8 Resource Allocation

Learning Objectives

- Identify the resources required for a project
- Make the demand for resources more even throughout the life of a project
- Produce a work plan and resource schedule

8.1 Introduction

In Chapter 6, we saw how to use activity network analysis techniques to plan *when* activities should take place. This was calculated as a time span during which an activity should take place – bounded by the earliest start and latest finish dates. In Chapter 7, we used the PERT technique to forecast a range of expected dates by which activities would be completed. In both cases these plans took no account of the availability of resources.

In this chapter, we shall see how to match the activity plan to available resources and, where necessary, assess the efficacy of changing the plan to fit the resources. Figure 8.1 shows where resource allocation is applied in Step Wise.

In general, the allocation of resources to activities will lead us to review and modify the ideal activity plan. It may cause us to revise stage or project completion dates. In any event, it is likely to lead to a narrowing of the time spans within which activities may be scheduled.

The final result of resource allocation will normally be a number of schedules, including:

These schedules will provide the basis for the day-to-day control and management of the project. These are described in Chapter 9.

- an *activity schedule* indicating the planned start and completion dates for each activity;

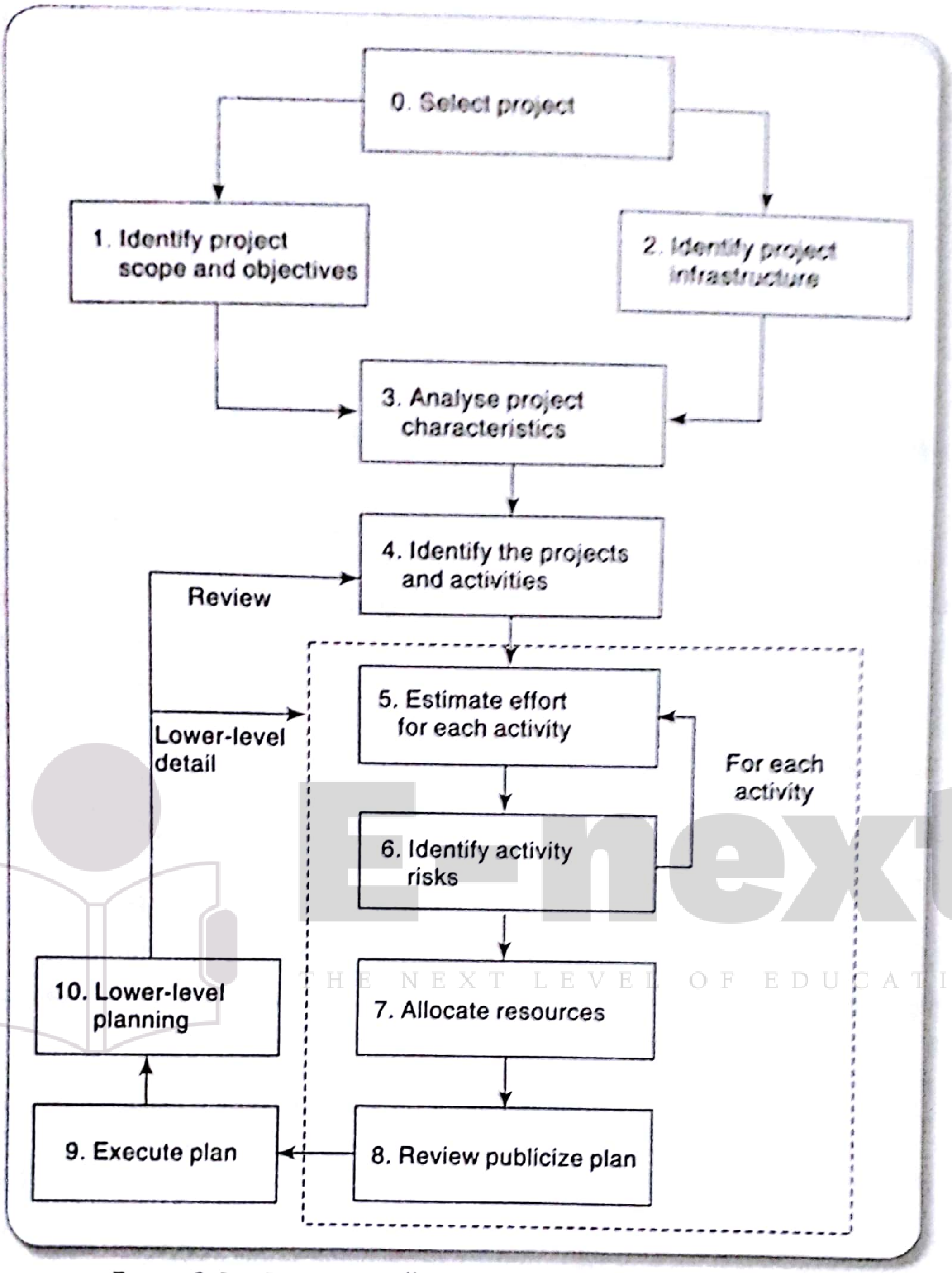

FIGURE 8.1 Resource allocation is carried out as Step 7

- a *resource schedule* showing the dates on which each resource will be required and the level of that requirement;
- a *cost schedule* showing the planned cumulative expenditure incurred by the use of resources over time.

8.2 Nature of Resources

A resource is any item or person required for the execution of the project. This covers many things – from paper clips to key personnel – and it is unlikely that we would wish to itemize every resource required, let alone draw up a schedule for their use. Stationery and other standard office supplies, for example, need not normally be the concern of the project manager – ensuring an adequate supply is the role of the office manager. The project manager must concentrate on those resources which, without planning, might not be available when required.

Some resources, such as a project manager, will be required for the duration of the project whereas others, such as a specific software developer, might be required for a single activity. The former, while vital to the success of the project, does not require the same level of scheduling as the latter. As we saw in Chapter 2, a project manager may not have unrestricted control over a developer who may be needed to work on a range of projects. The manager may have to request the use of a developer who belongs to a pool of resources controlled at programme level.

In general, resources will fall into one of seven categories.

- *Labour* The main items in this category will be members of the development project team such as the project manager, systems analysts and software developers. Equally important will be the quality assurance team and other support staff and any employees of the client organization who might be required to undertake or participate in specific activities.
- *Equipment* Obvious items will include workstations and other computing and office equipment. We must not forget that staff also need basic equipment such as desks and chairs.
- *Materials* Materials are items that are consumed, rather than equipment that is used. They are of little consequence in most software projects but can be important for some – software that is to be widely distributed might, for example, require supplies of disks to be specially obtained.
- *Space* For projects that are undertaken with existing staff, space is normally readily available. If any additional staff (recruited or contracted) should be needed then office space will need to be found.
- *Services* Some projects will require procurement of specialist services – development of a wide area distributed system, for example, requires scheduling of telecommunications services.
- *Time* Time is the resource that is being offset against the other primary resources – project timescales can sometimes be reduced by increasing other resources and will almost certainly be extended if they are unexpectedly reduced.
- *Money* Money is a secondary resource – it is used to buy other resources and will be consumed as other resources are used. It is similar to other resources in that it is available at a cost – in this case interest charges.

The cost of money as a resource is a factor taken into account in DCF evaluation.

8.3 Identifying Resource Requirements

The first step in producing a resource allocation plan is to list the resources that will be required along with the expected level of demand. This will normally be done by considering each activity in turn and identifying the resources required. It is likely, however, that there will also be resources required that are not activity specific but are part of the project's infrastructure (such as the project manager) or required to support other resources (office space, for example, might be required to house contract software developers).

Case Study — Examples

Amanda has produced a precedence network for the IOE project (Figure 8.2) and used this as a basis for a resource requirements list, part of which is shown in Table 8.1.

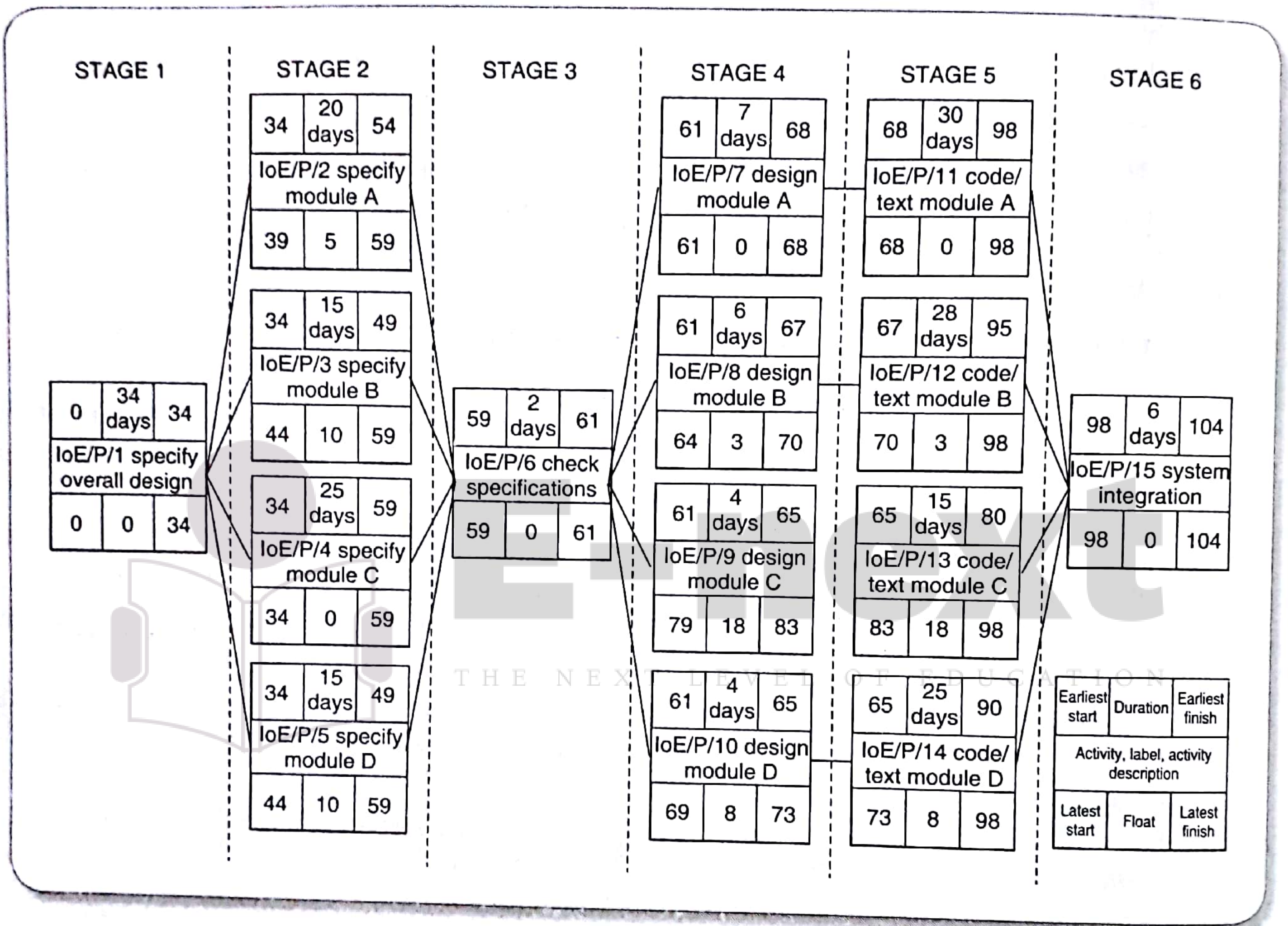

FIGURE 8.2 Amanda's IOE precedence network

Notice that, at this stage, she has not allocated individuals to tasks but has decided on the type of staff that will be required. The activity durations assume that they will be carried out by 'standard' analysts or software developers.

TABLE 8.1 Part of Amanda's resource requirements list

Stage	Activity	Resource	Days	Quantity	Notes
ALL	Project manager		104 F/T		
1	All	Workstation	–	34	Check software availability

(Contd.)

	IoE/P/1	Senior analyst	34 F/T		
2	All	Workstation	–	3	One per person essential
	IoE/P/2	Analyst/designer	20 F/T		
	IoE/P/3	Analyst/designer	15 F/T		
	IoE/P/4	Analyst/designer	25 F/T		
	IoE/P/5	Analyst/designer	15 F/T		Could use analyst/ programmer
3	All	Workstation	–	2	
	IoE/P/6	Senior analyst*	2 F/T		
4	All	Workstation	–	3	As stage 2
	IoE/P/7	Analyst/designer	7 F/T		
	IoE/P/8	Analyst/designer	6 F/T		
	IoE/P/9	Analyst/designer	4 F/T		
	IoE/P/10	Analyst/designer	4 F/T		
5	All	Workstation	–	4	One per programmer
	All	Office space	–		If contract programmers used
	IoE/P/11	Programmer	30 F/T		
	IoE/P/12	Programmer	28 F/T		
	IoE/P/13	Programmer	15 F/T		
	IoE/P/14	Programmer	25 F/T		
6	All	Full system access	–		Approx. 16 hours for full system test
	IoE/P/15	Analyst/designer	6 F/T		

* In reality, this would normally be done by a review involving all the analysts working on stage 2.

At this stage, it is necessary that the resource requirements list be as comprehensive as possible – it is better that something is included that may later be deleted as unnecessary than to omit something essential. Amanda has therefore included additional office space as a possible requirement, should contract software development staff be recruited.

8.4 Scheduling Resources

Note that in Section 7.12 an argument for starting activities as late as possible was presented. The resource allocation process is similar regardless of the policy adopted in this respect.

White rectangles indicate when an activity is scheduled and shaded rectangles the total float.

Having produced the resource requirements list, the next stage is to map this on to the activity plan to assess the distribution of resources required over the duration of the project. This is best done by representing the activity plan as a bar chart and using this to produce a resource histogram for each resource.

Figure 8.3 illustrates Amanda's activity plan as a bar chart and a resource histogram for analyst/designers. Each activity has been scheduled to start at its earliest start date – a sensible initial strategy, since we would, other things being equal, wish to save any float to allow for contingencies. Earliest start date scheduling, as is the case with Amanda's project, frequently creates resource histograms that start with a peak and then tail off.

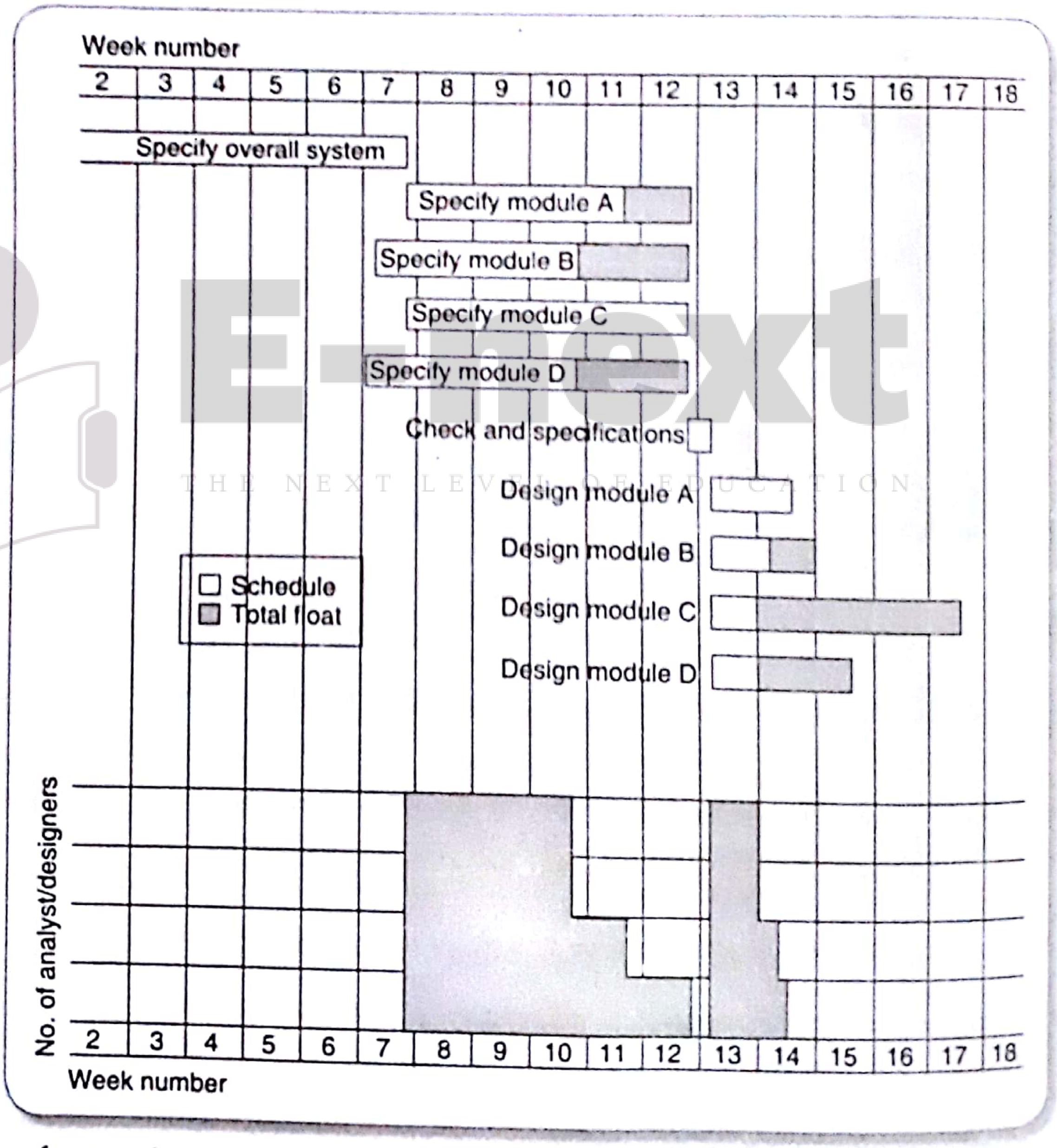

FIGURE 8.3 Part of Amanda's bar chart and resource histogram for analyst/designers

Changing the level of resources on a project over time, particularly personnel, generally adds to the cost of a project. Recruiting staff has costs and, even where staff are transferred internally, time will be needed for familiarization with the new project environment.

The resource histogram in Figure 8.3 poses particular problems in that it calls for two analyst/designers to be idle for twelve days, one for seven days and one for two days between the specification and design stage. It is unlikely that IOE would have another project requiring their skills for exactly those periods of time. This raises the question whether this idle time should be charged to Amanda's project. The ideal resource histogram will be smooth with, perhaps, an initial build-up and a staged run-down.

An additional problem with an uneven resource histogram is that it is more likely to call for levels of resource beyond those available. Figure 8.4 illustrates how, by adjusting the start date of some activities and splitting others, a resource histogram can, subject to constraints such as precedence requirements, be smoothed to contain resource demand at available levels. The different letters represent staff working on a series of module testing tasks, that is, one person working on task A, two on tasks B and C etc.

In Figure 8.4, the original histogram was created by scheduling the activities at their earliest start dates. The resource histogram shows the typical peaked shape caused by earliest start date scheduling and calls for a total of nine staff where only five are available for the project.

By delaying the start of some of the activities, it has been possible to smooth the histogram and reduce the maximum level of demand for the resource. Notice that some activities, such as C and D, have been split. Where non-critical activities can be split they can provide a useful way of filling troughs in the demand for a resource, but in software projects it is difficult to split tasks without increasing the time they take.

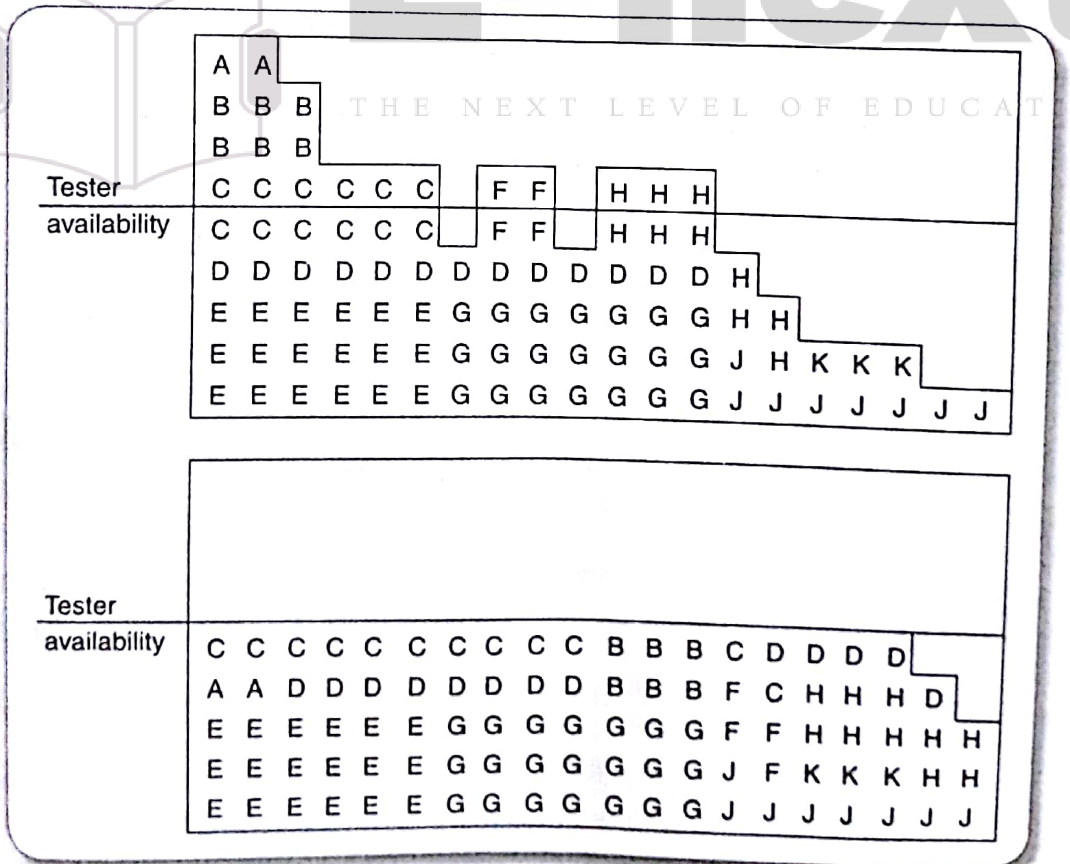

FIGURE 8.4 A resource histogram showing demand for staff before and after smoothing

Some of the activities call for more than one unit of the resource at a time – activity F, for example, requires two programmers, each working for two weeks. It might be possible to reschedule this activity to use one programmer over four weeks, although that has not been considered in this case.

Some project planning software tools will carry out resource smoothing automatically, although they are unlikely to take into account all the factors that could be used by a project manager. The majority of project planning software tools will produce resource histograms based on earliest activity start dates.

Exercise 8.1

Amanda has already decided to use only three analyst/designers on the project in order to reduce costs. Her current resource histogram, however, calls for four during both stage 2 and stage 4. Suggest what she might do to smooth the histogram and reduce the number of analyst/designers required to three.

In practice, resources have to be allocated to a project on an activity-by-activity basis and finding the 'best' allocation can be time consuming and difficult. As soon as a member of the project team is allocated to an activity, that activity acquires a scheduled start and finish date and the team member becomes unavailable for other activities for that period. Thus, allocating a resource to one activity limits the flexibility for resource allocation and scheduling of other activities.

There are some exceptional cases where it is better to favour a small non-critical activity if a number of large activities are dependent upon it.

It is therefore helpful to prioritize activities so that resources can be allocated to competing activities in some rational order. The priority must almost always be to allocate resources to critical path activities and then to those activities that are most likely to affect others. In that way, lower-priority activities are made to fit around the more critical, already scheduled activities.

Of the various ways of prioritizing activities, two are described below.

- *Total float priority* Activities are ordered according to their total float, those with the smallest total float having the highest priority. In the simplest application of this method, activities are allocated resources in ascending order of total float. However, as scheduling proceeds, activities will be delayed (if resources are not available at their earliest start dates) and total floats will be reduced. It is therefore desirable to recalculate floats (and hence reorder the list) each time an activity is delayed.

Exercise 8.2

Amanda considers whether, with only three analyst/designers, the specification of module D (see Figure 8.3) will have to be deferred until after the specification of module B. This will add five days to the overall project duration (making 109 in total). She had hoped to have the project completed within 100 days and this is a further disappointment. She therefore decides to have another look at her activity plan.

You will remember that early on she decided that she should check all of the specifications together (activity IoE/P/6) before allowing design to start. It is now apparent that this is causing a significant bottleneck and delaying module D will only exacerbate the problem. She therefore decides on a compromise – she will check the specifications for modules A, B and D together but will then go ahead with their design without waiting for the module C specification. This will be checked against the others when it is complete.

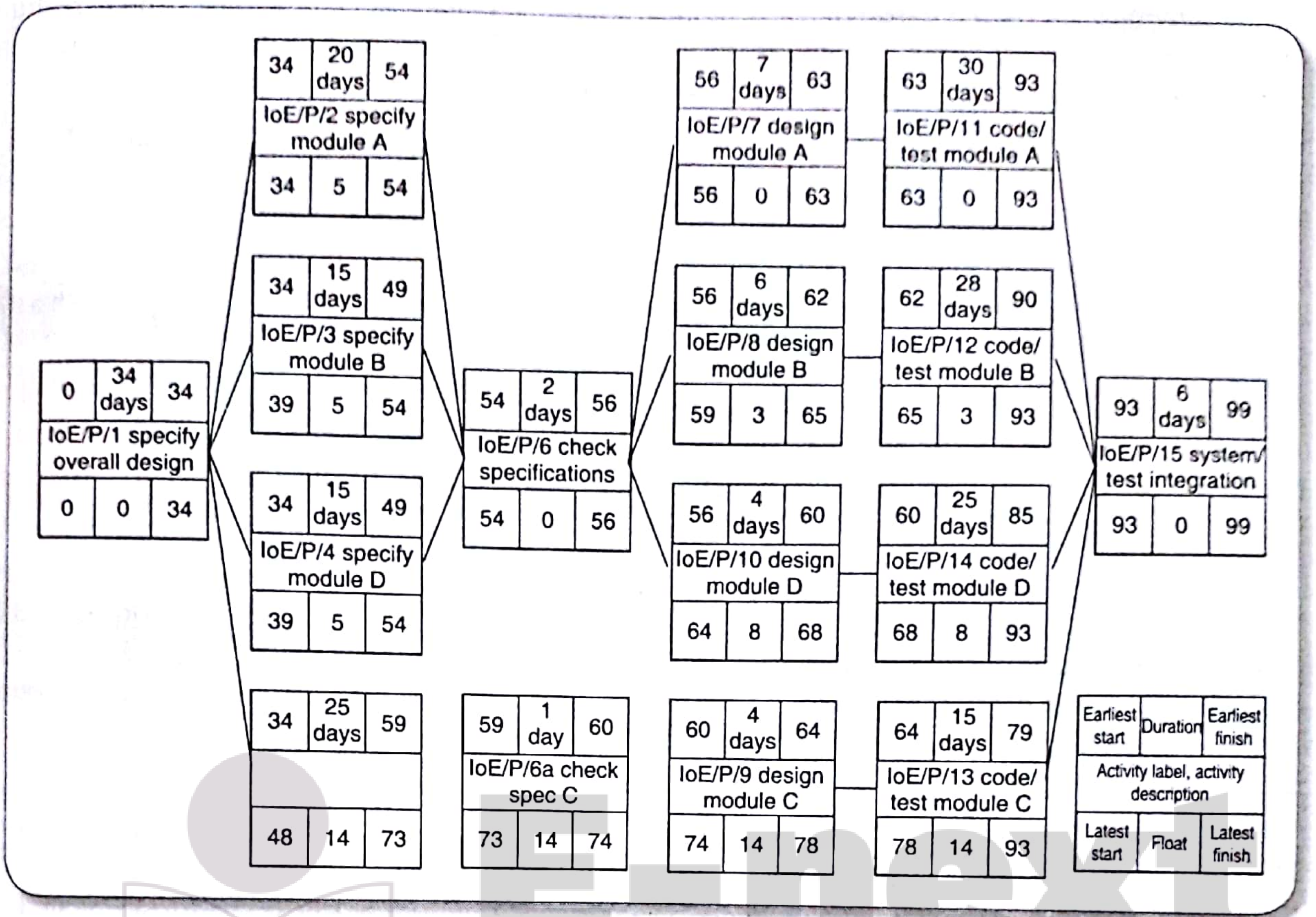

FIGURE 8.5 Amanda's revised precedence network

She redraws her precedence network to reflect this, inserting the new activity of checking the module C specification against the others (activity IoE/P/6a). This is shown in Figure 8.5. Draw a new resource histogram to reflect this change.

- *Ordered list priority* With this method, activities that can proceed at the same time are ordered according to a set of simple criteria. An example of this is Burman's priority list, which takes into account activity duration as well as total float:

  1. Shortest critical activity
  2. Critical activities
  3. Shortest non-critical activity
  4. Non-critical activity with least float
  5. Non-critical activities

P. J. Burman (1972) *Precedence Networks for Planning and Control*, McGraw-Hill.

Unfortunately, resource smoothing, or even containment of resource demand to available levels, is not always possible within planned timescales – deferring activities to smooth out resource peaks often puts back project completion. Where that is the case, we need to consider ways of increasing the available resource levels or altering working methods.

8.5 Creating Critical Paths

Scheduling resources can create new critical paths. Delaying the start of an activity because of lack of resources will cause that activity to become critical if this uses up its float. Furthermore, a delay in completing one activity can delay the availability of a resource required for a later activity. If the later one is already critical then the earlier one might now have been made critical by linking their resources.

Amanda's revised schedule, which still calls for four analyst/designers but only for a single day, is illustrated in the solution to Exercise 8.2 (check it in the back of the book if you have not done so already). Notice that in rescheduling some of the activities she has introduced additional critical activities. Delaying the specification of module C has used up all of its float – and that of the subsequent activities along that path! Amanda now has two critical paths – the one shown on the precedence network and the new one.

In a large project, resource-linked criticalities can be quite complex – a hint of the potential problems may be appreciated by looking at the next exercise.

Exercise 8.3

Amanda decides to delay the specification of module C for a further day to ensure that only three analyst/designers will be required. The relevant part of her revised bar chart and resource histogram are shown in Figure 8.6.

Which activities will now be critical?

8.6 Counting the Cost

The discussion so far has concentrated on trying to complete the project by the earliest completion date with the minimum number of staff. We have seen that doing this places constraints on when activities can be carried out and increases the risk of not meeting target dates.

Alternatively, Amanda could have considered using additional staff or lengthening the overall duration of the project. The additional costs of employing extra staff would need to be compared to the costs of delayed delivery and the increased risk of not meeting the scheduled date. The relationship between these factors is discussed later in this chapter.

8.7 Being Specific

Allocating resources and smoothing resource histograms is relatively straightforward where all resources of a given type can be considered more or less equivalent. When allocating labourers to activities in a large building project we need not distinguish among individuals – there are likely to be many labourers and they may be treated as equals so far as skills and productivity are concerned.

This is seldom the case with software projects. We saw in Chapter 5 that, because of the nature of software development, skill and experience play a significant part in determining the time taken and, potentially, the quality of the final product. With the exception of extremely large projects, it makes sense to allocate individual members of staff to activities as early as possible, as this can lead us to revise our estimate of their duration.

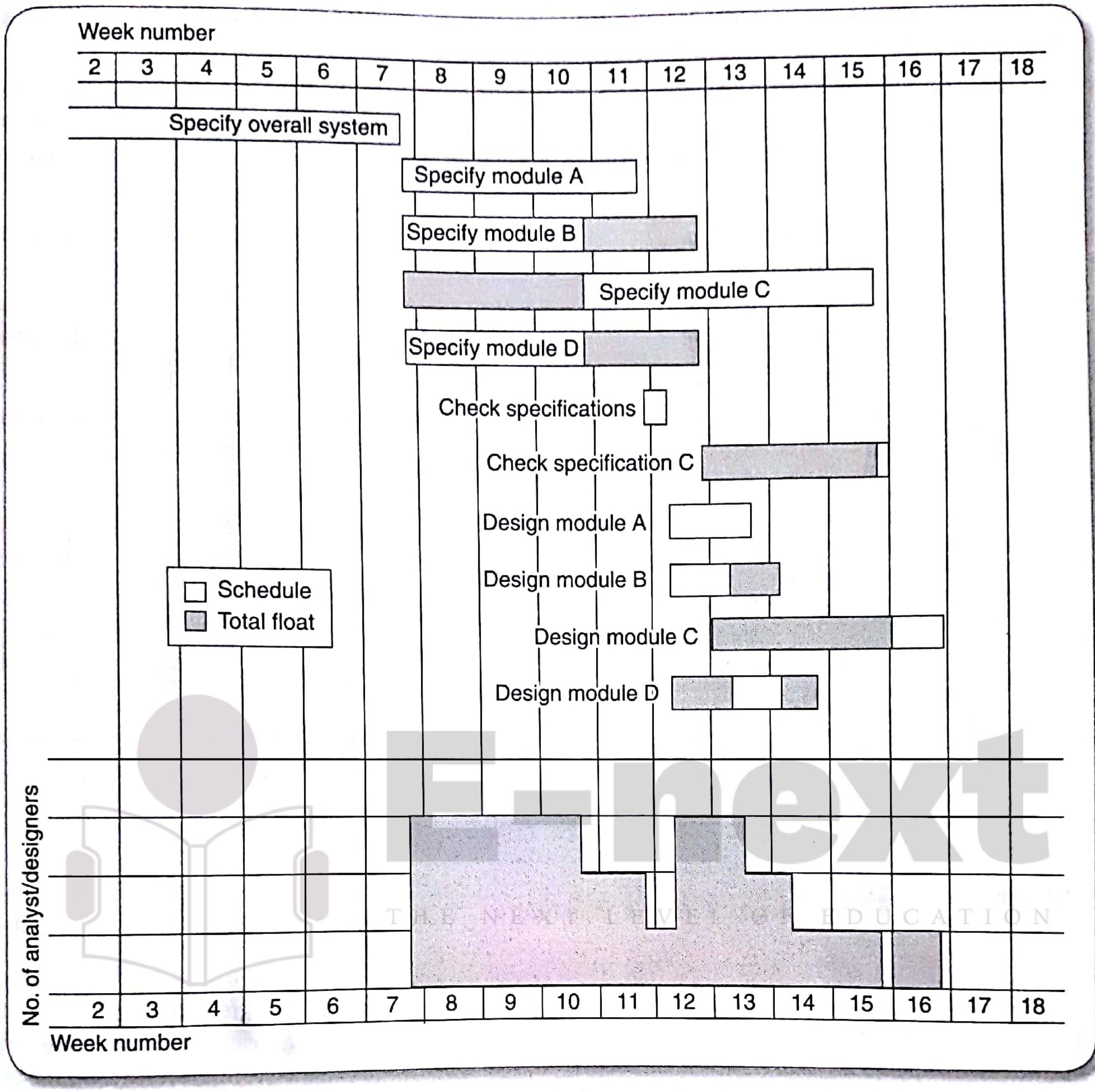

FIGURE 8.6 Amanda's project scheduled to require three analyst/designers

In allocating individuals to tasks, a number of factors need to be taken into account.

- *Availability* We need to know whether a particular individual will be available when required. Reference to the departmental work plan determines this but the wise project manager will always investigate the risks that might be involved – earlier projects might, for example, overrun and affect the availability of an individual.
- *Criticality* Allocation of more experienced personnel to activities on the critical path often helps in shortening project durations or at least reduces the risk of overrun.

Reappraisal of the critical path and PERT or Monte Carlo risk analysis might need to be carried out in parallel with staff allocation.

- *Risk* We saw how to undertake activity risk assessment in the previous chapter. Identifying those activities posing the greatest risk, and knowing the factors influencing them, helps to allocate staff. Allocating the most experienced staff to the highest-risk activities is likely to have the greatest effect in reducing overall project uncertainties. More experienced staff are, however, usually more expensive.

- *Training* It will benefit the organization if positive steps are taken to allocate junior staff to appropriate non-critical activities where there will be sufficient slack for them to train and develop skills. There can even be direct benefits to the particular project since some costs may be allocated to the training budget.
- *Team building* The selection of individuals must also take account of the final shape of the project team and the way they will work together. This and additional aspects of team management are discussed in Chapter 12.

Exercise 8.4

Amanda has decided that, where possible, whoever writes the specification for a module should also produce the design, as she believes this will improve the commitment and motivation of the three analyst/designers, Belinda, Tom and Daisy.

'Span' in this context is the period of time between the earliest start for an activity and its latest finish.

She has decided that she will use Tom, a trainee analyst/designer, for the specification and design of module D as both of these activities have a large float compared to their activity span (6/21 and 9/13 of their span respectively). Since the specification and design of module C are on the critical path, she decides to allocate both of these tasks to Belinda, a particularly experienced and capable member of staff.

Having made these decisions, she has almost no flexibility in how she assigns the other specification and design activities. Work out from the activity bar chart produced as part of the solution to Exercise 8.2 (shown in Figure 8.6) whom she assigns to which of the remaining specification and design activities.

8.8 Publishing the Resource Schedule

In allocating and scheduling resources we have used the activity plan (a precedence network in the case of the examples in this chapter), activity bar charts and resource histograms. Although good as planning tools, they are not the best way of publishing and communicating project schedules. For this we need some form of work plan. Work plans are commonly published as either lists or charts such as that illustrated in Figure 8.7. In this case, Amanda has chosen not to include activity floats (which could be indicated by shaded bars) as she fears that one or two members of the team might work with less urgency if they are aware that their activities are not critical.

Notice that, somewhat unusually, it is assumed that there are no public holidays or other non-productive periods during the 100 days of the project and that none of the team has holidays for the periods they are shown as working.

Amanda has also made no explicit allowance for staff taking sick leave.

Amanda now transfers some of the information from the work schedule to her precedence network. In particular, she amends the earliest start dates for activities and any other constraints (such as revised latest finish dates where resources need to be made available) that have been introduced. A copy of her revised precedence network is shown in Figure 8.8 – notice that she has highlighted all critical activities and paths.

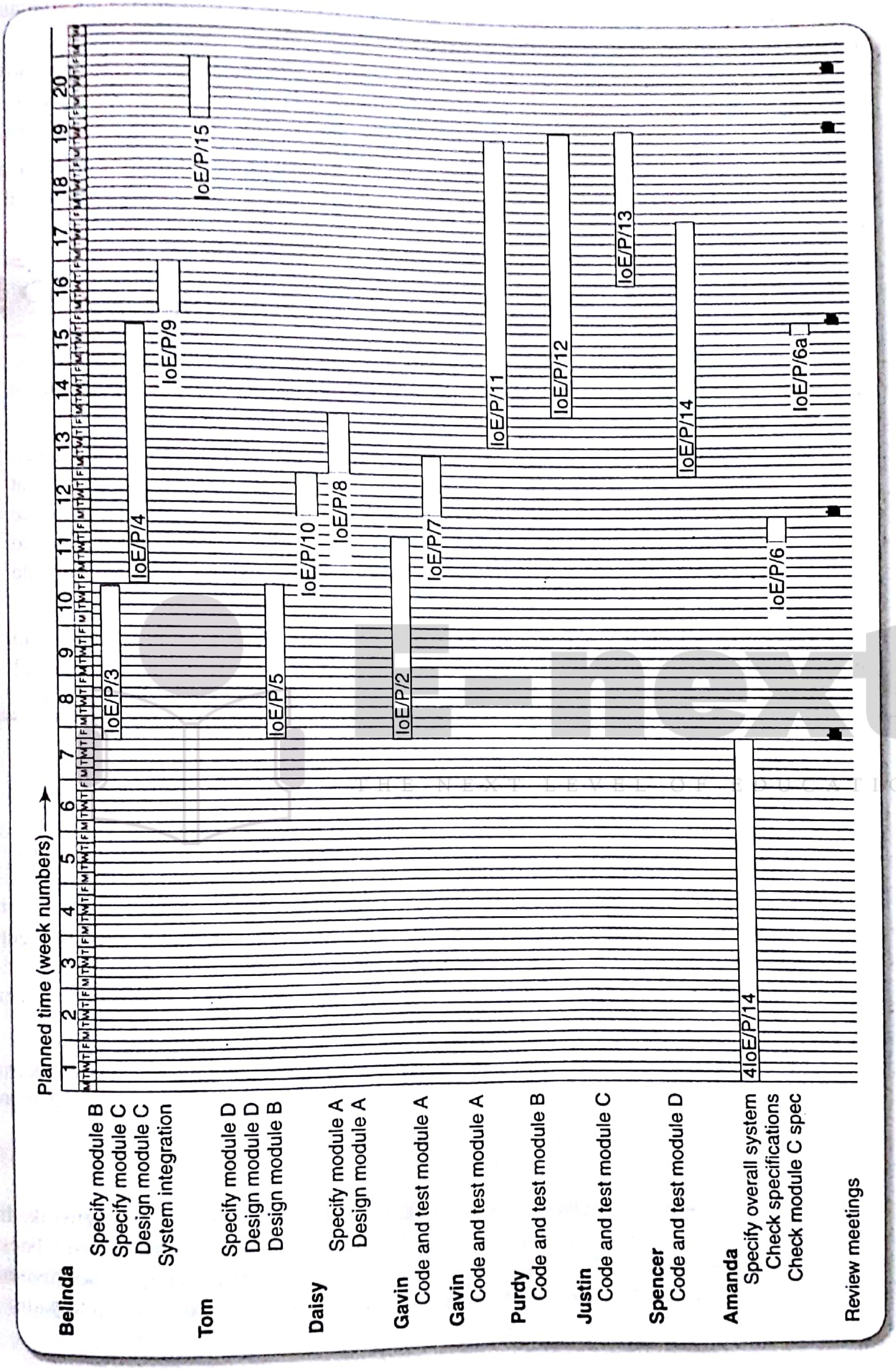

FIGURE 8.7 Amanda's work schedule

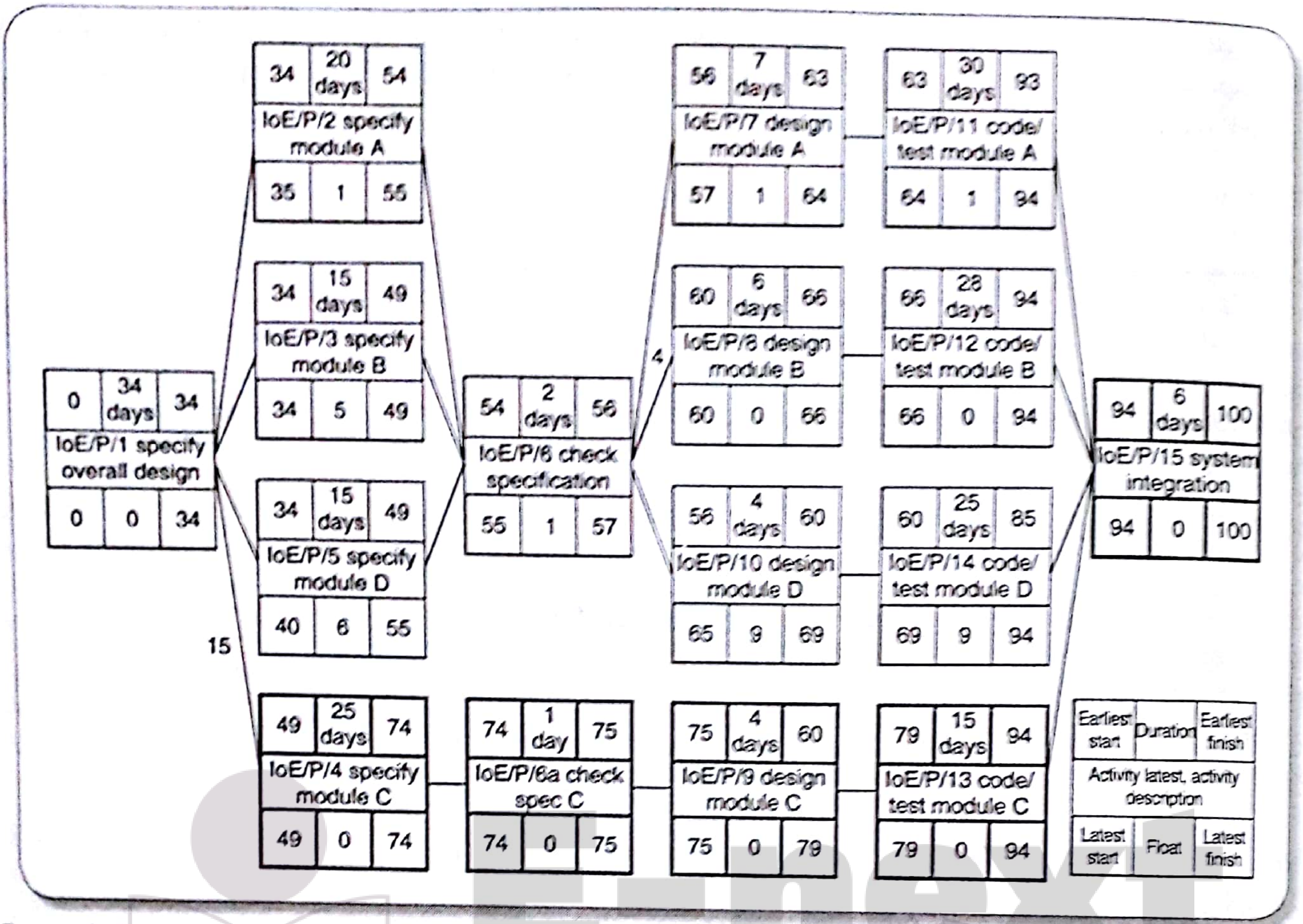

FIGURE 8.8 Amanda's revised precedence network showing scheduled start and completion dates

8.9 Cost Schedules

It is now time to produce a detailed cost schedule showing weekly or monthly costs over the life of the project. This will provide a more detailed and accurate estimate of costs and will serve as a plan against which project progress can be monitored.

Calculating cost is straightforward where the organization has standard cost figures for staff and other resources. Where this is not the case, then the project manager will have to calculate the costs.

In general, costs are categorized as follows:

- *Staff costs* These will include staff salaries as well as the other direct costs of employment such as the employer's contribution to social security funds, pension scheme contributions, holiday pay and sickness benefit. These are commonly charged to projects at hourly rates based on weekly work records completed by staff. Note that contract staff are usually charged by the week or month – even when they are idle.
- *Overheads* Overheads represent expenditure that an organization incurs, which cannot be directly related to individual projects or jobs, including space rental, interest charges and the costs of service departments (such as human resources). Overhead costs can be recovered by making a fixed charge on development departments (in which case they usually appear as a weekly or monthly charge for a project), or by an additional percentage charge on direct staff employment costs. These additional charges or on-costs can easily equal or exceed the direct employment costs.

- *Usage charges* In some organizations, projects are charged directly for use of resources such as computer time (rather than their cost being recovered as an overhead). This will normally be on an 'as used' basis.

Exercise 8.5

Amanda finds that IOE recovers some overheads as on-costs on direct staff costs, although others are recovered by charging a fixed £200 per day against projects. Staff costs (including overheads) are as shown in Table 8.2. Amanda has been working as project leader on the project for its duration. She also estimates that, in total, she will have spent an additional 10 days planning the project and carrying out the post-project review.

Calculate the total cost for Amanda's project on this basis. How is the expenditure spread over the life of the project?

Table 8.2 Staff costs (including on-costs) for Amanda's project team

Staff member	Daily cost (£)
Amanda	300
Belinda	250
Tom	175
Daisy	225
Gavin	150
Purdy	150
Justin	150
Spencer	150

Figure 8.9 shows the weekly costs over the 20 weeks that Amanda expects the project to take. This is a typical cost profile – building up slowly to a peak and then tailing off quite rapidly at the end of the project. Figure 8.10 illustrates the cumulative cost of the project and it is generally this that would be used for cost control purposes.

8.10 Scheduling Sequence

Going from an ideal activity plan to a cost schedule can be represented as a sequence of steps, rather like the classic waterfall life-cycle model. In the ideal world, we would start with the activity plan and use this as the basis for our risk assessment. The activity plan and risk assessment would provide the basis for our resource allocation and schedule from which we would produce cost schedules.

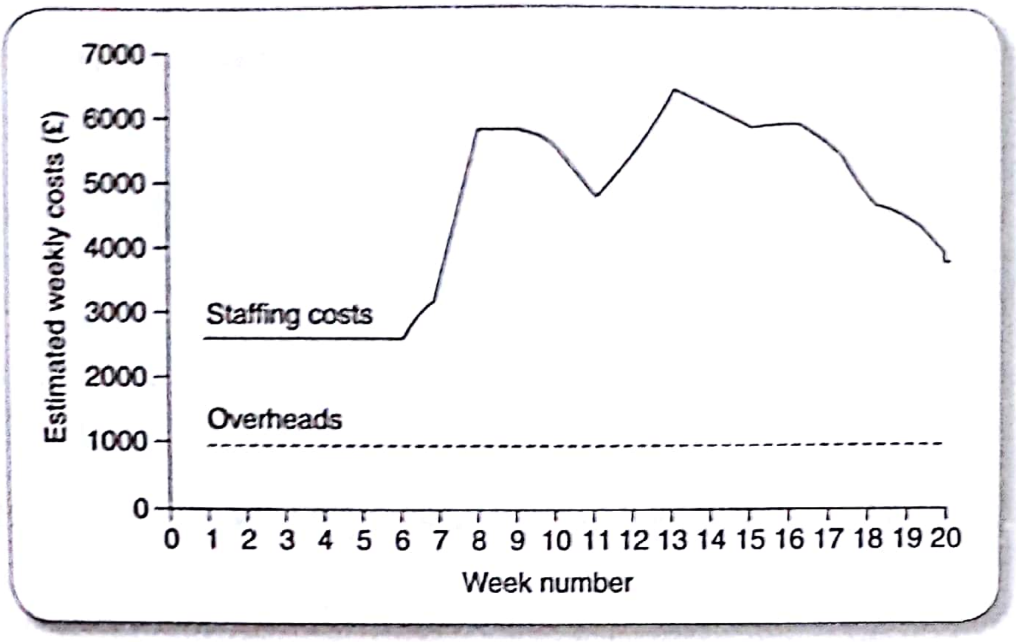

FIGURE 8.9 Weekly project costs for the IOE project

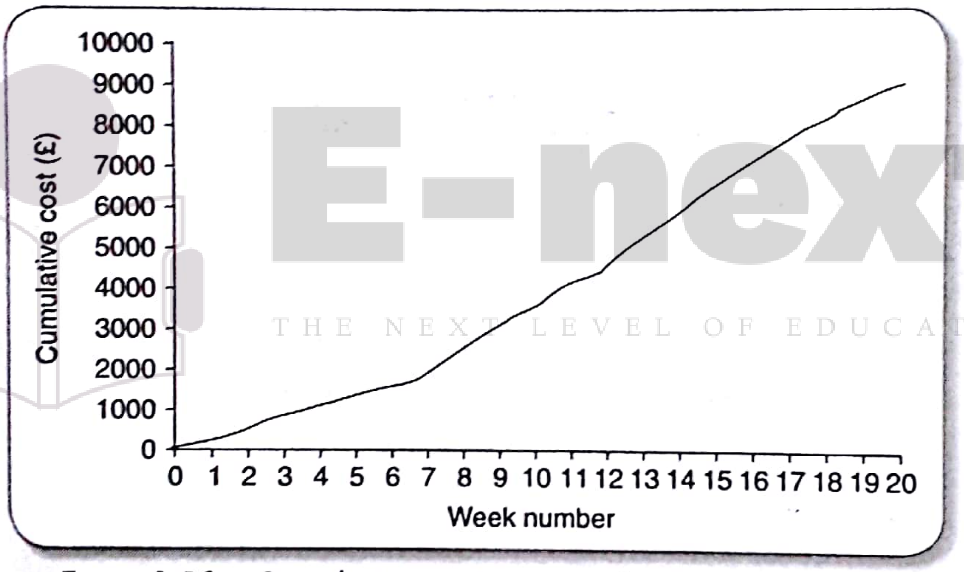

FIGURE 8.10 Cumulative project costs for the IOE project

In practice, as we have seen by looking at Amanda's project, successful resource allocation often necessitates revisions to the activity plan, which, in turn, will affect our risk assessment. Similarly, the cost schedule might indicate the need or desirability to reallocate resources or revise activity plans – particularly where that schedule indicates a higher overall project cost than originally anticipated.

The interplay between the plans and schedules is complex – any change to any one will affect each of the others. Some factors can be directly compared in terms of money – the cost of hiring additional staff can be balanced against the costs of delaying the project's end date. Some factors, however, are difficult to express in money terms (the cost of an increased risk, for example) and will include an element of subjectivity.

While good project planning software will assist greatly in demonstrating the consequences of change and keeping the planning synchronized, successful project scheduling is largely dependent upon the skill and experience of the project manager in juggling the many factors involved (Figure 8.11).

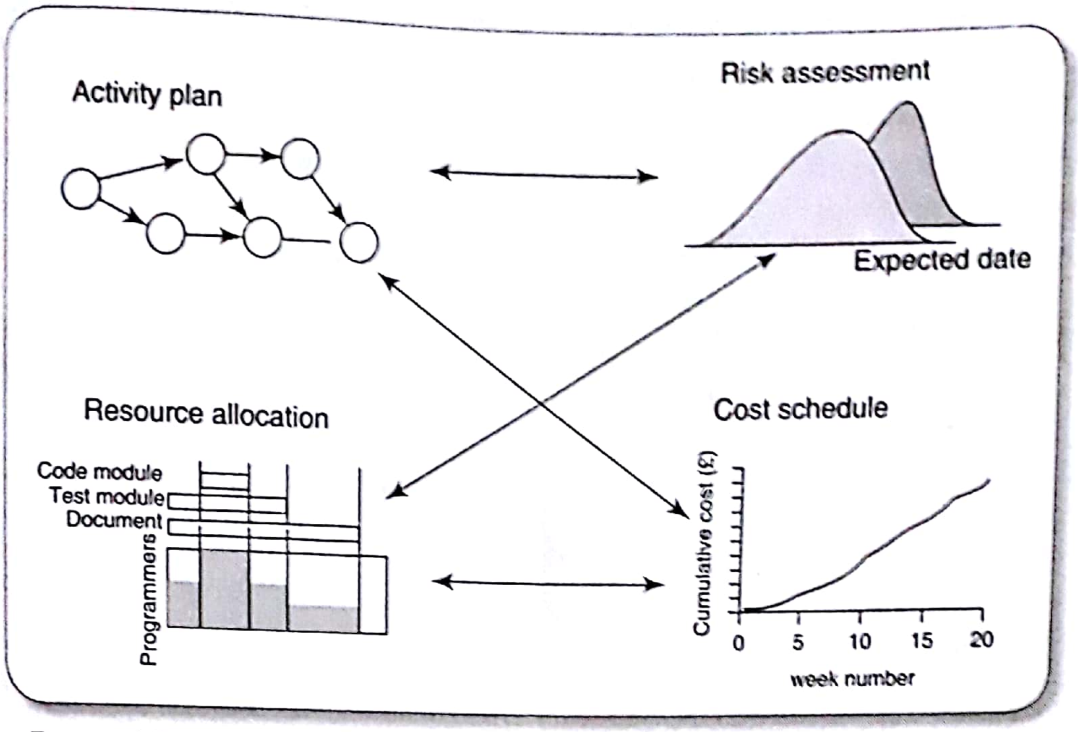

FIGURE 8.11 Successful project scheduling is not a simple sequence

Conclusion

In this chapter we have discussed the problems of allocating resources to project activities and the conversion of an activity plan to a work schedule. In particular, we have seen the importance of the following:

- Identifying all the resources needed
- Arranging activity starts to minimize variations in resource levels over the duration of the project
- Allocating resources to competing activities in a rational order of priority
- Taking care in allocating the right staff to critical activities

Further Exercises

1. Burman's priority ordering for allocating resources to activities takes into account the activity duration as well as its total float. Why do you think this is advantageous?
2. If you have access to project planning software, use it to produce an activity plan for Amanda's project and include the staff resource requirements for each activity.

   Explore the facilities of your software and answer the following questions.

   - Can you set up resource types and ask the application to allocate individuals to tasks?
   - Will your software allow you to specify productivity factors for individual members of staff so that the duration of an activity depends upon who is carrying it out?
   - Will your software carry out resource smoothing or provide a minimum cost solution?
   - Can you replicate Amanda's work schedule (see Figure 8.7) – or produce a better one?

3. On a large project, it is often the responsibility of a team leader to allocate tasks to individuals. Why might it be unsatisfactory to leave such allocations entirely to the discretion of the team leader?
4. In scheduling her project, Amanda ignored the risks of absence due to staff sickness. What might she have done to estimate the likelihood of this occurring and how might she have taken account of the risk when scheduling the project?
5. (a) Draw up an activity network and calculate the earliest finish for the following project:

Activity	Duration	Depends on	Resource type
A	3 days		SA
B	1 day	A	SD
C	2 days	A	SD
D	4 days	A	SD
E	3 days	B	SC
F	3 days	C	SC
G	6 days	D	SC
H	3 days	E, F, G	SA

SA = systems analyst; SD = systems designer; SC = software coder

   (b) Produce a table showing the number of specialists of each type needed on each day of the project if every activity was started as soon as possible. How many of each type of resource will need to be recruited for the project as a whole if the earliest finish date is to be preserved?

   (c) What impact would there be on the project if there were only two systems designers?

   (d) What impact would there be on the project if there was only one systems designer, but you had three software coders?

   (e) Assuming that the systems designers were employed for the duration of the project, what would be the percentage utilization of the systems designers in the case of both (c) and (d) above?

6. (a) Draw up an activity network for the activities below, identifying the critical path.

Activity	Duration	Depends on	Resource type
A	2 days		SA
B	10 days	A	SD
C	2 days	A	SD
D	2 days	C	SC
E	3 days	C	SC
F	2 days	C	SC
G	4 days	B, D, E, F	SA

SA = systems analyst; SD = systems designer; SC = software coder

(b) Draw up a resource table showing the number of each type of resource needed on each day of the project and assuming that there is only one systems designer.

(c) Identify the best way of revising the plan to remove resource clashes.

7. Consider a software development project with seven tasks T1–T7. The estimated duration of these seven tasks in weeks are 3, 2, 3, 5, 2, 4, and 5 respectively. T2 and T4 can start when T1 is complete. T3 can start when T2 is complete. T5, T6, and T7 can start when both T3 and T4 are complete. If developer A is available from the start of the project and developer B and C become available after three weeks of the start of the project. Schedule the project and show your results in the form of a bar chart and resource histogram.

8. For each of the following questions, exactly one option is correct. Select the appropriate option.

   (ii) Which one of the following is not true about resource histograms?

   (a) A resource histogram is a representation of the distribution of the resources required over the duration of the project.

   (b) Based on the resource histogram, some activities may be delayed to reduce the maximum demand of a resource.

   (c) A resource histogram is used to estimate activity durations.

   (d) The initial activity network is refined based on the resource histogram.

   (iii) Which one of the following is false regarding resource scheduling?

   (a) Resource scheduling may lead to changing the duration of some activities on the PERT chart.

   (b) Resource scheduling may not affect the critical path.

   (c) Resource scheduling usually shortens the critical path.

   (d) Resource scheduling can create additional critical paths.