CHAPTER 11

Solutions to Chapter-End Problems

A. Key Concepts

Project Life-Cycle:

11.1 The purpose of a charter is to clearly and concisely document the agreed upon scope, objectives, and deliverables of a project. It is important because it serves as a communications device to stakeholders with different backgrounds and different interests. It helps ensure that all the project stakeholders "are on the same page". It reduces the chance of miscommunication, confusion, and the possibility of conflicting stakeholder interests.

11.2 The purpose of project planning is to clarify who is accountable for every aspect of the project, the approach being taken, the major deliverables, and the timing of the key decisions and review points. It provides a roadmap for the project.

It is important because it is used to understand what needs to be done, when and what resources will be necessary. It also provides a mechanism to measure project status and provides early warning of problem areas, allowing risk management and the running of "what if" scenarios to mitigate any risks that may have arisen. Without adequate planning projects may overrun on resources, and may put the project benefits in jeopardy.

11.3 One possible sequence is as follows (other sequences are possible because there are several steps in each stage and they may occur concurrently)

- Identify stakeholders
- Define deliverables
- Form project team
- Identify project activities
- Develop schedule
- Estimate costs
- Approval of project Plan
- Track project expenses
- Manage schedule changes
- Make progress reports to stakeholders
- Deliverables accepted by client

11.4 The activities have been divided into stages as follows:

Initiation:
- Identifying who the project steering committee should be and how often they should meet.

Planning:
- Establishing the project team members.
- Looking up industry standard costs for materials
- Project funding is approved.
- A discussion of whether a programming team has worked together before on a project.
- Looking into whether your company has done a project like this before.

Execution:
- Selecting a contractor to lay optical cabling
- Pouring concrete footings

Monitoring and Controlling
- A meeting to discuss the implications of late delivery for a key piece of equipment needed to complete a project activity.
- Paying a bill, and allocating its cost to the project.

Closure:
- Documenting an unexpected complication in the project for future reference.

Work Breakdown Structure:

11.5 The purpose of a WBS is to define and organise the work to be done as part of a project. The WBS breaks the project deliverables into specific and measurable pieces of work that can be used to assign responsibility, to allocate resources and to monitor the project. The WBS is useful because it makes the work to be done concrete so that the project team knows exactly what is to be accomplished within each deliverable. It allows for better estimating of cost, risk, and time because you can start from the smaller tasks and roll them up to the level of the entire project. It is also useful to double check all the deliverables with the stakeholders and make sure there is nothing missing or double-counted.

11.6 The work packages have been divided as follows:

Food	Guests	Facilities	Reunion Event	Supervision
Menu Planning	Guest List	Utensils	Door Prizes	Co-ordination
Caterer Selection	Invitations/RSVP	Seating/Tables	Business Card Draw	Bill Payment
		Decorations	Name Tags	Purchase Orders
			Coat Check	Budget

11.7 It is important that they not overlap so that work is identified only once in the WBS. If work packages overlap, then the amount of work, and thus resources will be overestimated. Also, overlapping work packages will make assigning responsibilities more difficult.

11.8 One possible answer is as follows. The project is to plan and hold a research workshop for approximately 30 people. Some of the attendees will make presentations on their research. There will be a keynote speaker.

The initial WBS is below:

0.0 Research Workshop		
	1.0 Planning	
		1.1 Select Time and Location
		1.2 Select venue
		1.3 Budget
		1.4 Schedule Talks
		1.5 Plan meals
	2.0 Room and Equipment	
		2.1 Tables and Chairs
		2.2 Data Projector
		2.3 Computer
	3.0 Speakers	
		3.1 Call for presentations
		3.2 Collect responses
		3.3 Post tentative schedule
		3.4 Post final schedule
	4.0 Keynote Speaker	
		4.1 Select Speaker
		4.2 MakeTravel Arrangements
		4.3 Purchase Gift
	5.0 Food	
		5.1 Budget

		5.2 Plan Meals
		5.3 Initial Booking
		5.4 Food selection
		5.5 Final booking
		5.6 Pay bill

After reviewing the initial WBS for whether it a) consists of distinct deliverables, b) it has mutually exclusive and collectively exhaustive items and c) work items are not larger than 80 hours work, several changes needed to be made.

First, the "budget" item appears in several places. It should be broken down into Food Budget, Travel Budget (for the keynote speaker), and Facilities Budget. Booking the venue is missing, and scheduling the talks and planning for food appears in two places. The speakers will bring their own computer for presentation. The work packages appear to be under 80 hours each, so no changes are needed for this best practice. Below is a revised WBS (many other revisions are possible).

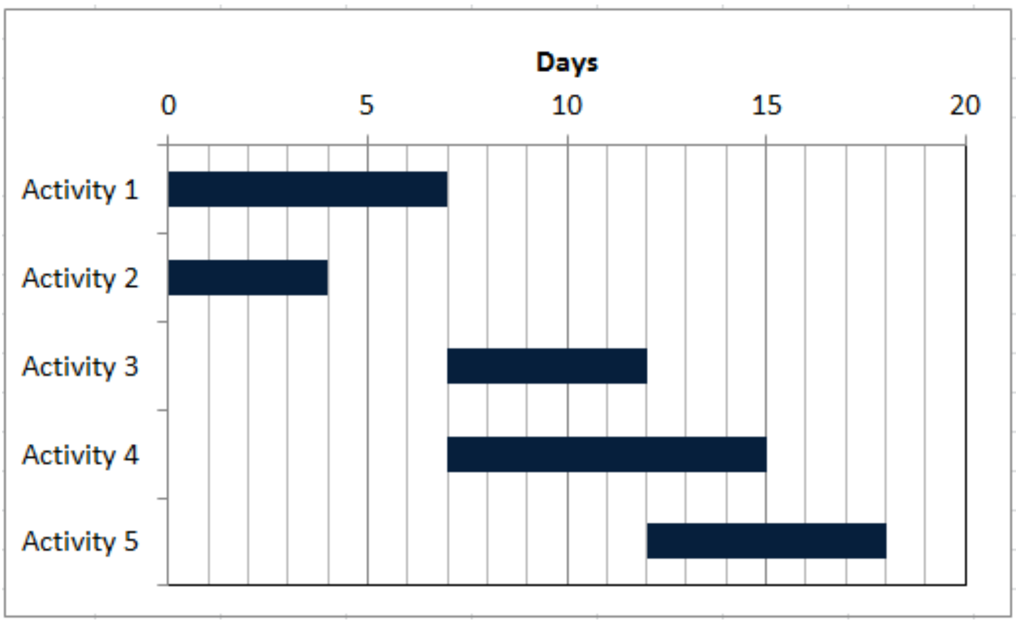
0.0 Research Workshop		
	1.0 Planning	
		1.1 Select Time and Location
		1.2 Select venue
		1.3 Overall Budget
		1.4 Select Organizing Team and Responsibilities
	2.0 Room and Equipment	
		2.2 Book room
		2.2 Arrange for sufficient tables and chairs
		2.3 Book Data Projector
		2.5 Arrange for notepaper, pens
	3.0 Speakers	
		3.1 Call for presentations
		3.2 Collect responses
		3.3 Post tentative schedule
		3.4 Post final schedule
		3.5 Registration (day of workshop)
	4.0 Keynote Speaker	
		4.1 Select Speaker
		4.2 MakeTravel Arrangements
		4.3 Purchase Gift
		4.4 Give gift
	5.0 Food	
		5.1 Food Budget
		5.2 Plan Meals

		5.3 Initial Booking
		5.5 Final booking (1 week prior)
		5.6 Pay bill

Gantt Charts:

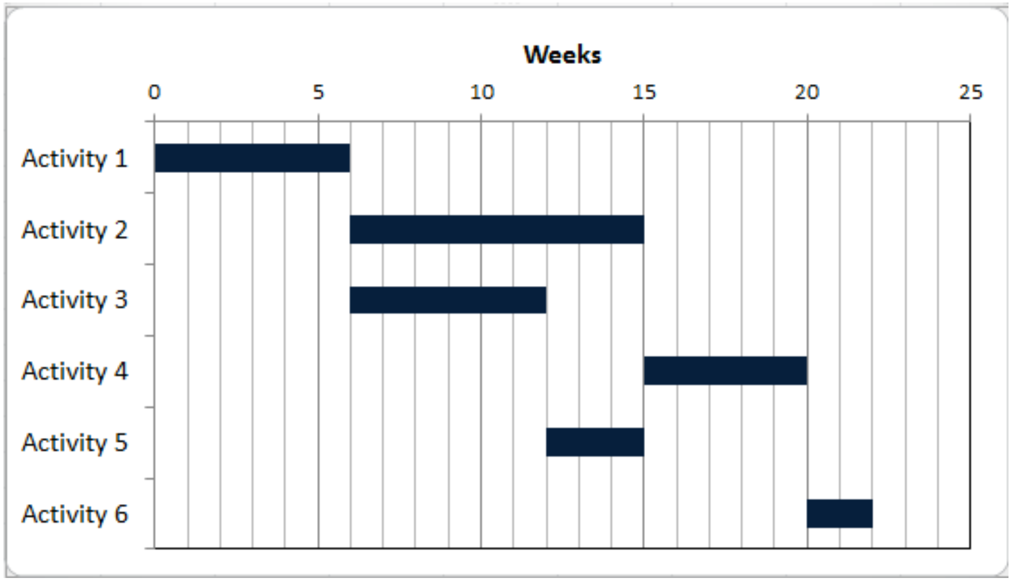
11.9 The Gantt chart is below. The project is expected to take 18 days to complete.

Activity	Start (days)	Duration (days)	End (days)
Activity 1	0	7	7
Activity 2	0	4	4
Activity 3	7	5	12
Activity 4	7	8	15
Activity 5	12	6	18

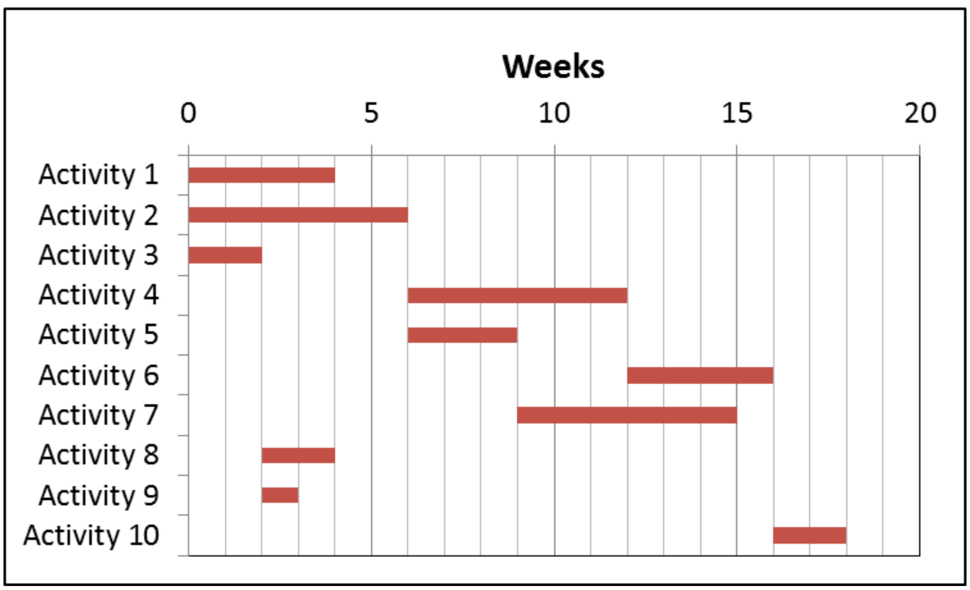


11.10 The project is expected to take 22 weeks to complete.

Activity	Start (wks)	Duration (wks)	End (wks)
Activity 1	0	6	6
Activity 2	6	9	15
Activity 3	6	6	12
Activity 4	15	5	20
Activity 5	12	3	15
Activity 6	20	2	22

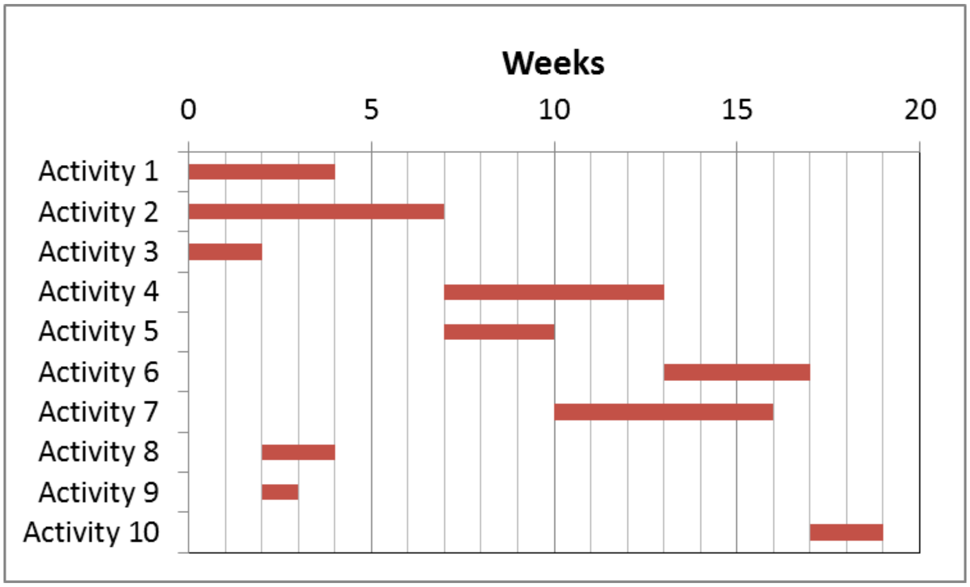


11.11 a) The Gantt chart is below:



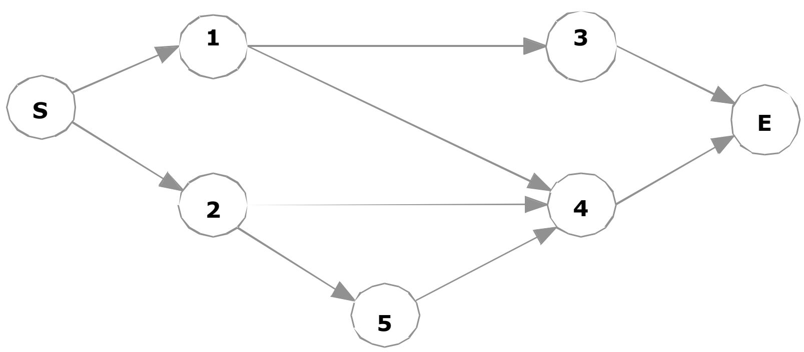
b) The project is expected to take 18 weeks to complete.

11.12 If activity 5 will take 7 weeks rather than 6 weeks, activities 4 and 5 will be delayed by one week. Since activity 4 is delayed one week, activity 6 will also be affected by one week, and hence activity 10 will be delayed also. This means that the project will be delayed one week to 19 weeks.

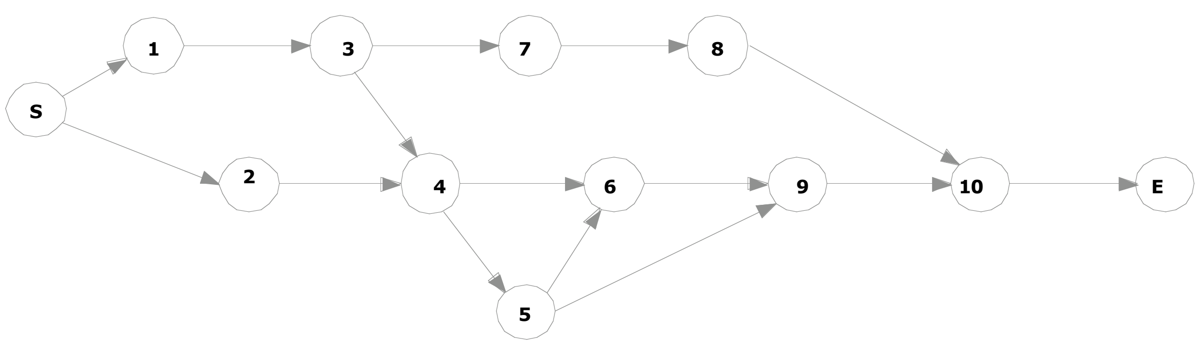


PERT/CPM Networks:

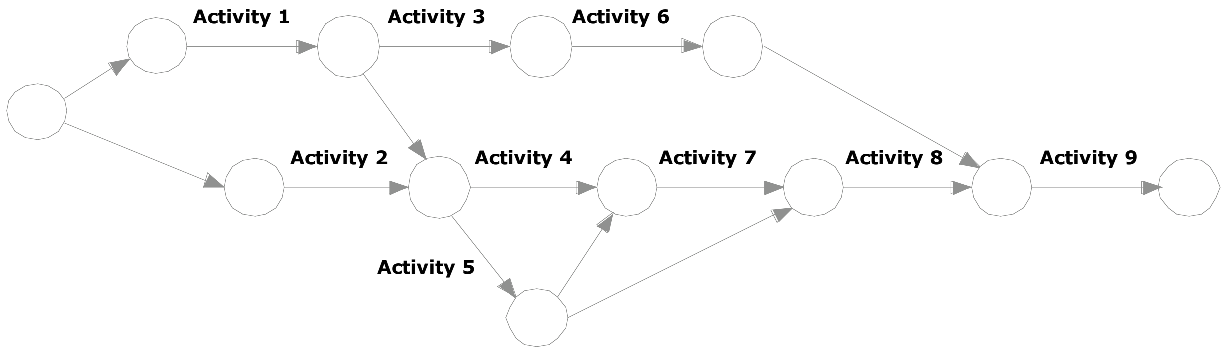
11.13



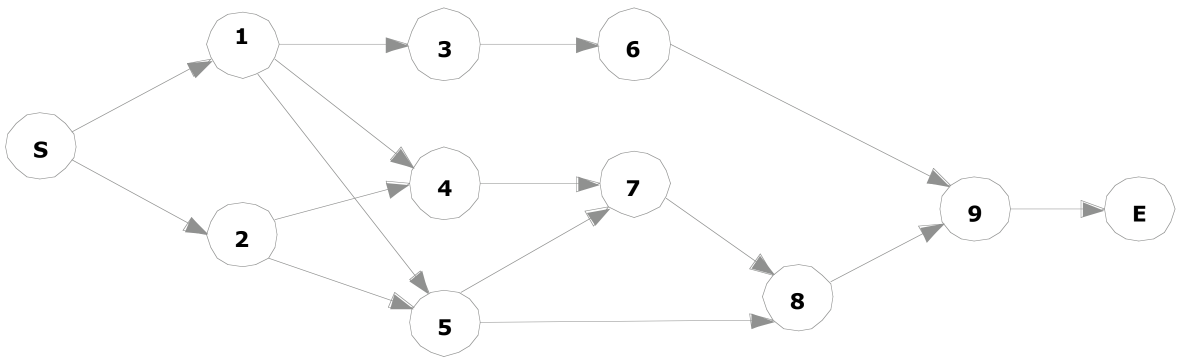
11.14



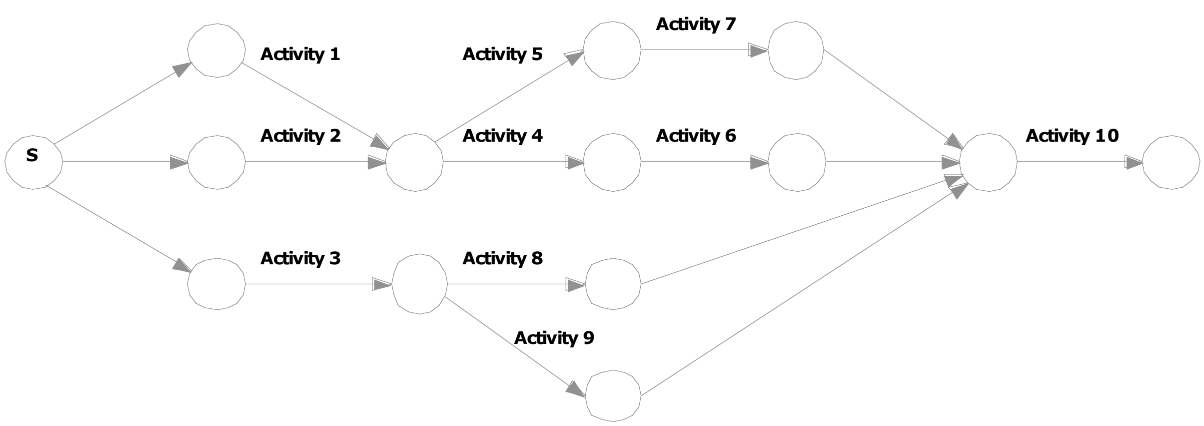
11.15 a)



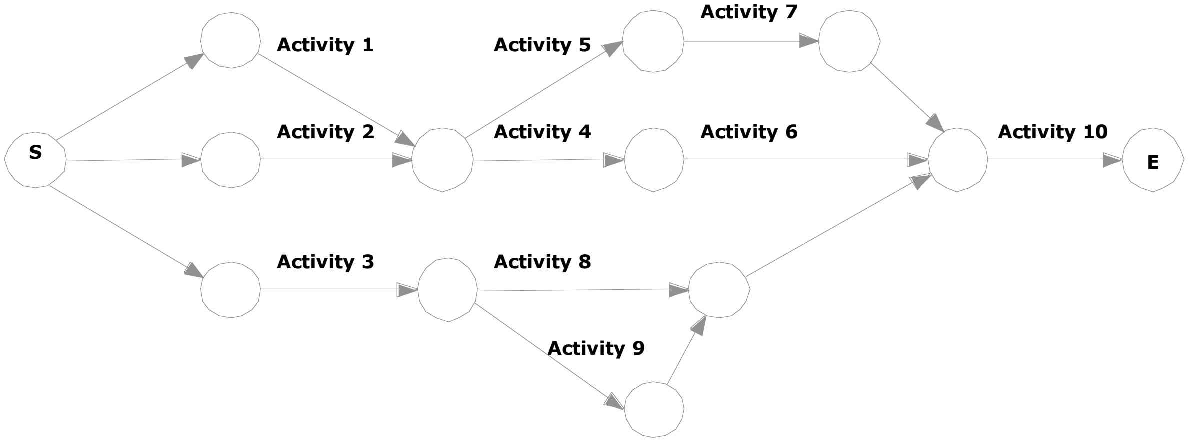
b)



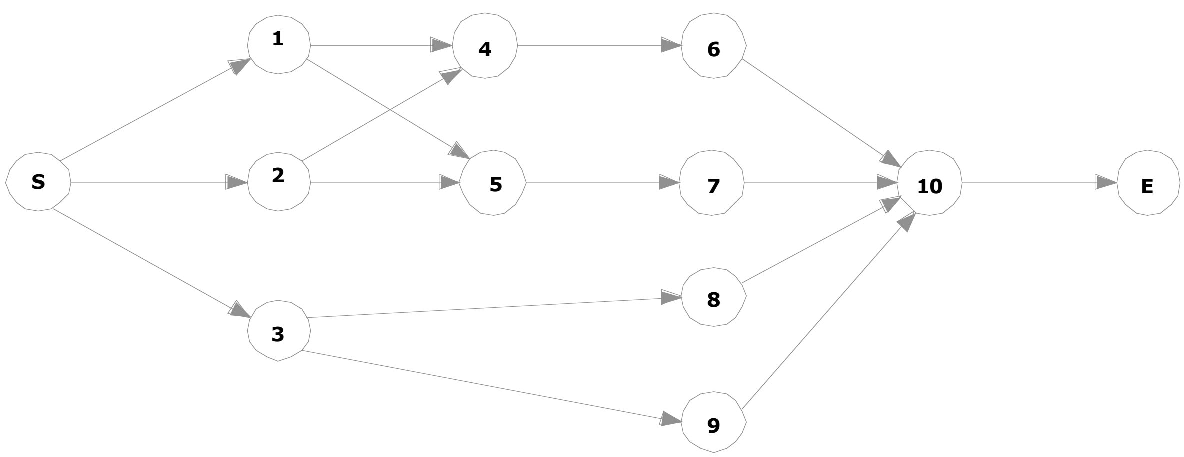
11.16 a) (note that there are several ways this network can be correctly written)



Here is a second solution:

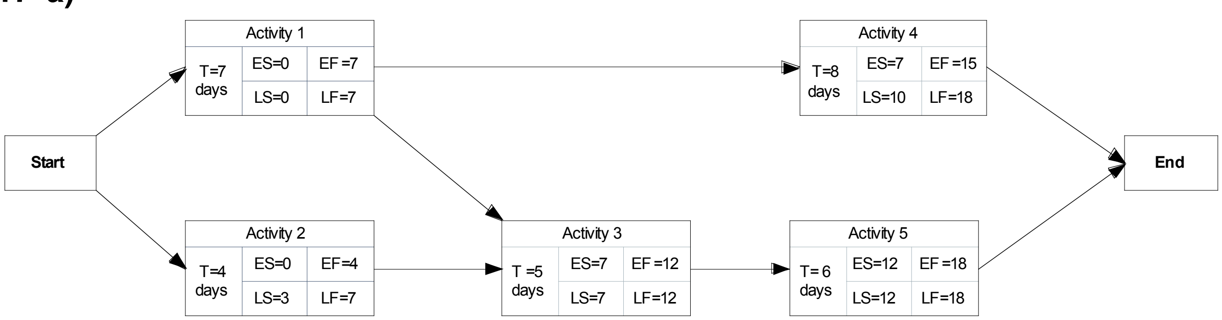


b)



Critical Path:

11.17 a)



This is the latest of the completion times for Activities 4 and 5. Both must be complete for the project to be considered complete.

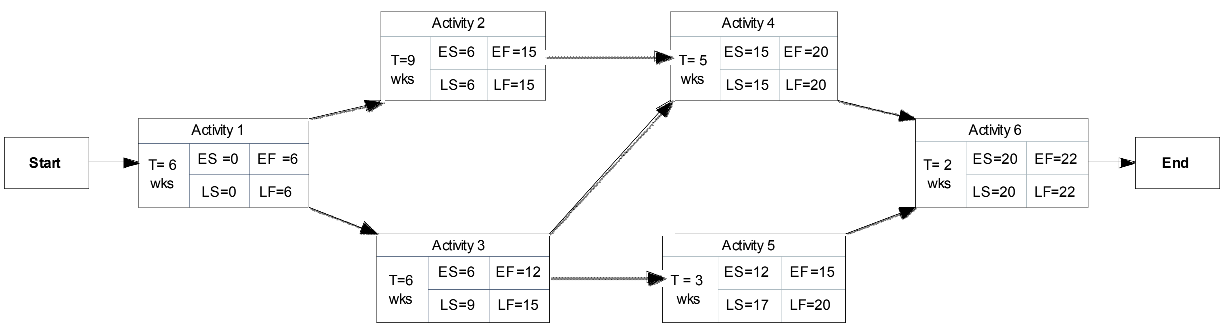
b) The earliest start time for activity 3 depends on when Activities 1 and 2 complete. Activity 1 takes the longest, completing by day 7. Even through Activity 2 is done by day 4, Activity 3 cannot start until both are done, which is day 7.

c) The latest finish time for activity 1 depends on the latest start times for its successor activities (3 and 4). The latest start time for Activity 4 is 10 days, and for Activity 3 is 7 days. Therefore, Activity 1 can finish no later than day 7 in order not to delay the project.

d) The critical path is Activities 1-3-5.

e) The project should take 18 days to complete

11.18 a)



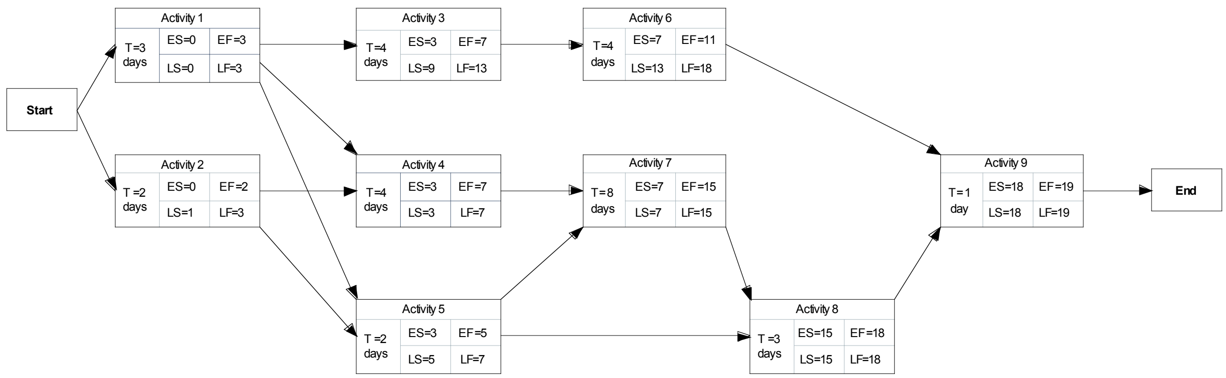
b) The earliest Activity 4 can begin is the earliest time at which both activities 2 and 3 are completed. Activity 2 can be completed at the earliest by week 15, and activity 3 by 12 weeks. Therefore activity 4 must wait until week 15 to start.

c) The latest finish time for activity 2 depends on how late Activities 4 and 5 can start. Activity 5 can start as late as week 17 and still have the project complete on time. Activity 4 must begin no later than week Therefore, since both follow Activity 3, activity 3 must finish no later than week 15 in order not to delay the project.

d) The critical path is activities 1-2-4-6.

e) The expected project completion time is 22 weeks.

11.19 a) See diagram:

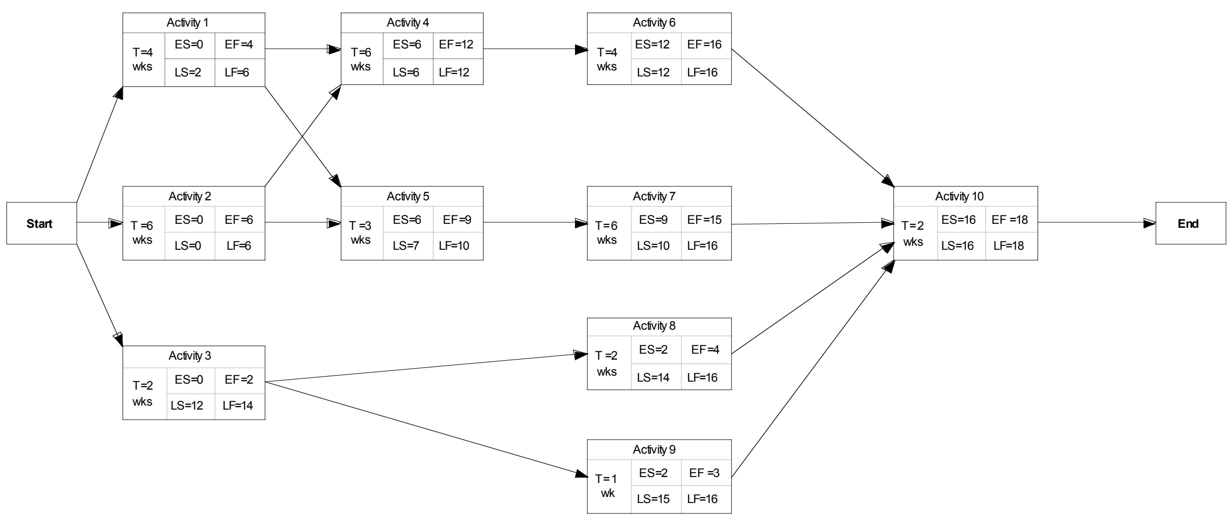


b) The project is expected to take 19 days.

c) The critical path activities are 1-4-7-8-9

d) Activities 2,3,5 and 6 have slack of 1,6,2 and 6 days, respectively.

11.20 a)



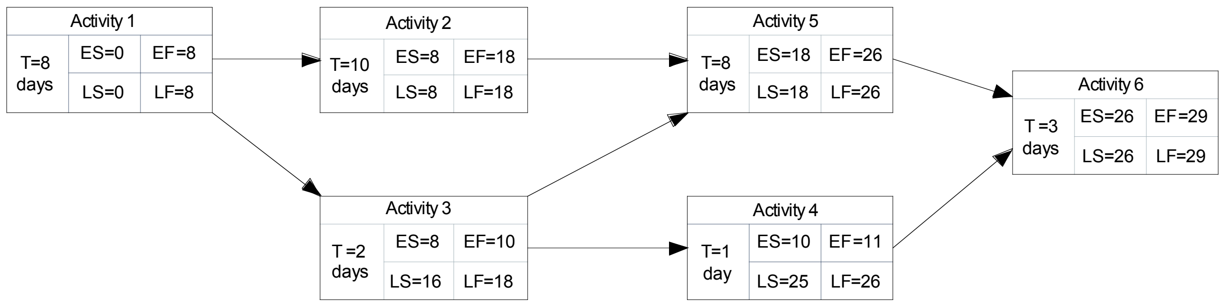
b) The project is expected to take 18 weeks.

c) The critical path is activities 2-4-6-10

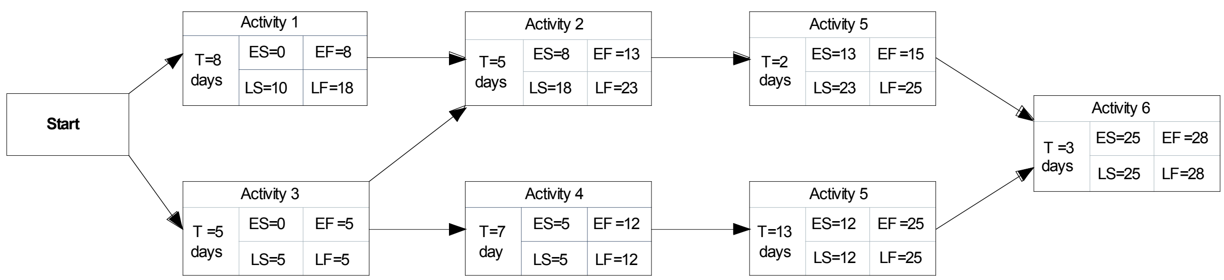
d) Activities 1,3,5,7,8 and 9 have slack of 2,12,1,1,12 and 13 weeks respectively.

Project Crashing:

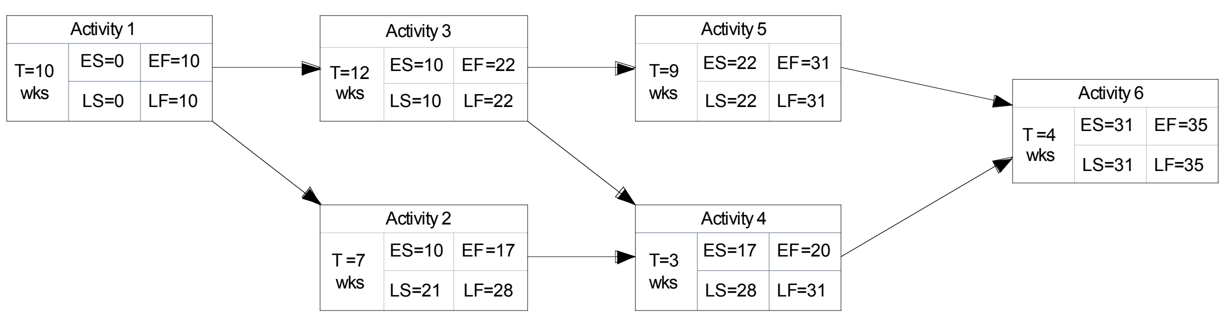
11.21 a) See below. The critical path is activities 1-2-5-6 (29 days). Crashing Activity 1 by three days will not create a new critical path, and will shorten the completion time of the project by 3 days.



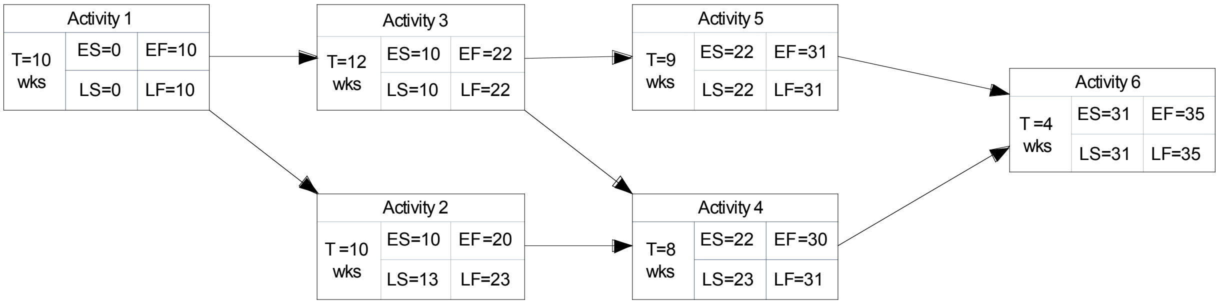
b) See below. The critical path is activities 3-4-5-6 (28) days. Activity 1 has 10 days of slack. Therefore crashing it by 3 days will not affect the completion time of the project.



11.22 a) See below. The critical path is activities 1-3-5-6 (35 weeks). Activities 2 and 4 have 11 weeks of slack each. Crashing activity 1 by seven weeks will not introduce new critical paths, and will reduce the slack in Activity 2 by seven weeks.



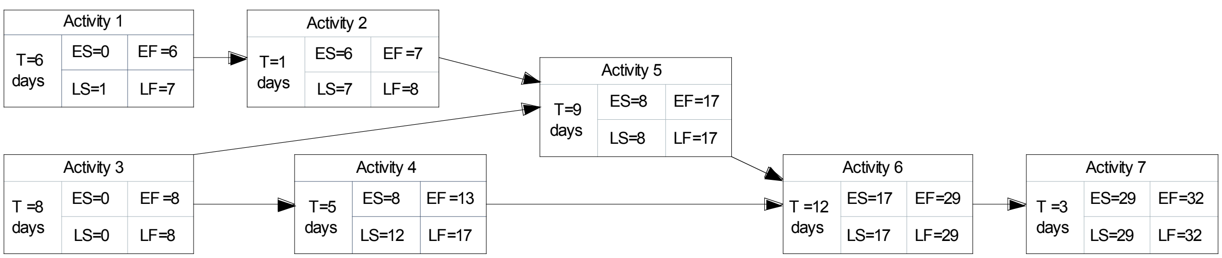
b) The critical path is activities 1-3-5-6 (35 weeks). The slack in Activities 2 and 4 is 3 weeks. If Activity 1 is crashed by 7 weeks, a new critical path emerges: activities 1-2-4-6. The slack in Activity 2 is now zero weeks, down by three weeks.



11.23 a) Activities 2 and 4 are on the critical path since they have zero slack. Activity 2 costs (70 000-25 000)/((7-4)=$16 667 per week to crash, and can be crashed by up to 3 weeks. Activity 4 costs (40 000-20 000)/(5-4) = $20 000 per week to crash, and can be crashed by up to one week. The least cost way to crash the project by 1 week is to crash Activity 2 by this amount.

b) the additional cost is $16 667.

11.24 a), b)



a) The critical path is 3-5-6-7
b) The project will take 32 days to complete
c) The normal cost of the project is $70 000
d) The critical path activities are 3,5,6 and 7. The cost per day to crash activity 3 is (16 000)/4 = $4000 per day. The cost per day for activity 5 is 8000/4 = $2000 per day. The cost per day for activity 6 is ($16 000)/6 = $26 667 per day, and for activity 7 is 8000/1 = $8000 per day. The least cost per day is $2000, which corresponds to activity 5.

B. Applications

11.25 What is the purpose of project monitoring and controlling? Why are these activities important?

The purpose of project monitoring and controlling is to track and communicate the project's progress. It will identify when a project's performance deviates significantly from the plan so that appropriate corrective actions can be taken.

Executing a project without monitoring and controlling is like driving a car with your eyes closed. You could find yourself heading over a cliff before you realize that slowing down and turning left could have kept you comfortably on the road. Monitoring and Controlling permit a manager to assess how well the project is proceeding compared to the plan. Controlling permits a manager to make changes to the execution of the project to put it back on track or to modify the plan if that is the appropriate course of action.

What is the purpose of project closure? Why is it important?

The purpose of project closure is to formally conclude the project. Closure is important because it permits an opportunity to leveraging all of the lessons learned from the project, loose ends are "wrapped up", staff evaluations completed, and deliverables formally transitioned to support or operations. Resources allocated to the project will be terminated, and the closure document acts as a communications vehicle so that all stakeholders are aware of the results.

11.26 **a)** The three examples are construction, software development and process redesign. Many others can be found on the web.

Civil Engineering – construction example	Lifecycle Stage
Market Demands or Perceived Needs	Initiation
Conceptual Planning and feasibility Study	Planning
Design and Engineering	Planning
Procurement and Construction	Execution/Monitoring and Controlling
Startup for Occupancy	Closure
Software Engineering – Software Development	Lifecycle Stage
Requirements Analysis and Planning	Initiation
System Design and Specification	Planning
Coding and Verification	Execution

Testing and Integration	Execution/Monitoring and Controlling
Implementation	Closure
Maintenance	(maintenance is post-closure)
Process Improvement Project	**Lifecycle Stage**
Define Goals of Project	Initiation
Develop performance metrics for process	Planning
Analyze current process	Planning
Design improvements	Planning
Pilot testing of new process and feedback	Execution/Monitoring and Controlling
Education/Training	Execution
Rollout	Execution
Post Implementation Assessment	Closure

b) Construction example resources: People: Architects, Engineers, construction labourers, project manager, lawyers. Equipment: computer hardware and software for planning, construction machinery such as cranes, trucks, backhauls. Materials: concrete, steel, wood, furniture, heating and cooling equipment. Money: salaries, capital funding for construction costs.

Software engineering example resources: People: software engineers, programmers, project manager. Equipment: computers, printers, peripherals, test system equipment. Materials: paper, computer supplies. Money: staff salaries, materials.

Process Improvement example: People: industrial or management engineers, project manager, domain expert staff Equipment: computer systems and software, materials, process equipment as needed. Materials: paper, computer and other supplies. Money: salaries, funding for materials.

11.27

Initiation	Decision to attend university made. Decision to stay in residence made. Agreement regarding any financial support from family struck.
Planning	Evaluate alternative residences and select preferred. Create budget for year. Plan what items you will need.

	Evaluate transportation alternatives, select preference.
Execution	Send paperwork to University residence to confirm selection Purchase items needed for residence Pay residence fees Purchase transportation ticket(s) (if applicable) Pack Travel to Residence Fill out necessary paperwork; obtain keys Move luggage in, unpack Meet some neighbours Evaluate facilities, identify gaps
Monitoring and Controlling	Confirm residence space Check list of needed items as items are being purchased. Review checklist as packing. Ensure that all luggage items have been loaded, unloaded and moved into residence.
Closure	Call home to indicate move has been completed. Arrange for any forgotten items to be sent.

11.28

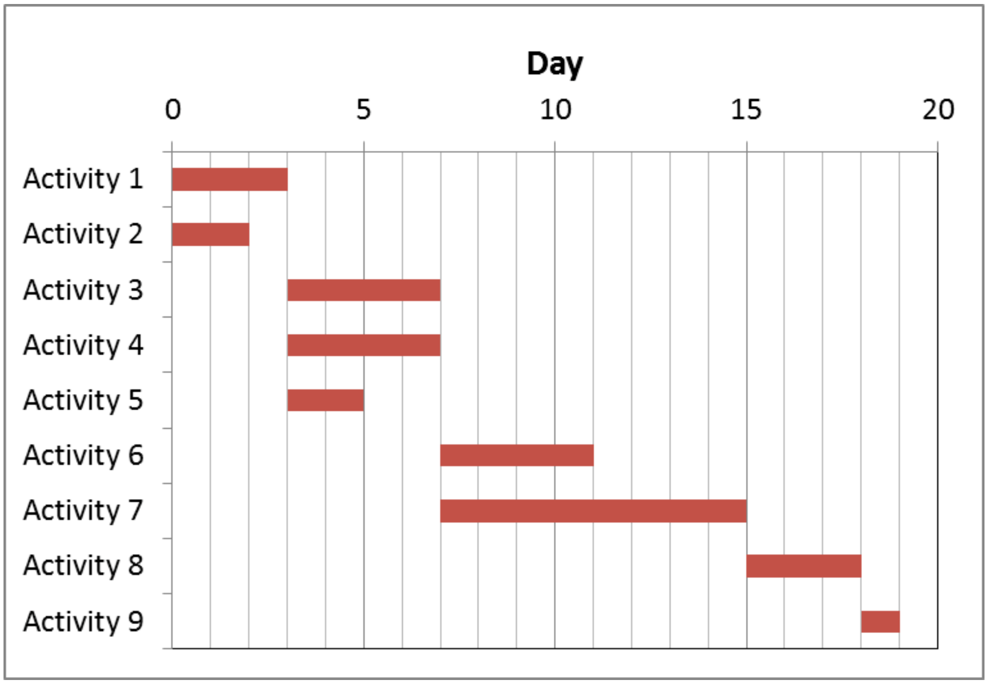
Initiation	Idea to take a trip Create rough plan of locations to visit, including costs, and timing. Decide whether you have enough funding to go (or not).
Planning	Create a list of all locations you wish to visit and benefits of each. Evaluate transportation and accommodation alternatives and costs. Carry out a cost/benefit analysis to determine subset of locations to see and modes of transportation to take. Determine what visa requirements are and whether you need special travel inoculations. Create a list of clothing/equipment you will need. Determine gaps. Construct itinerary evaluating feasibility and costs.
Execution	Purchase transportation tickets, Make accommodation reservations Get visas, inoculations (if necessary). Purchase/borrow any necessary equipment. Arrange housitting Pack
Monitoring and	Review itinerary

Controlling	Confirm reservations Check list of required equipment as it is being purchased/borrowed. Monitor costs as tickets, reservations are made. Check list of equipment/clothing while packing.
Closure	Confirm itinerary is complete Leave on trip

11.29

Level 0	Level 1	Level 2	Time estimate (mins)
Trip			
	1.0		
		1.1Identify alternatives	60
		1.2 Read information and compare	30
		1.3 Select preferred residence	10
		1.4 Send in confirmation paperwork	15
		1.5 Create budget	45
		1.6Pay fees	15
		1.7 Arrival paperwork	30
	2.0 Travel		
		2.1 Identify Alternatives	30
		2.2 Compare and Select Alternative	120
		2.3 Purchase tickets	60
		2.4 Travel	720-840
	3.0 Materials		
		3.1 List of essential items	45
		3.2 List of other items	60
		3.3 Gap analysis	15
		3.4 Acquisition of items	180-600
		3.5 Pack	180
		3.6 Check list	10
		Unpack	120
	4.0Other		
		Meet Neighbours	60-300

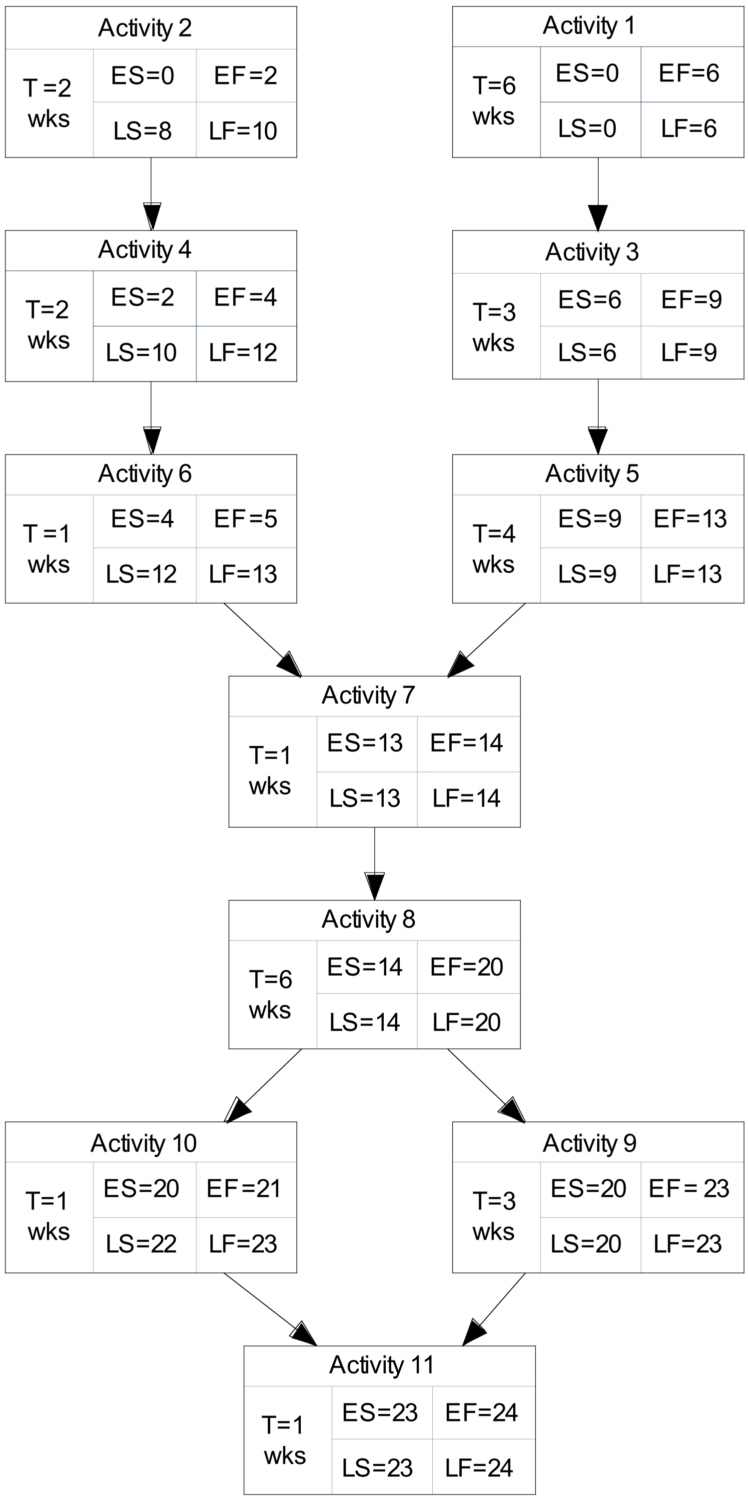
11.30 a)



b) The project is expected to take 19 days to complete.

c) If activity 6 is delayed by 3 days, it will not delay the project completion because its successor (activity 9) must wait for 7 to complete. Currently activity 7 completes on day 15. Activity 6 start on day 10 and end on day 14.

11.31 a) and b)



c) The critical path is activities 1-3-5-7-8-9-11. The project should take 24 weeks to complete.

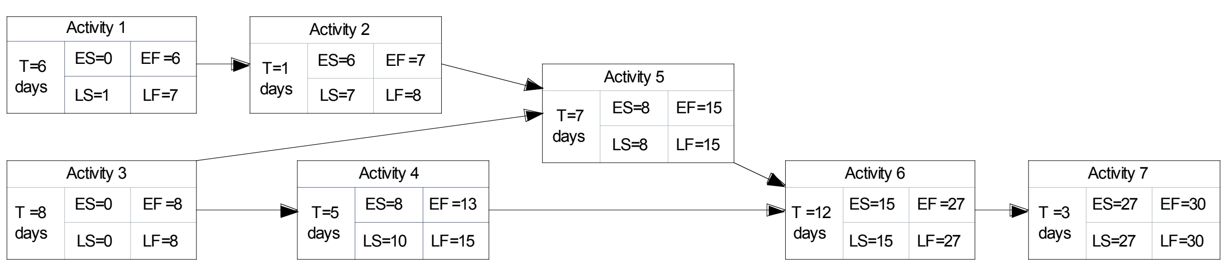
11.32 Refer to the solution of problem 11.31 for the CPM representation.

The cost of crashing each of the critical path activities is as follows:

Activity	Crashing Cost/week ($000)
1	30/(6-4) = 15
3	8/1 = 8
5	13/2.5 = 5.2
7	6/0.5 = 12
8	22/2 = 11
9	15/1 = 15
11	N/A

To crash the project by two weeks, we start with the least expensive activity to crash. That is activity 5. It can be crashed up to two and one half weeks at a cost of $5200 per week. Crashing Activity 5 by two weeks does not cause any new critical paths to arise, so activity 5 should be shortened to 11 weeks. The cost is $10 400.

11.33 **a)** Using the data from problem 11.24, the least cost activity to crash is Activity 5. It can be crashed by two days, at a cost of $2000 per day, or a total of $4000. The total project cost will then be $74 000. The revised CPM diagram is below:



b) Activity 5 can be crashed one more week (for a total of three weeks) at an additional cost of $2000. The project will then cost $76 000.

C. More Challenging Problems

11.34 Risks are either controllable or not controllable. For risks we cannot control, contingency plans help deal with the event to help mitigate consequences. For controllable risks, planning ahead can reduce the likelihood of the events. Contingency plans help mitigate the impact.

Construction project risks: cold temperatures delay construction activities, contamination of construction site stops work, water table is too high for water containment to be effective.

To mitigate the likelihood or impact of these risks: Cold temperatures are not controllable. If the project is being done in a region that experiences cold temperatures regularly, some additional time might be allowed in the schedule to allow for this. A thorough assessment of the site prior to construction will reveal whether contamination or water table issues are present. Effective planning can reduce the likelihood of these events.

Software development project: project team has dysfunctional relationship which delays deliverables, scope of project has enlarged threatening the completion date, one of the key project team members leaves her job.

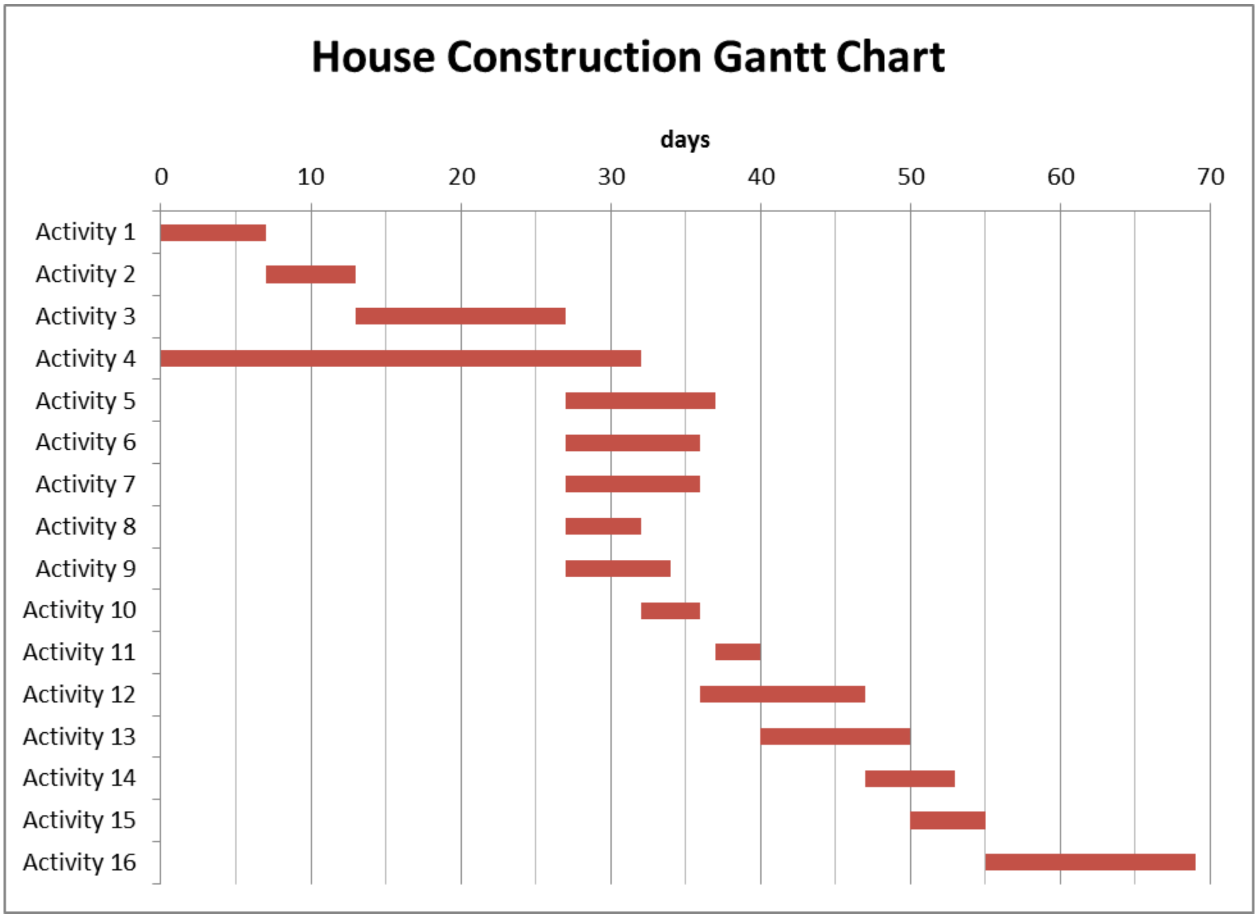
In constructing the software development schedule, the background of the programmers is something that should be examined. If the team has had little experience working together, this should be built into the effort estimation computations. The risk of scope creep is minimized by having a very clear scope statement. Having good documentation and e.g. frequent design reviews can help mitigate the impact of a departure of a team member. Cross-trained staff can also help.

Process Improvement project: staff are resisting and undermining the change process, a major step (and stakeholder) in the process has been omitted, the project is dragging on.

Frequent consultation and communication with affected staff are important to reduce the likelihood of resistance. Training is also important. Documentation and process evaluation should catch missing steps in the process; if event does occur, then communication and rectification is needed. A project that is dragging on could be because its scope is unclear, or milestones have not been set. The project manager should rectify either if they occur.

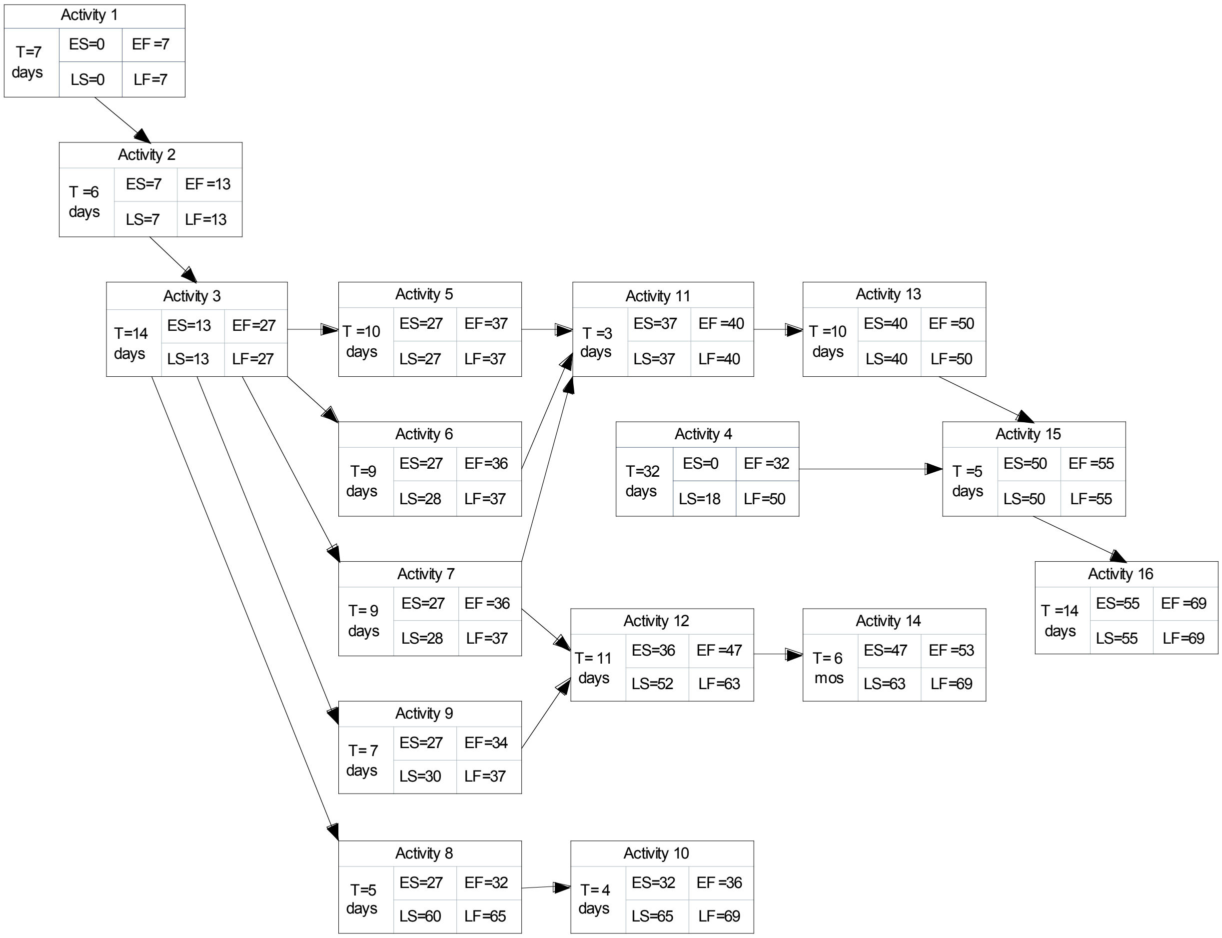
A lessons learned document at the close of each project will help with planning for future projects. This can help reduce the likelihood of controllable risks.

11.35



The project is expected to take 69 days

11.36 a)

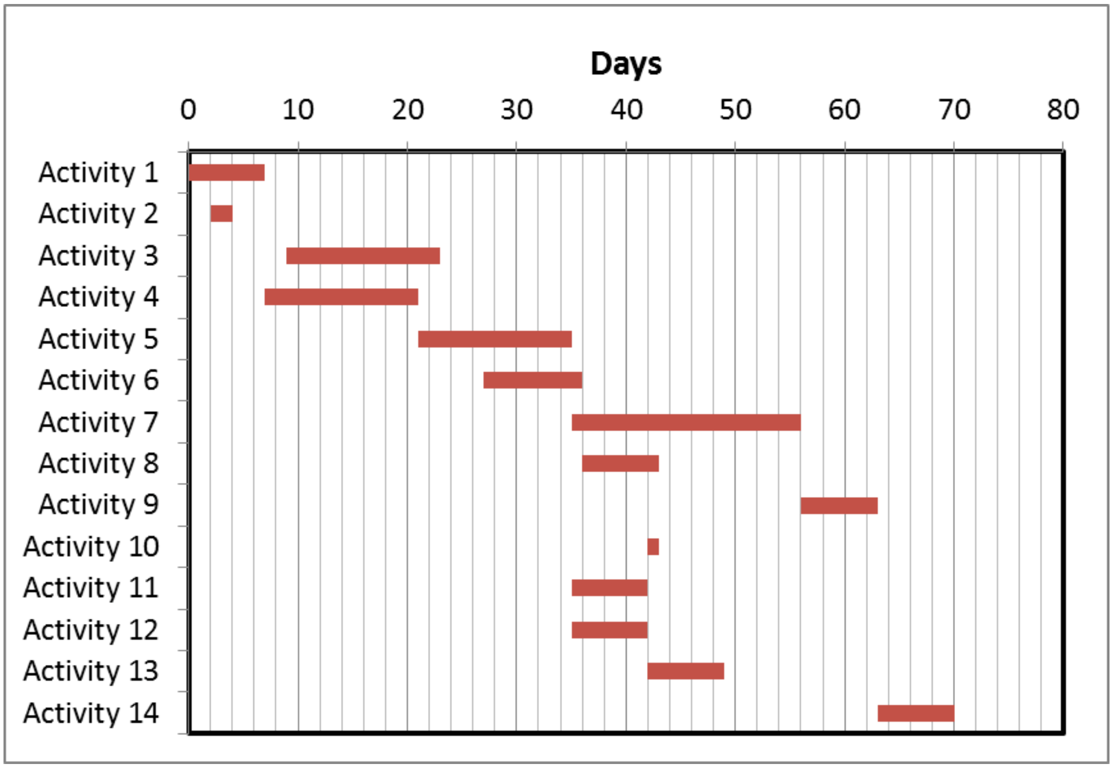


b) The house is expected to take 69 days to complete.

c) The critical path is activities 1-2-3-5-11-13-15 -16.

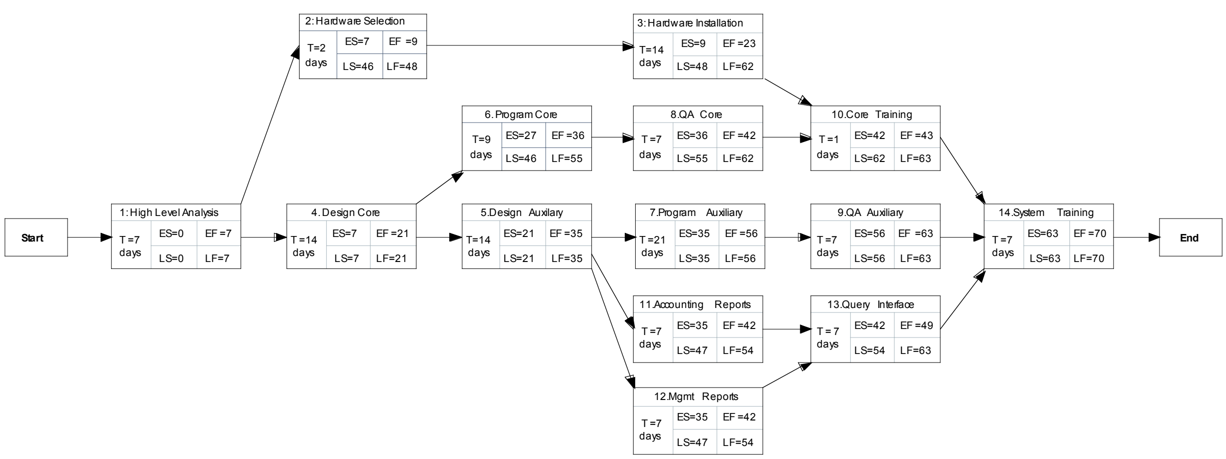
d) The windows were supposed to be ready by day 27 of the project. A 21 day delay will extend the project by 20 days: there is one day of slack in this activity; the remaining days will delay the entire project.

11.37



The expected completion time is 70 days.

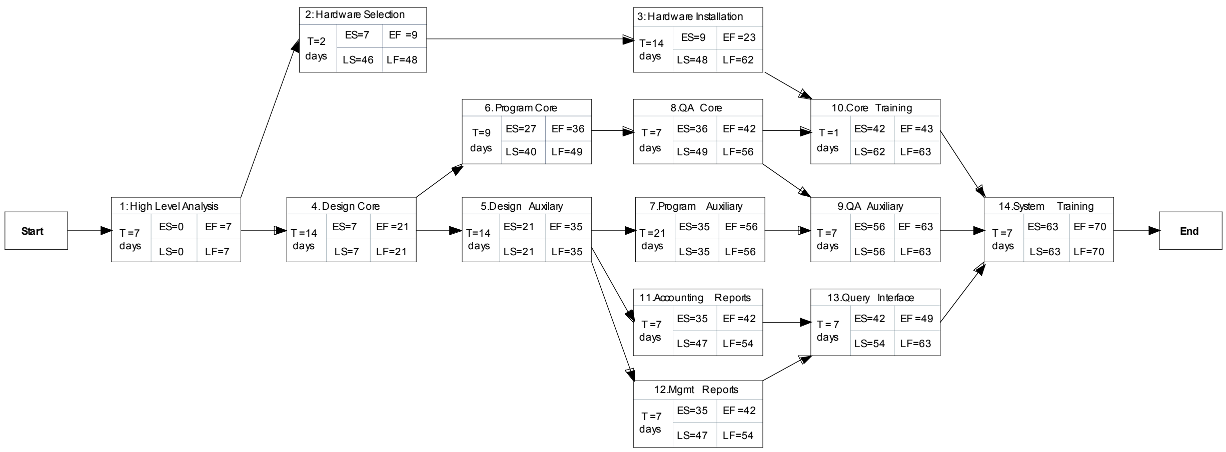
11.38 a)



b) The critical path is activities 1-4-5-7-9-14. The project is expected to take 70 days to complete.

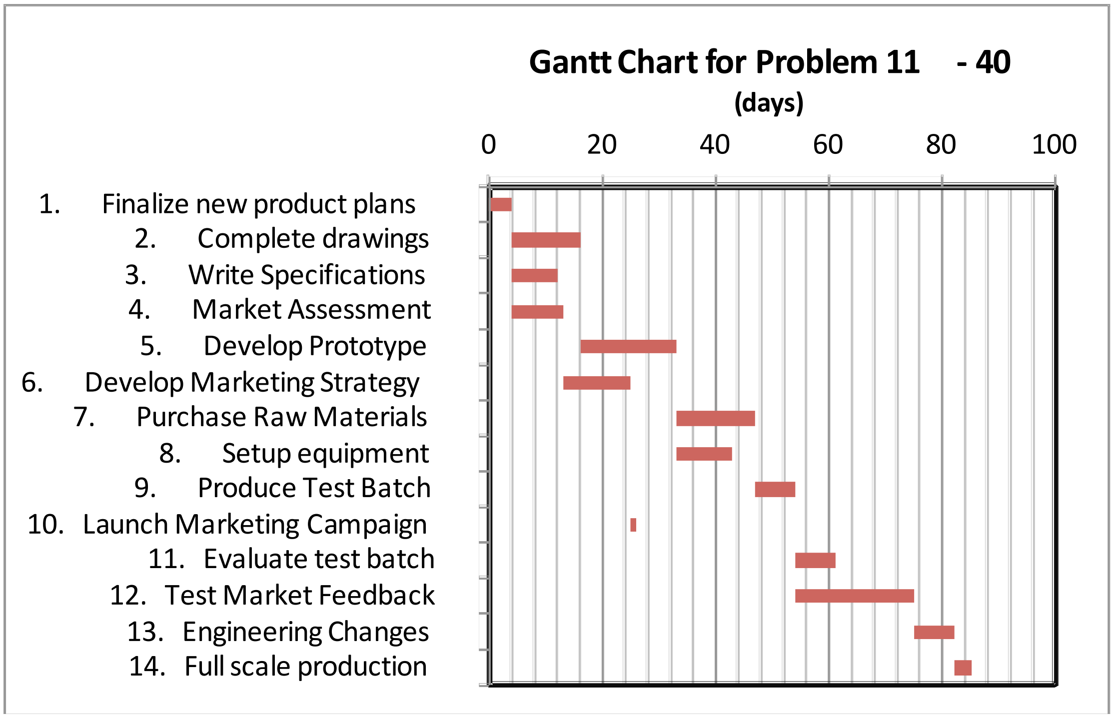
11.39 If the QA specialist can only work on one major activity at a time, then QA on the core modules (Activity 8) and the QA on the auxiliary modules (Activity 9) cannot overlap in time. In other words, they must occur in sequence. At the moment, the earliest Activity 8 can start is day 36, and the latest 56. Activity 9 can start at the earliest day 56 and the latest day 56 (it is on the critical path). Adding a precedence relationship between activities 8 and 9 will ensure the sequential completion of the QA activities.

Making this change alters the LS and LF times for activities 6 and 8. The revised times are shown in the PERT/CPM network below:



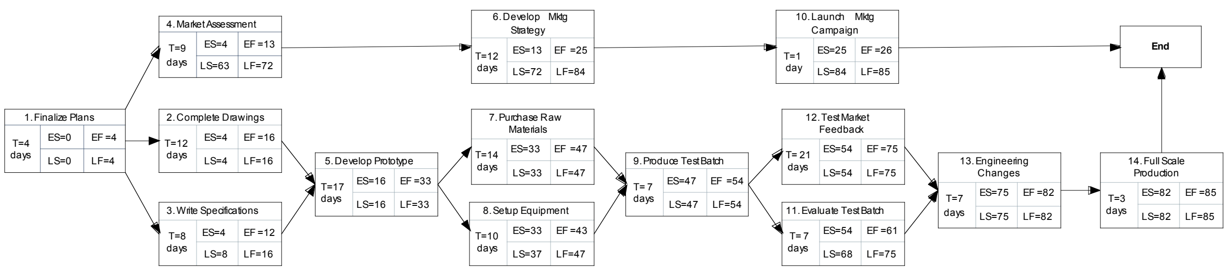
11.40

Activity	Earliest Start	Duration (days)
1. Finalize new product plans	0	4
2. Complete drawings	4	12
3. Write Specifications	4	8
4. Market Assessment	4	9
5. Develop Prototype	16	17
6. Develop Marketing Strategy	13	12
7. Purchase Raw Materials	33	14
8. Setup equipment	33	10
9. Produce Test Batch	47	7
10. Launch Marketing Campaign	25	1
11. Evaluate test batch	54	7
12. Test Market Feedback	54	21
13. Engineering Changes	75	7
14. Full scale production	82	3

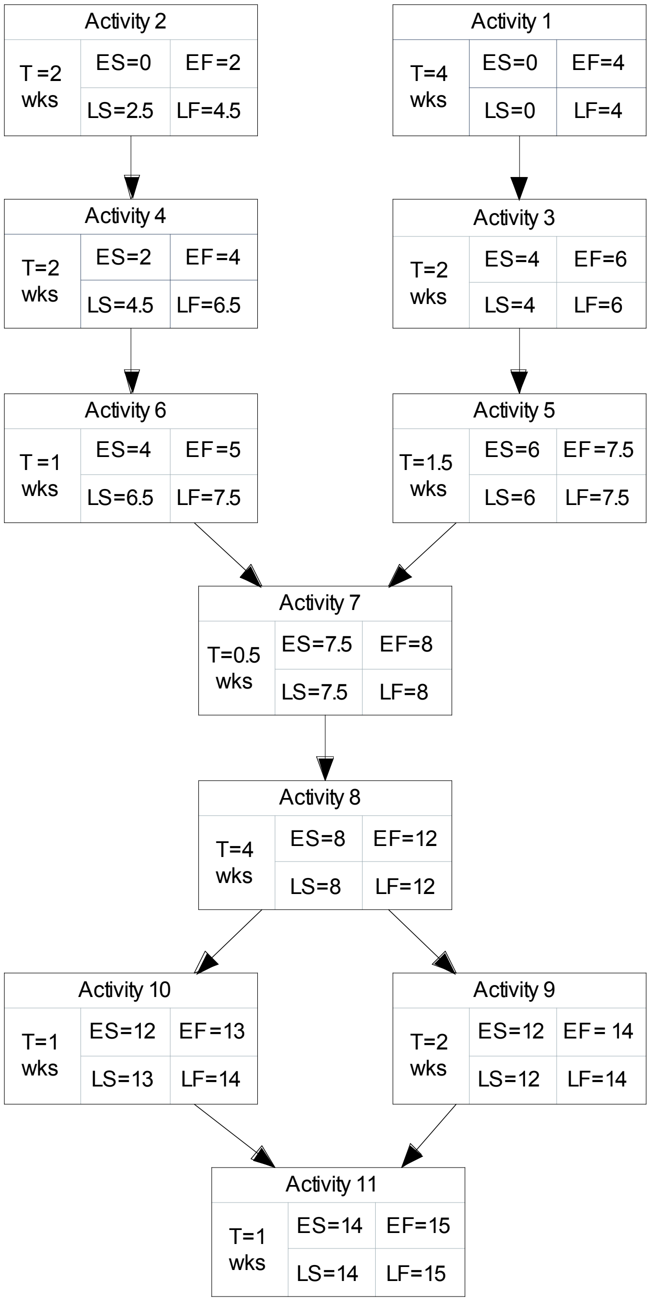


a)

b) Full scale production is expected to begin on day 82.



11.41 The shortest time in which the project can be completed depends on the activities on the critical path. As a starting point, look at crashing all of the activities on the critical path as much as possible. The resulting CPM diagram is below. Crashing all of the activities on the critical path as much as possible does not make any other sequence of activities critical. Therefore the shortest completion time is 15 weeks. The crashing cost is then \$94 000 (30+8+13+6+22+15 = 94, the cost to crash each critical path activity as much as possible).



Activity 2
T =2 wks
ES=0
EF=2
LS=2.5
LF=4.5
Activity 1
T=4 wks
ES=0
EF=4
LS=0
LF=4
Activity 4
T=2 wks
ES=2
EF=4
LS=4.5
LF=6.5
Activity 3
T=2 wks
ES=4
EF=6
LS=4
LF=6
Activity 6
T =1 wks
ES=4
EF=5
LS=6.5
LF=7.5
Activity 5
T=1.5 wks
ES=6
EF=7.5
LS=6
LF=7.5
Activity 7
T=0.5 wks
ES=7.5
EF=8
LS=7.5
LF=8
Activity 8
T=4 wks
ES=8
EF=12
LS=8
LF=12
Activity 10
T=1 wks
ES=12
EF=13
LS=13
LF=14
Activity 9
T=2 wks
ES=12
EF= 14
LS=12
LF=14
Activity 11
T=1 wks
ES=14
EF=15
LS=14
LF=15

Notes for Mini-Case 10.1

1) 10% does make sense as an abstract deviation for sensitivity analysis purposes because it provides a way to compare the effect of changes to different parameters. It can also be easily scaled to approximate other particular variation values. Although a change of 10% of the assumed value is a sensible amount for many parameters, for cost of borrowing, which is already a percentage, a 1% change is simply more meaningful. Again, it can be easily scaled to approximate other particular variations.

2) No. Although a 10% change in revenue had the largest effect on profit, it doesn't take in to account how likely a 10% change in revenue is compared to the chance of other parameters varying by 10%. For example, even though the effect of a 10% change on cost of sales is less, it may be much more likely to occur, making it the larger risk.

3) You would have to research the likelihood of each of the relevant parameters varying by a significant amount. You might focus particularly on the risks of changes to revenue, cost of sales and cost of borrowing, but all of the parameters would merit some deeper evaluation.

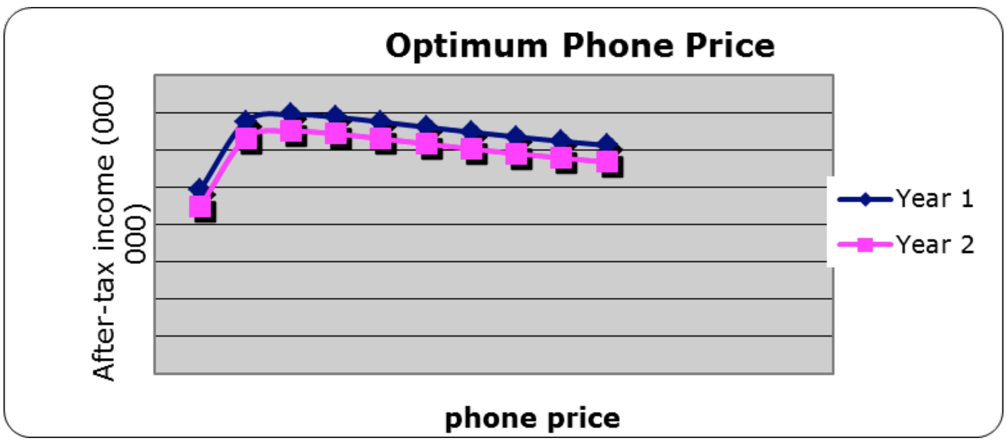
4) Examples include: researching land values, establishing building costs early, determining expected usage through surveys, etc., researching similar facility fee methods and revenues, get an early commitment on subsidies, etc.

Solutions to All Additional Problems

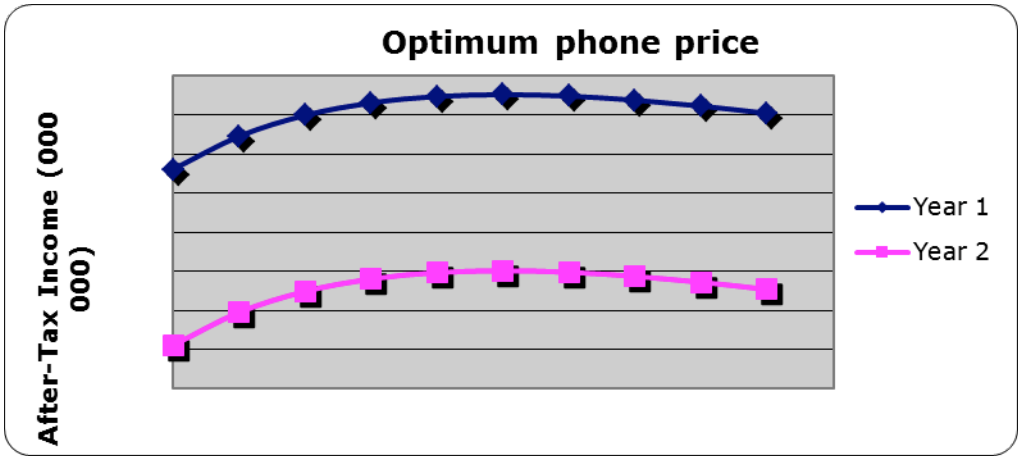
Note: Solutions to odd-numbered problems are provided on the Student CD-ROM.

11S.1

The solution is shown in the accompanying spreadsheet, **11S_1a.xls**. Note that all values in columns to the right of column B are given in thousands of won. We see that the maximum income for both years is obtained at the same selling price, which is approximately □30 000. It is therefore unnecessary to bring this future income back to present value—since the future income for each selling price will be reduced by the same factor, the position of the optimum will not change.



If we want to locate the optimum more precisely, we can make a simple change to the first column of the spreadsheet, examining a narrower range of pricing options on either side of the approximate optimum. This is done in the second spreadsheet, **11S_1b.xls**. Further refinement of the position of the optimum is not worthwhile, since the market research data we are using does not have perfect accuracy.



11S.2

Taking a ten-year study period, the initial expenses are the cost of the building and the machinery. We can represent the tax consequences of the straight-line depreciation of the building as a deduction of £(0.04 ×1 000 000) from pre-tax income every year, but we will represent the after-tax cost of buying the machinery by multiplying its first cost by (1–*TBF*), where the *TBF* is defined by

$TBF = td / (i+d)$ = 0.5 × 0.25 / (0.1+0.25) = 0.357

So the after-tax start-up cost of the project is:
–1 000 000 – 500 000(1–0.357)

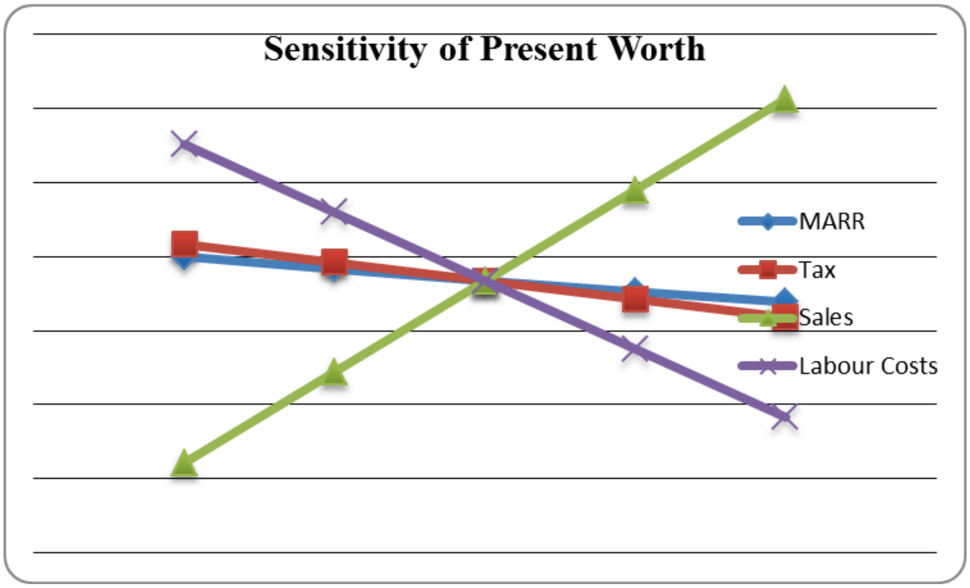
The annual before-tax net income is:
2 000 000 – 40 000 – 50 × 30 000

So the after-tax income is:
(2 000 000 – 40 000 – 50 × 30 000)(0.5) + 40 000

and the present worth of this income is:
((2 000 000 – 40 000 – 50 × 30 000)(0.5) + 40 000)(*P/A*,0.1,10)

So the total after-tax present worth of the project is:
–1 000 000 – 500 000(1–0.357) + ((2 500 000 – 40 000 – 50 × 30 000)(0.5) + 40 000)(*P/A*,0.1,10)

This is calculated on the accompanying spreadsheet, **11S_2.xls**, and graphed in the chart below:



We see from this chart that the two most sensitive parameters are sales and labour costs; a small reduction in the sales volume could make the project unprofitable. It would be advisable to do further research on these two parameters before investing.

11S.3

We can solve the first part of this question by looking at a single year, since the cash flows are the same every year. Before the advertising campaign, Piet's net income from pie sales is R 20 000 per month. To pay for the advertising campaign, he must pay an additional amount *A* per month, such that
10 000 = *A* (*P/A*,1%,12)

Referring to Table 3A.1 in the text, we see that this is equivalent to

$$10\,000 = A\,\frac{e^{rN}-1}{(e^{r}-1)e^{rN}}$$

$$= A\frac{e^{0.01(12)}-1}{(e^{0.01}-1)e^{0.01(12)}}$$

$$= 11.25\,A$$

So *A* = 10 000/11.25 = R 889 per month, which is a 4.4% increase in sales.

To replace his oven, Piet needs to put aside an amount B every month, such that

$$800\ 000 = B\frac{e^{0.005(60)}-1}{(e^{0.005}-1)e^{0.005(60)}}$$
$$= 51.7\ B$$

So B = 800 000 / 51.7 = R 15 473 per month, which is a 77% increase in sales.

So if the advertising campaign is to pay both its own costs and the costs of replacing Piet's ovens, it will have to increase sales by at least 81.4%.

11S.4

We first build up a table (see the accompanying spreadsheet, **11S_4.xls**) showing the present cost, in thousands of yuan per 10 000 firecrackers of producing various numbers of firecrackers and storing them for up to three years. (Since even in the case of maximum production and minimum demand, the last firecracker will be sold after three years.) We see at once that it is not worth making only 10 000 firecrackers, since each will cost more than the present value of the selling price. We next work out the difference between the present value of manufacturing plus storage costs, and the present value of the selling price, for firecrackers sold in years one, two and three, labelling these as "Profit1," "Profit2," and "Profit3," respectively, and remembering that the income from sales in year N must be brought back to its present value by dividing by the factor (P/F,0.2,N).

Now we build a second table calculating the total profit for each production volume, considering six possible cases of annual demand: 25 000, 30 000, 35 000, 40 000, 45 000 and 50 000. We assume that any fireworks not sold in a given year are stored till the next year.

So the general expression for profit is:

If (Total_made < Annual _Demand) then (total made × Profit1);
otherwise, (If Total_made < 2 × Annual_Demand) then
(Annual_Demand × Profit1)
+ (Total_made – Annual_Demand) × profit2
otherwise, (Annual_Demand × Profit1
+ Annual_Demand × Profit2
+ (Total_made – 2 × Annual_Demand) × Profit3)

Demand :	2.5	3.0	3.5	4.0	4.5	5.0	Average
Total Made							
2	–200	–200	–200	–200	–200	–200	–200
3	167	300	300	300	300	300	278
4	300	433	567	700	700	700	567
5	433	567	700	833	967	1100	767
6	344	700	833	967	1100	1233	863
7	256	611	967	1100	1233	1367	922

The table shows the present value, in thousands of yuan, for each level of production under each of the six possible scenarios for demand (production and demand being in tens of thousands of firecrackers). From this table we see that it *is* worth investing in the factory, since we can choose a production level that will have a positive present worth for each possible demand scenario. We also see that our production level should be at least 50 000 firecrackers per year, since this dominates all lower levels of production.

Which production level should we choose? The highest level of production, 70 000 firecrackers per year, has the highest present value averaged across all scenarios, and it is only for the two lowest-demand scenarios that lower production levels are more profitable. So without further information, this is probably the level we choose.

If we knew that the actual demand was going to be for 25 000 firecrackers per year, we would set our production level at 50 000 and increase our present value by 元177 000. So this is an upper bound on what it would be worth paying for a market study.

11S.5

***N* = 3**

Examining the cases listed above in order, Strategy 1 scores (1, 1, 2, 2, 3, 3), for an average present worth of 2. To compare this with other values of *N*, it is useful to normalize by dividing by the average value of the present worths, which is also 2.

So Strategy 1 has a normalized present worth of 1.0.

Strategy 2 scores (2, 3, 3, 3, 2, 1) for an average present value of 2.333, normalized to 1.15.

Strategy 3 scores (3, 2, 5, 1, 2, 1) for an average present value of 2, normalized to 1.0.

Strategy 4 is the same as Strategy 2 if we round *N*/2 down, the same as Strategy 3 if we round up.

***N* = 4**
Giving normalized values, Strategy 1 scores 1.00, Strategy 2 scores 1.25, Strategy 3 scores 1.17.

Strategy 4 is the same as Strategy 3.

***N* = 5**
Strategy 1 scores 1.00, Strategy 2 scores 1.30, Strategy 3 scores 1.26.
Strategy 4 is the same as Strategy 3.

***N* = 6**
Strategy 1 scores 1.00, Strategy 2 scores 1.34, Strategy 3 scores 1.34, and
Strategy 4 scores 1.26.

We tentatively conclude that Strategy 2 gives the best results for small values of *N,* and its superiority to simply picking the first opportunity that comes along seems to increase as *N* increases. This strategy may be useful in a range of circumstances beyond economics, for example, selecting a spouse from a series of potential candidates. However, the authors can accept no responsibility for the consequences of its use for this purpose.

Here is a computer program, written in C, that can be used for testing the strategies:

```
#include <math.h>

#include <stdio.h>

main()

{

       int   i, j, k,l,m,  N;

        int   sequence2[3][3], sequence3[7][4],
     sequence4[25][5],sequence5[121][6];

        int   sequence6[721][7], fact[7];
```

```
        int   strategy1[721], strategy2[721], strategy3[721],
strategy4[721];

        int   strategy2Best, strategy3Best,strategy4Best;

        int   flag1, flag2, flag3, flag4, flag5, flag6;

        float sumOne, sumTwo,sumThree,sumFour;


        fact[2] = 2;

        fact[3] = fact[2] * 3;

        fact[4] = fact[3] * 4;

        fact[5] = fact[4] * 5;

        fact[6] = fact[5] * 6;


        N = 6;


      sequence2[1][1] = 1;

      sequence2[1][2] = 2;

      sequence2[2][1] = 2;

      sequence2[2][2] = 1;


/* Generate the sequences of length 3, using Knuth's algorithm  */


  k = 0;

    for (i=1; i<= fact[2]; i++)

      {

         for  (j=1; j<= 3; j++)

            {

               l = 1;
```

```
            for (m=1; m<= 3; m++)
              {
                 if (m==j) sequence3[k+j][m] = 3;
                 else
                   {
                     sequence3[k+j][m]=sequence2[i][l];
                     l++
                   }
              }
        }
       k = k+3;
      }
   }
```

```
/* Next generate the sequences of length 4 */

   k = 0;
   for (i=1; i<= fact[3]; i++)
      {
         for  (j=1; j<= 4; j++)
         {
           l = 1;
           for (m=1; m<= 4; m++)
```

```
            {
               if (m==j) sequence4[k+j][m] = 4;
               else
                 {
                    sequence4[k+j][m] =sequence3[i][l];
                    l++;
                 }
            }
        }
        k = k+4;
      }

/* And the sequences of length 5 */

    k = 0;
    for (i=1; i<= fact[4]; i++)
       {
         for  (j=1; j<= 5; j++)
         {
            l = 1;
            for (m=1; m<= 5; m++)
                {
                   if (m==j) sequence5[k+j][m] = 5;
                   else
                      {
                         sequence5[k+j][m] =sequence4[i][l];
                         l++;
```

```
                    }
                }
            }
          k = k+5;
        }

/* Finally the sequences of length 6*/

        k = 0;
        for (i=1; i<= fact[5]; i++)
         {
           for  (j=1; j<= 6; j++)
             {
                l = 1;
                for (m=1; m<= 6; m++)
                  {
                     if (m==j) sequence6[k+j][m] = 6;
                     else
                        {
                           sequence6[k+j][m] =sequence5[i][l];
                           l++;
                        }
                  }
           }
          k = k+6;
        }
```

```
/*     Zero the scores for each of the strategies   */


        for (i=1; i<= fact[N]; i++)
              {
                  strategy1[i] = 0;
                  strategy2[i] = 0;
                  strategy3[i] = 0;
                  strategy4[i] = 0;
              }


/* Run each of the strategies on one of the sequences, in this case
the sequence of
   length 6  */


        for (i=1; i<= fact[N]; i++)
              {
                strategy1[i] = sequence6[i][1];
                strategy2Best = sequence6[i][1];
                strategy3Best = sequence6[i][1];
                if (sequence6[i][2] > strategy3Best) strategy3Best =
sequence6[i][2];
                strategy4Best = sequence6[i][1];
                if (sequence6[i][2] > strategy4Best) strategy4Best =
sequence6[i][2];
                if (sequence6[i][3] > strategy4Best) strategy4Best =
sequence6[i][3];


                for(j=1; j<= N; j++)
                  {
```

```
                    if (sequence6[i][j] >
strategy2Best)strategy2[i]=sequence6[i][j];

                    if (sequence6[i][j] >
strategy3Best)strategy3[i]=sequence6[i][j];

                    if (sequence6[i][j] >
strategy4Best)strategy4[i]=sequence6[i][j];

                 }

               if (strategy2[i] == 0)strategy2[i]=sequence6[i][N];

               if (strategy3[i] == 0)strategy3[i]=sequence6[i][N];

               if (strategy4[i] == 0)strategy4[i]=sequence6[i][N];

             }


/* The strategies have selected their candidates, now we calculate
their scores */


        sumOne = 0.0;

        sumTwo = 0.0;

        sumThree = 0.0;

        sumFour = 0.0;


        for (i=1; i<= fact[N]; i++)

               {

                  sumOne += strategy1[i];

                  sumTwo += strategy2[i];

                  sumThree += strategy3[i];

                  sumFour += strategy4[i];

               }

        sumOne = sumOne/fact[N];

        sumTwo = sumTwo/fact[N];
```

```
        sumThree = sumThree/fact[N];

        sumFour = sumFour/fact[N];

       printf("sumOne   =   %f,   sumTwo   =   %f,   sumThree   =   %f,
sumFour%f\n",sumOne,sumTwo,sumThree,

 sumFour);

}
```