32.11	AEFGJKM	31.90
ACFGJLM	32.57	AEFGJLM	32.36
ACFIJKM	22.95	AEFIJKM	22.74
ACFIJLM	23.41	AEFIJLM	23.20
ACHGJKM	30.86	AEHGJKM	30.65
ACHGJLM	31.32	AEHGJLM	31.11
ACHIJKM	21.70	AEHIJKM	21.49
ACHIJLM	22.16	AEHIJLM	21.95

2. To simplify this analysis, we will focus on the top four most critical paths identified above. First, we need to determine the variance of each activity on those four paths. Second, for each of the four paths, we will determine the variance and then the standard deviation.

Activity	Variance
A	12.25
B	3.36
F	0.44
G	7.11
H	0.34
J	0.02
K	0.02
L	0.11
M	0.44

Path	Variance	Standard Deviation
ABFGJKM	23.64	4.862
ABFGJLM	23.73	4.871
ABHGJKM	23.54	4.852
ABHGJLM	23.63	4.861

Probability that the project is completed within 30 months:

The solution shown below used the NORMDIST Excel function to determine the probability that each path would be completed within the desired time.

Path	Expected Completion Time	Standard Deviation	Z Value	Prob. ≤ 30
ABFGJKM	35.07	4.862	(30-35.07)/4.862 = -1.043	0.1485
ABFGJLM	35.53	4.871	(30-35.53)/4.871 = -1.135	0.1281
ABHGJKM	33.82	4.852	(30-33.82)/4.852 = -0.787	0.2156
ABHGJLM	34.28	4.861	(30-34.28)/4.861 = -0.880	0.1893

The probability that the project will be completed within 30 months = 0.1485 * 0.1281 * 0.2156 * 0.1893 = 0.000776 or 0.08%.

Probability that the project is completed in more than 40 months:

This probability will equal 1 – the probability that the project is completed within 40 months.

Path	Expected Completion Time	Standard Deviation	Z Value	Prob. ≤ 40
ABFGJKM	35.07	4.862	(40-35.07)/4.862 = 1.014	0.8447
ABFGJLM	35.53	4.871	(40-35.53)/4.871 = 0.918	0.8206
ABHGJKM	33.82	4.852	(40-33.82)/4.852 = 1.274	0.8986
ABHGJLM	34.28	4.861	(40-34.28)/4.861 = 1.177	0.8803

The probability that the project will be completed within 40 months =
0.8847 * 0.8206 * 0.8986 * 0.8803 = 0.5483 or 54.83%.

The probability that the project will take more than 40 months =
1 – 0.5483 = 0.4517 or 45.17%.

Probability that the project will take between 30 and 40 months:

This probability can be determined by taking the probability that the project will be completed within 40 months less the probability that the project will be completed within 30 months:

54.83% - 0.08% = 54.75%.

3. We could design a spreadsheet as shown below in Crystal Ball. In the spreadsheet below, assumption cells were defined for activities A-M in cells A3:M3 as triangular using the parameters in cells A5:M7. Columns N to AS correspond to the 32 paths, were a formula in row 3 calculates the path duration using the assumption cells in columns A-M. For example, the duration for path A-B-F-G-J-K-M is calculated in cell N3 as =A3+B3+F3+G3+J3+K3+M3. Finally, determining the project duration boils down to finding the longest path. This was done in cell A2 with the following formula: =MAX(N3:AS3). This cell in turn was defined as a forecast cell.

Crystal Ball Simulation Model:

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Activity	Activity	Activity	Activity	Activity	Activity	Activity	Activity	Activity	Activity	Activity	Activity	Activity
2	A	B	C	D	E	F	G	H	I	J	K	L	M
3	12.500	3.621	0.542	0.317	0.333	3.333	13.333	2.083	4.222	0.542	0.542	1.000	1.370
4													
5	3	1	0.25	0.2	0.2	2	8	0.5	1	0.25	0.25	0	0
6	12	2	0.5	0.3	0.3	3	12	2	3	0.5	0.5	1	1
7	24	12	1	0.5	0.6	6	24	4	12	1	1	2	4
8													

	N	O	P	Q	R	S	T	U	V	W
1	Path	Path	Path	Path	Path	Path	Path	Path	Path	Path
2	A B F G J K M	A B F G J L M	A B F I J K M	A B F I J L M	A B H G J K M	A B H G J L M	A B H I J K M	A B H I J L M	A C F G J K M	A C F G J L M
3	35.24051487	35.69851487	26.12962003	26.58762003	33.99051487	34.44851487	24.87962003	25.33762003	32.16169868	32.61969868
4										

	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
1	Path	Path	Path	Path	Path	Path	Path	Path	Path	Path
2	A C F I J K M	A C F I J L M	A C H G J K M	A C H G J L M	A C H I J K M	A C H I J L M	A D F G J K M	A D F G J L M	A D F I J K M	A D F I J L M
3	23.05080385	23.50880385	30.91169868	31.36969868	21.80080385	22.25880385	31.93669868	22.39469868	22.82580385	23.28380385
4										

	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT
1	Path	Path	Path	Path	Path	Path	Path	Path	Path	Path	Path	Path	
2	A D H G J K M	A D H G J L M	A D H I J K M	A D H I J L M	A E F G J K M	A E F G J L M	A E F I J K M	A E F I J L M	A E H G J K M	A E H G J L M	A E H I J K M	A E H I J L M	Max
3	30.68669868	31.14469868	21.57580385	22.03380385	31.95269868	32.41069868	22.84180385	23.29980385	30.70269868	31.16069868	21.59180385	22.04980385	35.69851
4													

Sample Results after Simulation Project 10,000 Times:

Forecast: Project Completion Time - Triangular Task Times

Edit View Forecast Preferences Help

10,000 Trials — Statistics View

Statistic	Forecast values
Trials	10,000
Base Case	35.70
Mean	39.75
Median	39.50
Mode	27.32
Standard Deviation	6.10
Variance	37.19
Skewness	0.1714
Kurtosis	2.79
Coeff. of Variation	0.1534
Minimum	21.85
Maximum	61.44
Mean Std. Error	0.06

The simulation was run 10,000 times. The results of the simulation are shown below. The mean completion time was 39.75 months with a standard deviation of 6.10 months.

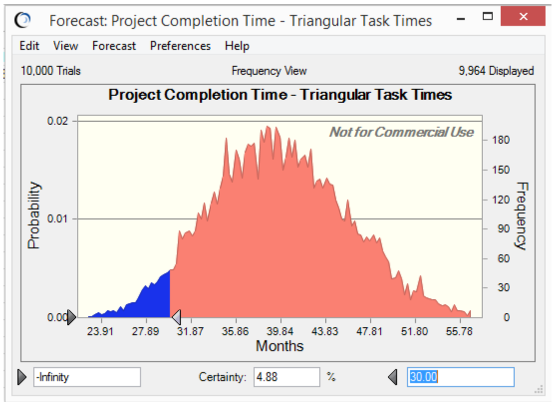
Forecast: Project Completion Time - Tria

Edit View Forecast Preferences Help

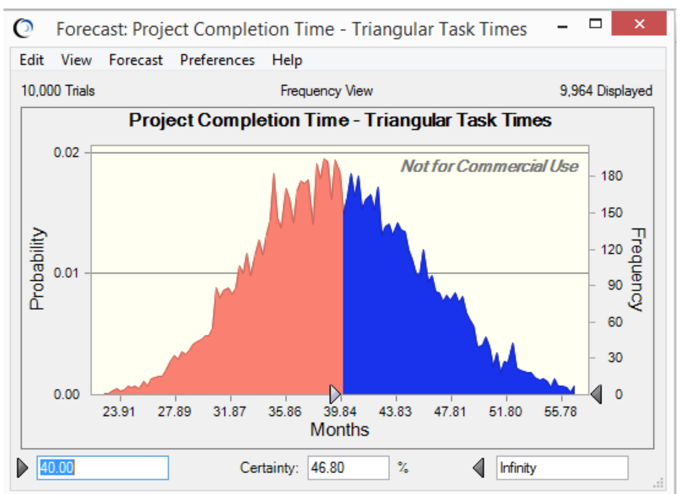
10,000 Trials Statistics View

Statistic	Forecast values
Trials	10,000
Base Case	35.70
Mean	39.75
Median	39.50
Mode	27.32
Standard Deviation	6.10
Variance	37.19
Skewness	0.1714
Kurtosis	2.79
Coeff. of Variation	0.1534
Minimum	21.85
Maximum	61.44
Mean Std. Error	0.06

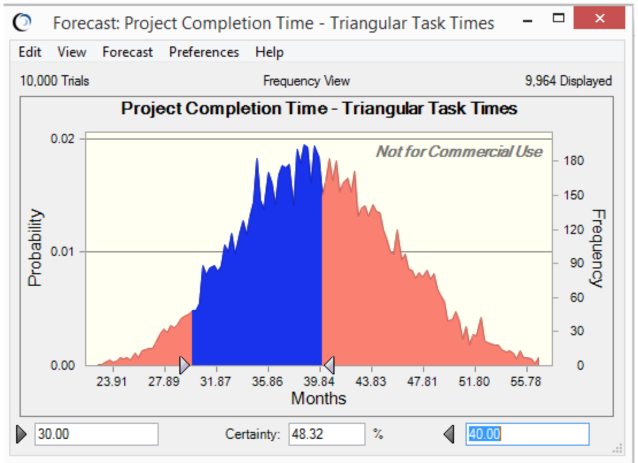
The probability that the project will be completed within 30 months can be calculated using the Forecast Window of Crystal Ball as 4.88%. In Question 2, this probability was 0.08%.



The probability that the project will take longer than 40 months can be calculated using the Forecast Window of Crystal Ball as 46.8%. In Question 2, this probability was 45.17%.



The probability that the project will take between 30 and 40 months can be calculated using the Forecast Window of Crystal Ball as 52.20%. In Question 2, this probability was 54.75%.



4. At the end of the plan definition phase, they would need the time estimates and related probabilities for the completion of the project. While not discussed in the case, there would be cost estimates at this point so they could compare the completion times and net value of the project to perform an economic analysis to verify that it is cost-effective to continue with the project.
5. As with many projects, senior management hasn't identified clearly what the benefits of the additional production space are supposed to achieve, so the role of the project owner is fairly minimal. In this case, the project owner should encourage management to make further plans about how to use this additional space and detail how to achieve the benefits they hope to get from it.

Answers to Exercises

Exercise 2.1

Path	Time
A-C-I	6 days
A-D-G-J	14 days
B-E-G-J	12 days
B-F-H-J	11 days

The critical path is A-D-G-J at 14 days. The activities on this path should be monitored most closely.

The time to complete the 4 paths is now:

Path	Time
A-C-I	4.5 days
A-D-G-J	12.5 days
B-E-G-J	13.5 days
B-F-H-J	12.5 days

The critical path is now B-E-G-J. The project completion is expected to be 13.5 days.

Activities G & J from the original critical path are still critical, while A & D are no longer critical.

Exercise 2.2

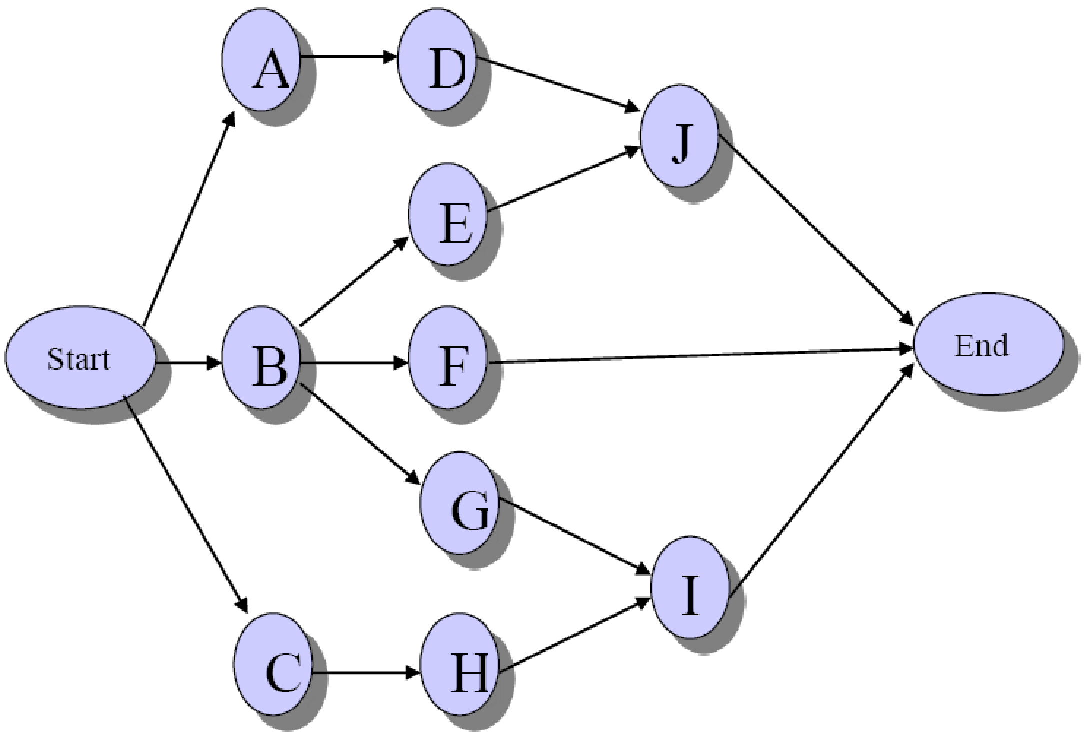
Activity	T_{ES}	T_{EF}	T_{LS}	T_{LF}	Slack
A	0	4	0	4	0
B	0	3	2	5	2
C	4	5	12	13	8
D	4	9	4	9	0
E	3	7	5	9	2
F	3	4	6	7	3
G	9	12	9	12	0
H	4	9	7	12	3
I	5	6	13	14	8
J	12	14	12	14	0

Path Slacks:

Path	Slack
A-C-I	8 days
A-D-G-J	0 days
B-E-G-J	2 days
B-F-H-J	3 days

Exercise 2.3

Precedence Diagram:



Activity Expected Times, Variances, & Standard Deviations:

	A	B	C	D	E	F	G
1							**Standard**
2	**Activity**	**Optimistic**	**Most Likely**	**Pessimistic**	**t_e**	**Variance**	**Deviation**
3	A	5	11	11	10	1	1
4	B	10	10	10	10	0	0
5	C	2	5	8	5	1	1
6	D	1	7	13	7	4	2
7	E	4	4	10	5	1	1
8	F	4	7	10	7	1	1
9	G	2	2	2	2	0	0
10	H	0	6	6	5	1	1
11	I	2	8	14	8	4	2
12	J	1	4	7	4	1	1
13							
14	*Formulas:*						
15	Cell E3	=(B3+(C3*4)+D3)/6 [copy to cells E4:E12]					
16	Cell F3	=((D3-B3)/6)^2 [copy to cells F4:F12]					
17	Cell G3	=SQRT(F3) [copy to cells G4:G12]					

Path Expected Times, Variances, & Standard Deviations:

Path	Path Expected Time	Path Variance	Path Standard Deviation	Path Expected Time + 2.33 Standard Deviations
ADJ	21	6	2.45	26.71
BEJ	19	2	1.41	22.29
BF	17	1	1	19.33
BGI	20	4	2	24.66
CHI	18	6	2.45	23.71

Probability that the Project Finishes within 17 Weeks:

	A	B	C	D	E	F
1	**Specified Time**	17				
2						
3		**Path**		**Path**		
4		**Expected**	**Path**	**Standard**		
5	**Path**	**Time**	**Variance**	**Deviation**	**z**	**Probability**
6	ADJ	21	6	2.45	-1.63	0.0516
7	BEJ	19	2	1.41	-1.42	0.0778
8	BF	17	1	1	0.00	0.5000
9	BGI	20	4	2	-1.50	0.0668
10	CHI	18	6	2.45	-0.41	0.3409
11	**Product of**					**0.000046**
12	**Probabilities**					
13	*Formulas:*					
14	Cell E6	=(B1-B6)/D6 [copy to cells E7:E10]				
15	Cell F6	=NORMSDIST(E6) [copy to cells F7:F10]				
16	Cell F11	=PRODUCT(F6:F10)				

All paths will be considered because each path's expected time plus 2.33 standard deviations exceeds the specified value (17 weeks). The product of all path probabilities is 0.000046. Thus, there is a very small chance (0.0046%) that the project could be completed in 17 weeks or less.

Probability that the Project Finishes within 24 Weeks:

	A	B	C	D	E	F
1	**Specified Time**	2				
2		4				
3		**Path**		**Path**		
4		**Expected**	**Path**	**Standard**		
5	**Path**	**Time**	**Variance**	**Deviation**	**z**	**Probability**
6	ADJ	21	6	2.45	1.22	0.8888
7	BEJ	19	2	1.41	3.55	0.9998
8	BF	17	1	1	7.0	1.0000
9	BGI	20	4	2	2.00	0.9772
10	CHI	18	6	2.45	2.4	0.9929
11	**Product of**				5	**0.8622**
12	**Probabilities**					
13	*Formulas:*					
14	Cell E6	=(B1-B6)/D6 [copy to cells E7:E10]				
15	Cell F6	=NORMSDIST(E6) [copy to cells F7:F10]				
16	Cell F11	=PRODUCT(F6:F10)				

All paths could easily be included—the product of the probabilities = 0.8622 or 86.22% probability that the project will be completed within 24 weeks. Alternatively, if we used the simplified procedure, then we would only consider the probabilities of Path ADJ & Path BGI. In this case, the product of the probabilities = 0.8685 or 86.85% probability that the project will be completed within 24 weeks.

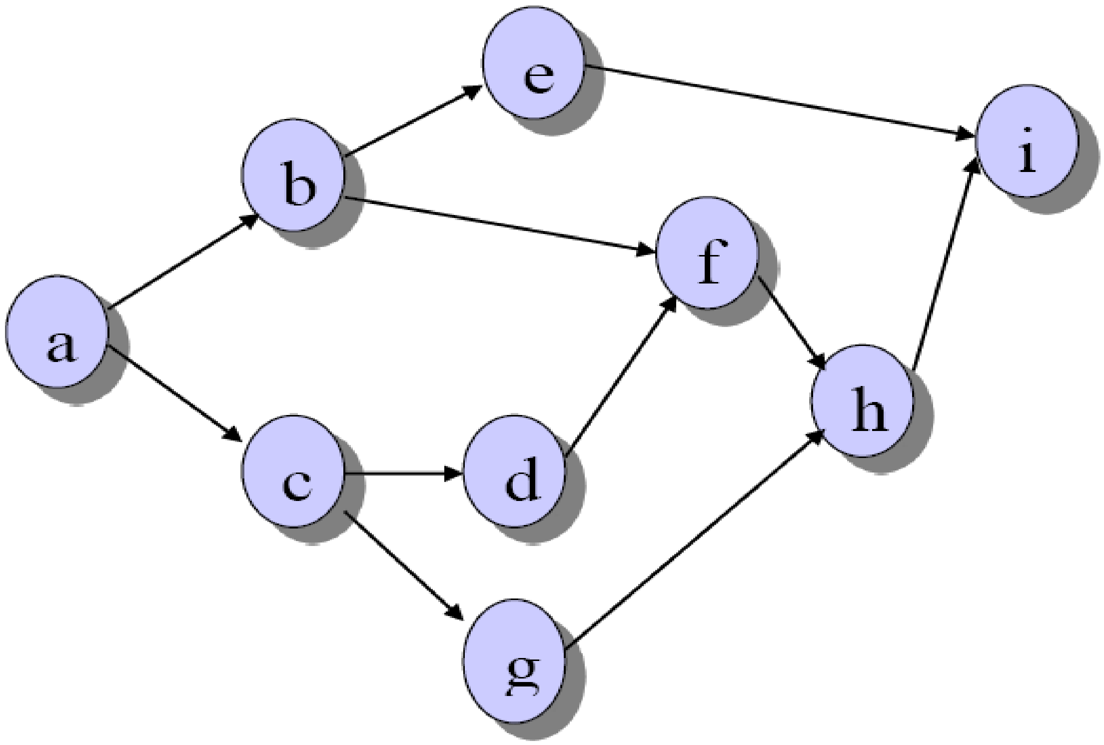
Should the project be pursued?

There will be a bonus of €10,000 if the project is completed within 18 weeks and a penalty of €5000 if the project is delayed beyond 22 weeks. First, we must find the probability that the project will be completed within 18 weeks. Second, we must determine the probability of completing the project within 22 weeks and then subtract that value from 1 to find the probability that the project will take longer than 22 weeks.

- Using the spreadsheet it can be easily determined that the probability of finishing within 18 weeks is 0.001773 and the probability of the project taking 22 weeks or longer is 0.4828. The expected value of the project is thus:

  $(0.001773 \times €10{,}000) + (0.4828 \times -€5{,}000) = -€2396.27$
- Given the negative expected value, the firm should ***not*** bid.

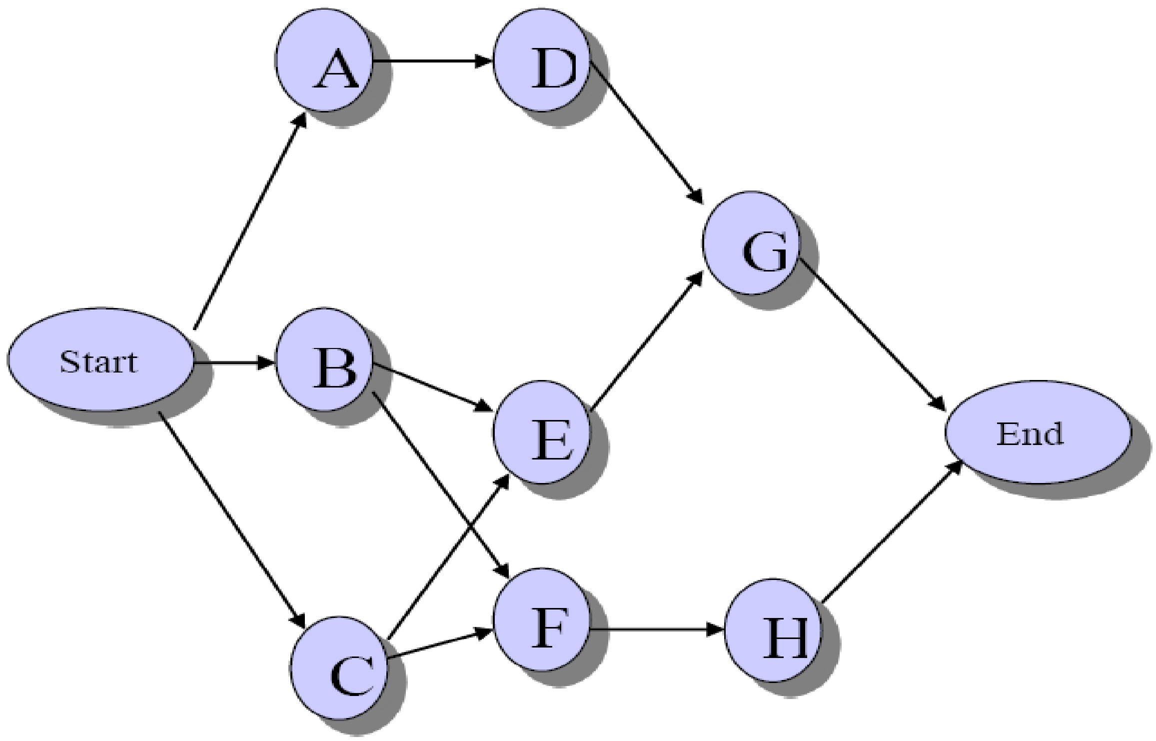
Exercise 2.4



PATH	TIME
ABEI	3+5+3+1 = 12
ABFHI	3+5+4+3+1 = 16
ACDFHI	3+3+1+4+3+1 = 15
ACGHI	3+3+2+3+1 = 12

The path with the longest expected time is ABFHI at 16 weeks.

Exercise 2.5



	A	B	C	D	E	F
1	**Activity**	**Optimistic**	**Most Likely**	**Pessimistic**	**t_e**	**Variance**
2	A	6	7	14	8.00	1.78
3	B	8	10	12	10.00	0.44
4	C	2	3	4	3.00	0.11
5	D	6	7	8	7.00	0.11
6	E	5	5.5	9	6.00	0.44
7	F	5	7	9	7.00	0.44
8	G	4	6	8	6.00	0.44
9	H	2.5	3	3.5	3.00	0.03
10						
11		**Expected**		**Standard**		
12	**Path**	**Time**	**Variance**	**Deviation**		
13	ADG	21.00	2.33	1.53		
14	BEG	22.00	1.32	1.15		
15	BFH	20.00	0.91	0.95		
16	CEG	15.00	0.99	0.99		
17	CFH	13.00	0.58	0.76		

Probability that the Project Finishes within 21 Days:

	A	B	C	D	E	F
1		**Expected**		**Standard**		**≤ 21**
2	**Path**	**Time**	**Variance**	**Deviation**	**Z**	**Prob.**
3	ADG	21.00	2.33	1.53	0.00	0.5000
4	BEG	22.00	1.32	1.15	-0.87	0.1923
5	BFH	20.00	0.91	0.95	1.05	0.8537
6	CEG	15.00	0.99	0.99	6.06	1.0000
7	CFH	13.00	0.58	0.76	10.53	1.0000
8	**Product of Probabilities**					**0.0821**

Probability of completing the project within 21 days = 0.0821 or 8.21%.

Probability that the Project Finishes within 22 Days:

	A	B	C	D	E	F
1		**Expected**		**Standard**		**≤ 22**
2	**Path**	**Time**	**Variance**	**Deviation**	**Z**	**Prob.**
3	ADG	21.00	2.33	1.53	0.65	0.7433
4	BEG	22.00	1.32	1.15	0.00	0.5000
5	BFH	20.00	0.91	0.95	2.11	0.9824
6	CEG	15.00	0.99	0.99	7.07	1.0000
7	CFH	13.00	0.58	0.76	11.84	1.0000
8	**Product of Probabilities**					**0.3651**

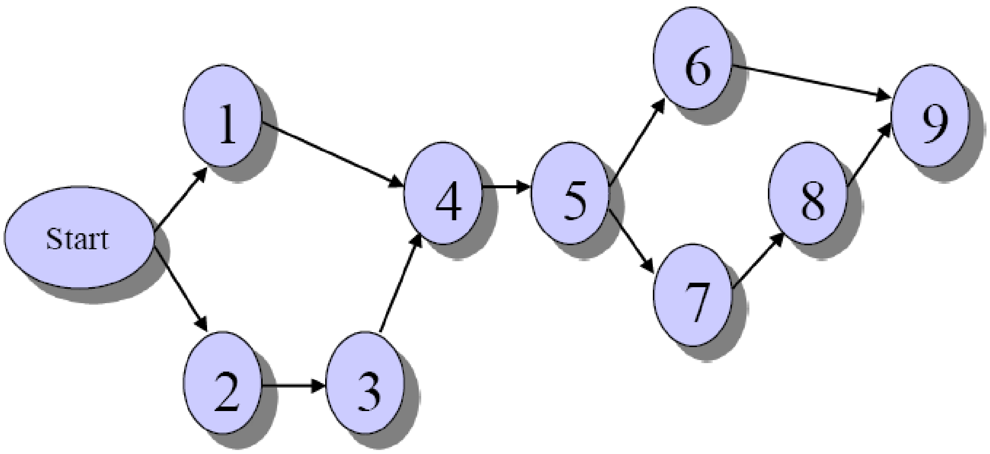
Probability of completing the project within 22 days = 0.3651 or 36.51%%.

Probability that the Project Finishes within 25 Days:

	A	B	C	D	E	F
1		**Expected**		**Standard**		**≤ 25**
2	**Path**	**Time**	**Variance**	**Deviation**	**Z**	**Prob.**
3	ADG	21.00	2.33	1.53	2.61	0.9955
4	BEG	22.00	1.32	1.15	2.61	0.9955
5	BFH	20.00	0.91	0.95	5.26	1.0000
6	CEG	15.00	0.99	0.99	10.10	1.0000
7	CFH	13.00	0.58	0.76	15.79	1.0000
8	**Product of Probabilities**					**0.9910**

Probability of completing the project within 25 days = 99.10%.

Exercise 2.6



	A	B	C	D	E	F	G
1							Standard
2	Activity	Optimistic	Most Likely	Pessimistic	t_e	Variance	Deviation
3	1	8	10	13	10.17	0.69	0.83
4	2	5	6	8	6.17	0.25	0.50
5	3	13	15	21	15.67	1.78	1.33
6	4	10	12	14	12.00	0.44	0.67
7	5	11	20	30	20.17	10.03	3.17
8	6	4	5	8	5.33	0.44	0.67
9	7	2	3	4	3.00	0.11	0.33
10	8	4	6	10	6.33	1.00	1.00
11	9	2	3	4	3.00	0.11	0.33
12							
13	*Formulas:*						
14	Cell E3	=(B3+(C3*4)+D3)/6 [copy to cells E4:E10]					
15	Cell F3	=((D3-B3)/6)^2 [copy to cells F4:F10]					
16	Cell G3	=SQRT(F3) [copy to cells G4:G10]					

Path	Path Expected Time	Path Variance	Path Standard Deviation
1-4-5-6-9	50.67	11.72	3.42
1-4-5-7-8-9	54.67	12.39	3.52
2-3-4-5-6-9	62.33	13.06	3.61
2-3-4-5-7-8-9	66.33	13.72	3.70

Path 2-3-4-5-7-8-9 is the longest path with an expected time of 66.33.

Exercise 2.7

As of Day 70:

Spending Variance = Earned Value – Actual Cost = ₤17,000 - ₤30,000 = -₤13,000. This indicates a cost overrun of ₤13,000.

Schedule Variance = Earned Value – Scheduled Cost = ₤17,000 - ₤24,000 = -₤7,000. This indicates the project is behind.

Time Variance = Effective Time – Actual Time = 55 – 70 = -15 days. This indicates a 15-day delay.

Exercise 2.8

As of Month 2:

Spending Variance = Earned Value – Actual Cost = $81,000 - $78,000 = $3,000.

Schedule Variance = Earned Value – Scheduled Cost = $81,000 - $84,000 = -$3,000.

Effective Time has to be estimated (it is approximately 1.5 months).
Time Variance = Effective Time – Actual Time = 1.5 – 2 = -0.5 months.
This indicates a 0.5-month delay.

Exercise 2.9

Spending Variance = Earned Value – Actual Cost = $39,000 - $34,000 = $5,000.

Schedule Variance = Earned Value – Scheduled Cost = $39,000 - $42,000 = -$3,000.

Exercise 2.10

Activity	T_{ES}	T_{EF}	T_{LS}	T_{LF}	Slack
A, 5	0	5	3	8	3
B, 3	0	3	3	6	3
C, 6	0	6	0	6	0
D, 7	0	7	7	14	7
E, 5	5	10	13	18	8
F, 6	5	11	8	14	3
G, 10	6	16	8	18	2
H, 8	6	14	6	14	0
I, 4	14	18	14	18	0

Part (a)

Critical path is C-H-I.

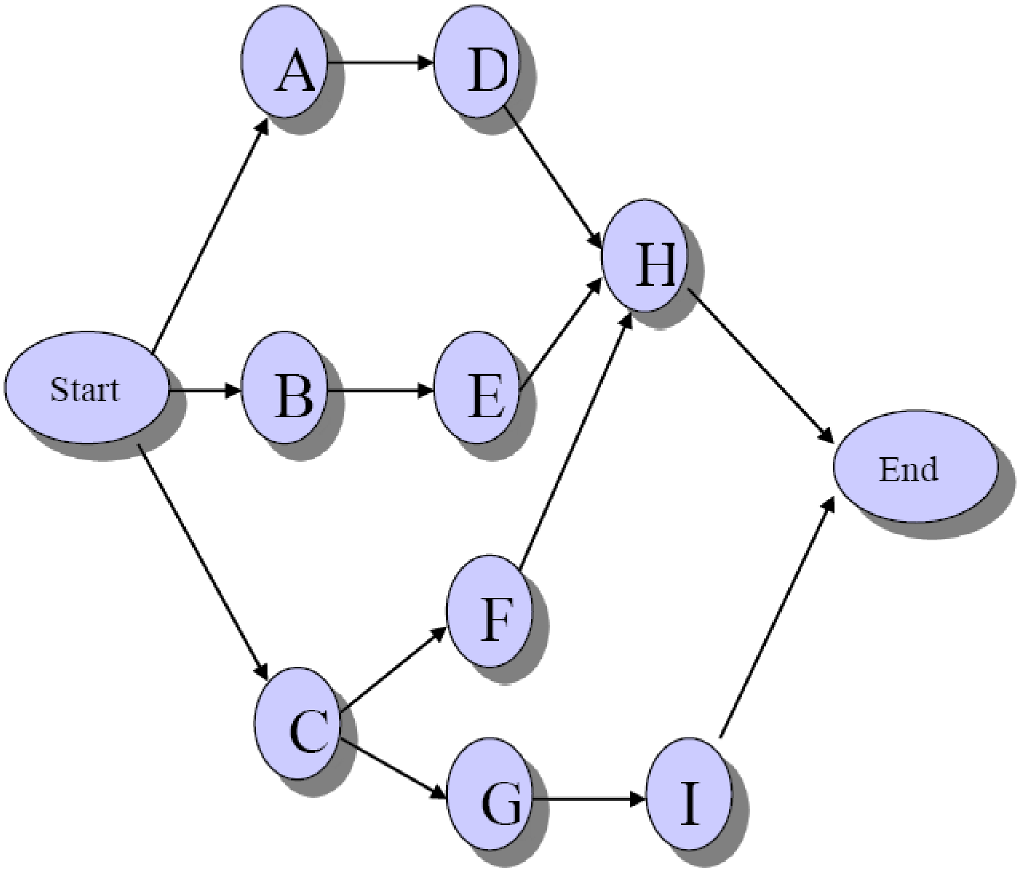
Part (b)

Earliest completion time is 18 periods.

Part (c)

Slack for each activity is shown in the table above.

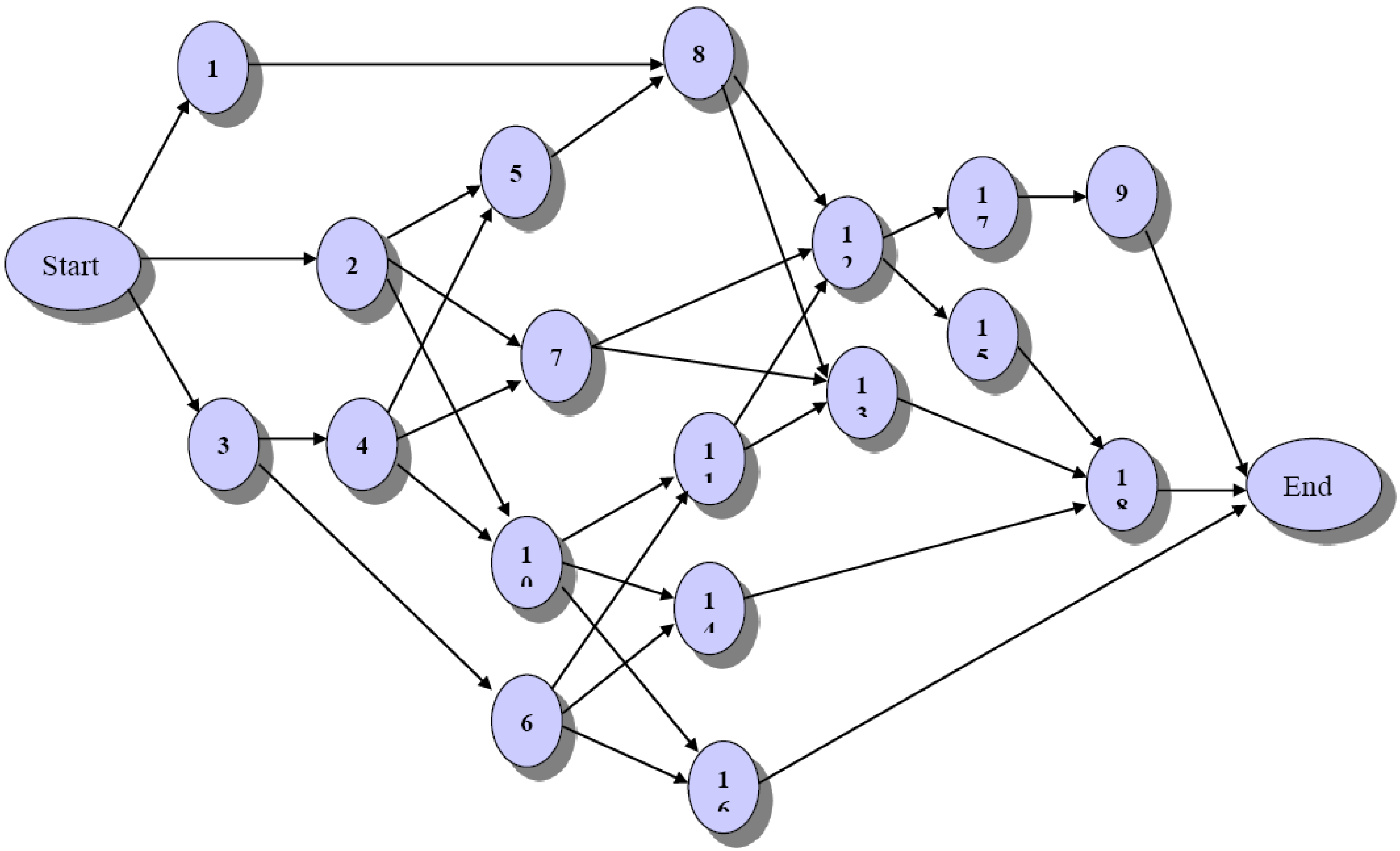
Exercise 2.11



Activity (Time)	T_{ES}	T_{EF}	T_{LS}	T_{LF}	Slack
A (3)	0	3	8	11	8
B (6)	0	6	7	13	7
C (8)	0	8	0	8	0
D (7)	3	10	11	18	8
E (5)	6	11	13	18	7
F (10)	8	18	8	18	0
G (4)	8	12	13	17	5
H (5)	18	23	18	23	0
I (6)	12	18	17	23	5

The critical path is C-F-H (23 weeks).

Exercise 2.12



PATH	TIME
1-8-12-17-9	29
1-8-12-15-18	30
1-8-13-18	22
2-5-8-12-17-9	33
2-5-8-12-15-18	34
2-5-8-13-18	26
2-7-12-17-9	28
2-7-12-15-18	29
2-7-13-18	21
3-4-7-12-17-9	33
3-4-7-12-15-18	34
3-4-7-13-18	26
3-4-10-11-12-17-9	42
3-4-10-11-12-15-18	43
3-4-10-11-13-18	42
3-4-10-14-18	20
3-4-10-16	16
3-6-11-12-17-9	40
3-6-11-12-15-18	41
3-6-11-13-18	33
3-6-14-18	18
3-6-16	14

Critical path is 3-4-10-11-12-15-18 at 43 periods.

Exercise 2.13

Activity	Time	T_{ES}	T_{EF}	T_{LS}	T_{LF}	Slack
A	2	0	2	0	2	0
B	4	0	4	9	13	9
C	3	0	3	4	7	4
D	3	2	5	2	5	0
E	5	2	7	8	13	6
F	6	3	9	7	13	4
G	4	3	7	8	12	5
H	4	5	9	11	15	6
I	8	5	13	5	13	0
J	2	13	15	13	15	0
KL	3	7	10	12	15	5

Critical Path: A-D-I-J at 15 periods.

Note: Excel files are available for the solutions shown below for Exercises 2.14 – 2.19 on instructor website.

Exercise 2.14

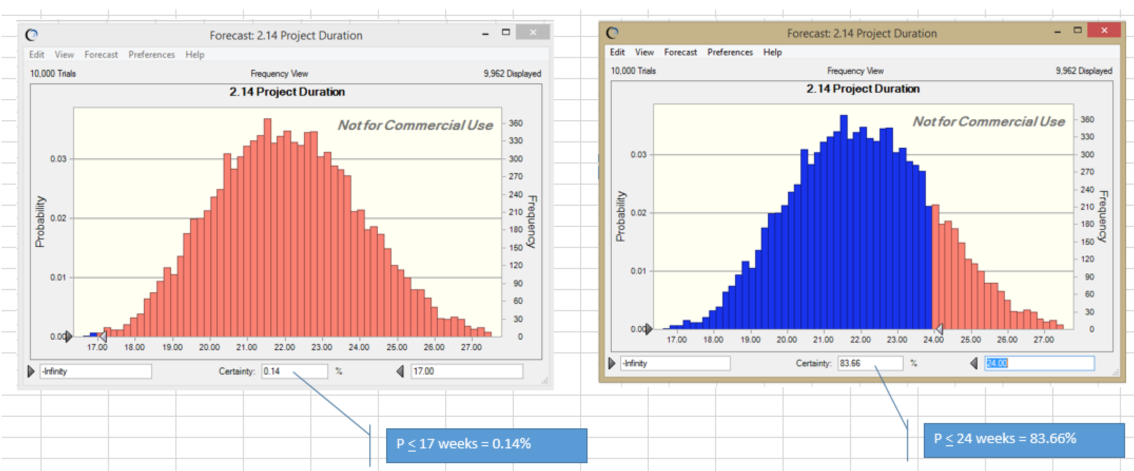
Model setup using Crystal Ball

	A	B	C	D	E
1	**Activity**	**Optimistic**	**Most Likely**	**Pessimistic**	**Activity Time**
2	A	5	11	11	11
3	B	10	10	10	10
4	C	2	5	8	5
5	D	1	7	13	7
6	E	4	4	10	4
7	F	4	7	10	7
8	G	2	2	2	2
9	H	0	6	6	6
10	I	2	8	14	8
11	j	1	4	7	4
12					
13					
14	**Paths**	**Duration**			
15	A-D-J	22			
16	B-E-J	18			
17	B-F	17			
18	B-G-I	20			
19	C-H-I	19			
20	**Project Duration**	22			
21					
22					
23					

Crystal Ball Assumption Cells

Crystal Ball Forecast Cell

Results:



Would have more confidence in simulation results because the results are not based on the assumption that the paths are indepdendent. In this case the paths are clearly not indepdent. Activities B, I, and J are on multiple paths. Thus, a delay to any of these activities would result in delaying mutliple paths.

Exercise 2.15

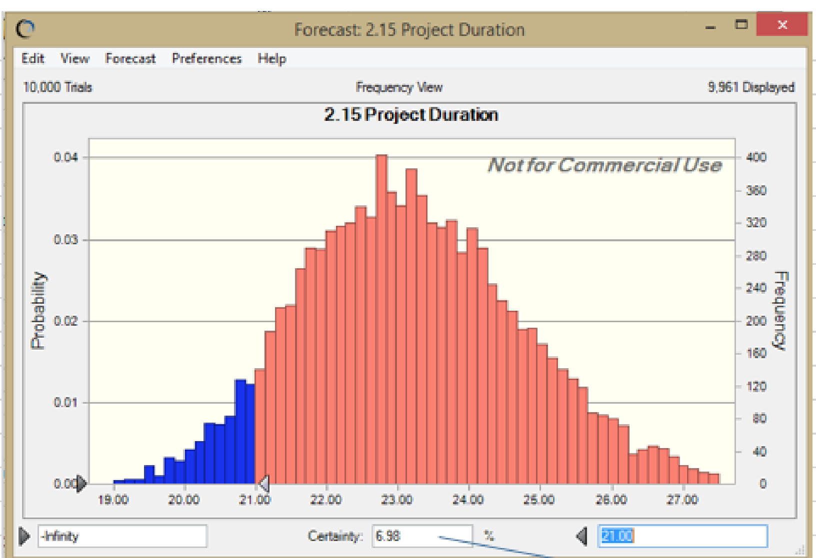
Model setup using Crystal Ball

	A	B	C	D	E
1	Activity	Optimistic	Most Likely	Pessimistic	Activity Time
2	A	6	7	14	6
3	B	8	10	12	8
4	C	2	3	4	2
5	D	6	7	8	6
6	E	5	5.5	9	5
7	F	5	7	9	5
8	G	4	6	8	4
9	H	2.7	3	3.5	2.7
10					
11					
12	Paths	Duration			
13	A-D-G	16			
14	B-E-G	17			
15	B-F-H	15.7			
16	C-E-G	11			
17	C-F-H	9.7			
18	Project Duration	17			

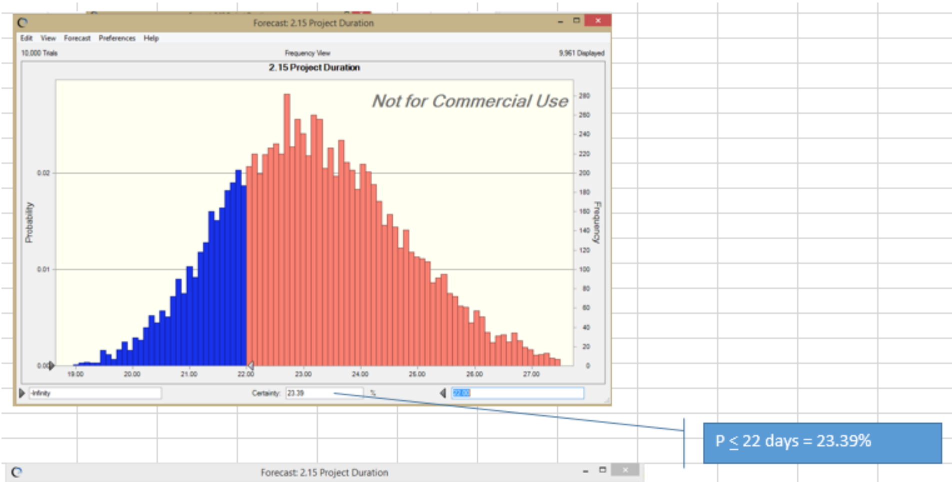
Crystal Ball Assumption Cells

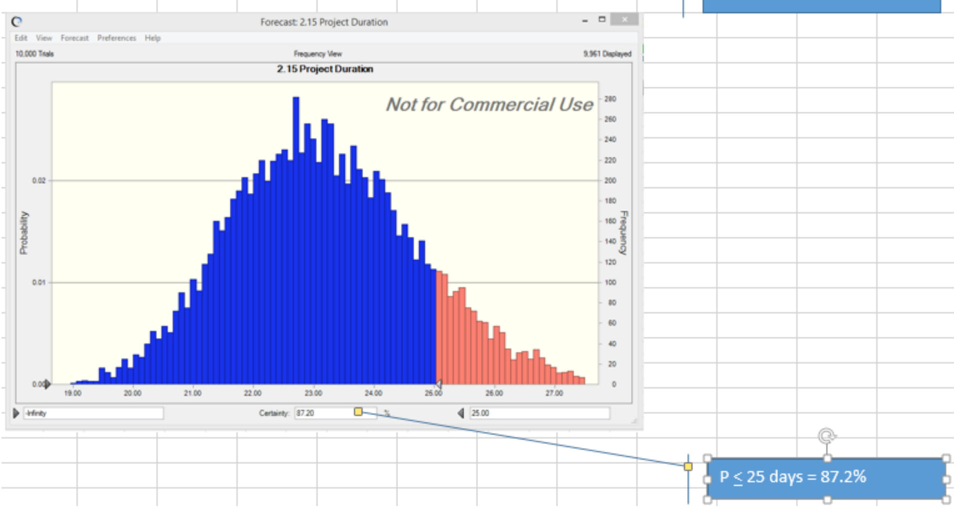
Crystal Ball Forecast Cell

Results:



P ≤ 21 days = 6.98%





Would have more confidence in simulation results because the results are not based on the assumption that the paths are indepdendent. In this case the paths are clearly not indepdent. Activities B, C, E, F, G and H are on multiple paths. Thus, a delay to any of these activities would result in delaying mutliple paths.

Exercise 2.16

Model setup using Crystal Ball

Activity	Optimistic	Most Likely	Pessimistic	Activity Time
A	6	7	14	6
B	8	10	12	8
C	2	3	4	2
D	6	7	8	6
E	5	5.5	9	5
F	5	7	9	5
G	4	6	8	4
H	2.7	3	3.5	2.7

Crystal Ball Assumption Cells

Paths	Duration	
A-D-G	16	
B-E-G	17	1
B-F-H	15.7	
C-E-G	11	
C-F-H	9.7	
Project Duration	17	

Crystal Ball Forecast Cell: Path B-E-G is has longest expected duration. Therefore Forecast Cell defined as 1 if this path is longest, 0 otherwise.

Results:

Forecast: 2.16 Probability Path B-E-G is Critical Path

Edit View Forecast Preferences Help

10,000 Trials Statistics View

Statistic	Forecast values
Trials	10,000
Base Case	1.00
Mean	0.58
Median	1.00
Mode	1.00
Standard Deviation	0.49
Variance	0.24
Skewness	-0.3441
Kurtosis	1.12
Coeff. of Variation	0.8426
Minimum	0.00
Maximum	1.00
Mean Std. Error	0.00

Probability path B-E-G is longest path is 58%

The path with the longest duration only has a 58% chance of actually taking the longest to complete. This suggests that is often not possible to determine which path will take the longest to complete at the beginning of the project when the activity times are uncertain. In fact, identifying a path as the critical path at the start of the project may be harmful as this path may get the majority of attention increasing the chances that some other path slips behind scchedule and ends up delaying the completion of the project.

Exercise 2.17

Model setup using Crystal Ball

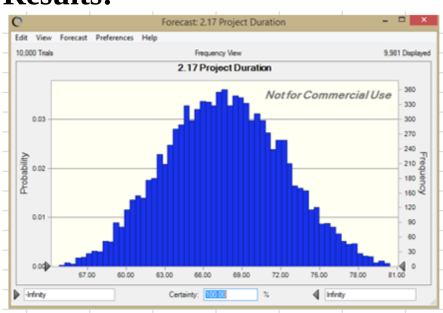
Activity	Optimistic	Most Likely	Pessimistic	Activity Time	
1	8	10	13	10	1
2	5	6	8	5	2
3	13	15	21	13	3
4	10	12	14	10	4
5	11	20	30	11	5
6	4	5	8	4	6
7	2	3	4	2	7
8	4	6	10	4	8
9	2	3	4	2	9

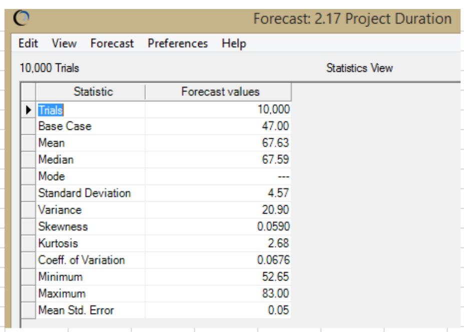
Crystal Ball Assumption Cells

Paths	Duration
1-4-5-6-9	37
1-4-5-7-8-9	39
2-3-4-5-6-9	45
2-3-4-5-7-8-9	47
Project Duration	47

Crystal Ball Forecast Cell

Results:

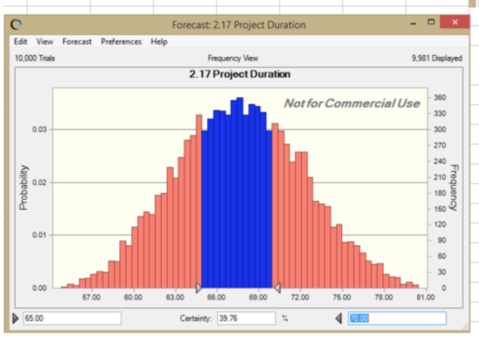



Forecast: 2.17 Project Duration

Edit View Forecast Preferences Help

10,000 Trials — Statistics View

Statistic	Forecast values
Trials	10,000
Base Case	47.00
Mean	67.63
Median	67.59
Mode	---
Standard Deviation	4.57
Variance	20.90
Skewness	0.0590
Kurtosis	2.68
Coeff. of Variation	0.0676
Minimum	52.65
Maximum	83.00
Mean Std. Error	0.05



The screen shots on this sheet are represenative outcomes from the simulation model created for this project. In the top figure on left, we see the distribution of project completion times. Observe how it is approximately normally distributed even though the activity timese were modelled using a triangular distribution. In the top figure on right we see that on average the project's duration was 67.63 weeks with a standard deviation of 4.57 weeks. We can also observe that on one replication the project was finished in as little as 52.65 weeks and on another repliction the project took 83 weeks to complete.

Having the distribution of project completion times is useful as it allows the project manager to gain a better understanding of how long the project will take to complete as well as to do some formal analysis and calcualte the probabilities of compelting the project by a certain deadline or withing a given time window.

In the bottom figure, we use the distribution of the project's compeltion time to determine there is a 39.76% of completing the project between 65 and 70 weeks.

Exercise 2.18

a.

	Normal		Crash			
Activity	Time (days)	Cost ($)	Time (days)	Cost ($)	Max Crash Days	Cost Slope ($/day)
A	3	40	2	80	1	40
B	2	20	1	80	1	60
C	2	20	2	20	0	
D	4	30	1	120	3	30
E	3	10	1	80	2	35
Total		$120		$380		

A. Will cost $120 to complete project at normal pace

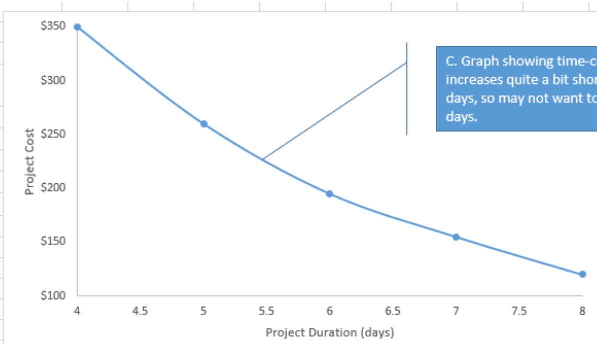
b.

		Path Durations				
Project Duration	Activity to Crash	A-B-E	A-C	A-D	Added Crash Cost	Project Cost
8		8	5	7	$0	$120
7	E	7	5	7	$35	$155
6	A	6	4	6	$40	$195
5	D, E	5	4	5	$65	$260
4	B, D	4	4	4	$90	$350

B. Shortest amount of time project can be completed in is 4 days. Path A-C cannot be reduced further. The cost of completing the project in 4 days is $350.

c.

Project Duration	Project Cost
8	$120
7	$155
6	$195
5	$260
4	$350



C. Graph showing time-cost tradeoff. Slope of line increases quite a bit shortening the project from 6 to 5 days, so may not want to crash project more than 2 days.

Exercise 2.19

a.

	Normal		Crash			
Activity	Time (days)	Cost ($)	Time (days)	Cost ($)	Max Crash Days	Cost Slope ($/day)
A	5	$50	3	$150	2	50
B	4	40	2	200	2	80
C	7	70	6	160	1	90
D	2	20	1	50	1	30
E	3	30	--	--	0	
F	8	80	5	290	3	70
G	5	50	4	100	1	50
H	6	60	3	180	3	40
Total		$400		$1,130		

A. Will cost $400 to complete project at normal pace

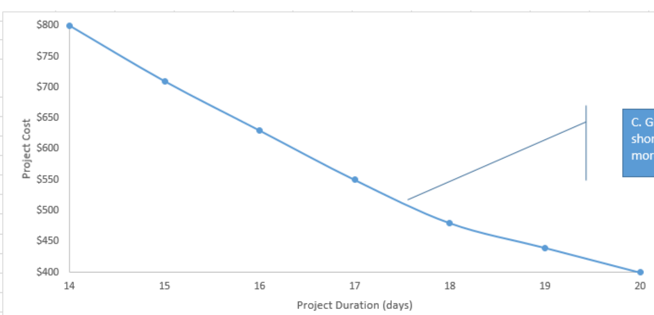
b.

		Path Durations						
Project Duration	Activity to Crash	A-D-G	A-E-H	B-C-D-G	B-C-E-H	B-F-H	Added Crash Cost	Project Cost
20		12	14	18	20	18	$0	$400
19	H	12	13	18	19	17	$40	$440
18	H	12	12	18	18	16	$40	$480
17	D, H	11	11	17	17	15	$70	$550
16	B	11	11	16	16	14	$80	$630
15	B	11	11	15	15	13	$80	$710
14	C	11	11	14	14	13	$90	$800

B. Shortest amount of time project can be completed in is 14 days. Path B-C-E-H cannot be reduced further. The cost of completing the project in 14 days is $800.

c.

Project Duration	Project Cost
20	$400
19	$440
18	$480
17	$550
16	$630
15	$710
14	$800



C. Graph showing time-cost tradeoff. Slope of line increases quite a bit shortening the project from 18 to 17 days, so may not want to crash project more than 2 days.

Suggested Cases/Readings

Case: Fuddruckers and the Crystal Coast Music Festival (S. M. Shafer and S. McCracken: *Case Research Journal*, #NAC2216, North American Case Research Association, 2002)

Fuddruckers has been selected to be the food vendor for the Crystal Coast Music Festival. Over the next week, decisions regarding the menu items, order quantities, and prices need to be finalized. Complicating these decisions are several uncertainties, including the weather, attendance, and the amount of food each attendee will consume.

Case: Biogen Inc.: rBeta Interferon Manufacturing Process Development (Hvd. 9-696-083)

Although there is no teaching note with this case, it is a great example of a failing major project and the focus of the analysis is fairly clear: What did Biogen do well? What did they do wrong? Was project management appropriate for them at this time? If not, what should they have done? What were the 3-4 root causes of their problems? What should they do now?

Case: The Project Manager/Customer Interface (U. of Virginia Darden School, UVA-OM-0739TN, 1993)

This is a good case for illustrating some of the behavioral issues that can arise between a project manager and the customer. In this situation, the project went fine but the customer's interference caused major cost overruns that the customer refused to pay. The issue of who on the customer's side is authorized legally to speak for the customer becomes a major point of contention in the case.

Case: Pan-Europa Foods S.A. (U. of Virginia Darden School, 1993)

This case portrays a firm with a variety of eleven possible projects and a limited budget, posing the typical situation of an organization trying to select the best projects to approve for the coming year(s). Extensive data is given for the cash flows and financial factors for each of the projects.

Case: Pelican Landing: Bender Corporation (S. E. Brodt, U. of Virginia Darden School, 1990)

This short case focuses on negotiation between a corporation and a city as they attempt to resolve eight issues stalling the approval of a residential community proposed for the city's "old town" district. The issues involve city financing, retail vs open space, contracting, condo/apartment ratios, low-income units, and building heights.

Case: The National Jazz Hall of Fame (U. of Virginia Darden School, 1984)

This is an interesting case concerning the ongoing development of a Hall of Fame in Charlottesville, VA. A consultant has been engaged to propose, based on two surveys, the next steps to take to achieve national recognition. The consultant has proposed three major recommendations and a few policy recommendations.

Reading: *Project Management: A Strategic Managerial Approach, 10th ed.* (J. R. Meredith, S. M. Shafer, S. J. Mantel, Jr., Wiley, 2018)

This latest edition of the first textbook in project management now includes strategic issues about using projects to implement strategy in both public and for-profit organizations. All aspects of project management from initiation to closure and benefits realization are covered.

Reading: *Project Management in Practice, 6th ed.* (J. R. Meredith, S. M. Shafer, S. J. Mantel, Jr., Wiley, 2017)

This short textbook focus on the tasks of the project manager in executing projects to meet the "iron triangle" of cost limits, time limits, and scope specifications. Topics covered include agile, risk planning, building the project team, scheduling the project tasks, earned value, PERT, and the critical chain.

Reading: An Assessment of Postproject Reviews. (J. S. Busby, *Project Management Journal*, September 1999)

This article analyzes how four organizations debriefed their projects to learn managerial lessons for their future projects. It reviews the benefits but also the drawbacks of such reviews and gives guidance on how to conduct such reviews.

Reading: *A Guide to the Project Management Body of Knowledge: PMBOK Guide*, 5th ed. (Project Management Institute, Newtown Square, PA, 2013)

This is the "bible" for project managers and a basis for certification in project management by PMI. Other societies (e.g., Association for Project Management, in Britain) also offer certification and have their own guides/bibles.

Reading: Project Management Maturity: An Industry Benchmark (J. S. Pennypacker and K. P. Grant, *Project Management Journal*, March 2003)

Based on a survey of 123 firms, this study assesses an organization's project delivery capability. Organizations can use these results to benchmark their own project management maturity.

Reading: *Executing your Strategy: How to Break it Down and Get it Done*. (M. Morgan, R. E. Levitt, and W. Malek, Boston: Harvard Business Review Press, 2007)

An insightful book about the major disconnect between organizational strategy and getting it actually implemented through the tools of project management.

Reading: When is a Project Successful? (J. R. Meredith and O. Zwikael, *IEEE Engineering Management Review*, September/October 2019)

This paper summarizes a study that determined there were three major dimensions of project success—the success of the project manager in conducting the project plan, the success of the project owner in achieving the business case for the project, and the net return of the project relative to its cost, as assessed by the client/funder of the project. Measures are given for each of these three dimensions in generic terms so they can be used for any project, public or private.

Reading: Why Good Projects Fail Anyway (N. E. Matta and R. N. Ashkenas, *Harvard Business Review*, September 2003, pp. 109-114)

This article discusses how difficult it is for project managers to predict all the activities and work streams that will be needed to complete a project and to integrate all of the disparate activities of a project. The author recommends the use of rapid-results initiatives to produce a measurable result for a small project rather than recommendations, analyses, or partial solutions for a larger project.

Reading: Why Bad Projects Are So Hard to Kill (I. Royer, *Harvard Business Review*, February 2003, pp. 48-56)

This article analyzes why companies continue to invest time and resources in projects that are destined for failure. The author discusses how collective belief among a project's champion and team members lead them to ignore increasingly negative feedback. The author recommends that companies include project skeptics on project teams, establish an early warning system for projects, and recognize the role of the exit champion.

Reading: Achieving Strategic Benefits from Project Investments: Appoint a Project Owner (J. R. Meredith and O. Zwikael, *Business Horizons*, forthcoming 2019-20)

The message in this paper is that a new project administrator is needed to assure that the benefits desired by the client/funder of the project are achieved—a project *owner*. The role of this new administrator is described and compared to the duties of the project manager.

Reading: From Experience: Linking Projects to Strategy (R.L. Englund and R.J. Graham, *Jr. of Product Innovation Management*, Vol. 16, No. 1, pp. 58-69. 1999)

An excellent article explaining how Hewlett-Packard used the Project Portfolio Process to winnow its project set down by 70% to just those that were strategically important to the firm and then managed them to success.

Reading: Planning for Crises in Project Management (L.M. Mallak et al. *Project Management Journal*, Vol. 28, No. 2, June 1997)

Excellent suggestions for how to handle crises in a project, and how to prepare for the inevitable crises that are sure to come. Good information for preparing for crises in general.

Reading: *Agile Project Management* (C. J. Holt, Blue Fox Publishing, 2015)

One of the few books describing the Agile approach to project management.

Reading: *Agile Project Management for Dummies* (Wiley, 2012)

Another of the famous Dummies books for the Agile approach to project management.

Reading: Balancing Strategy and Tactics in Project Implementation (D.P. Slevin et al., *Sloan Management Review*, Fall 1987, pp. 33-41)

This article presents the results of two studies, one about the ten critical factors in successful project implementation and another about the role of tactics versus strategy in running a project, with some surprising results. In addition, four examples are given of actual firms and their experiences for each of the combinations of tactics/strategy emphasis.

Reading: What Great Projects have in Common (D. Dvir and A. J. Shenhar, *MIT Sloan Management Review*, Spring 2001)

This article identifies seven common characteristics of projects that create exceptional value for their sponsors, far surpass expectations, and eventually impact their entire industry.

Reading: *Microsoft Project 2010 for Dummies* (N. C. Muir, Wiley Publishing, Inc., 2010)

Part of the "Dummies" series that explains MS Project 2000 in a clear and straightforward manner.

Reading: *Critical Chain* (E. M. Goldratt, North River Press, 1997)

An interesting and controversial approach to project management.