SPECIAL INDIAN EDITION

Sixth Edition

SOFTWARE PROJECT MANAGEMENT

Bob Hughes | Mike Cotterell
Rajib Mall

Mc Graw Hill Education

Detailed Table of Contents

1 Introduction to Software Project Management

Learning Objectives

- Define the scope of 'software project management'
- Understand some problems and concerns of software project managers
- Define the usual stages of a software project
- Explain the main elements of the role of management
- Appreciate the need for careful planning, monitoring and control
- Identify the stakeholders of a project and their objectives
- Define the success criteria for a project

1.1 Introduction

This textbook is about '*software* project management'. The first question is whether the management of *software* projects is really that different from that of other projects. To answer this, we need to look at some key ideas about the planning, monitoring and control of software projects. We will see that all projects are about meeting objectives. Like any other project, a software project must satisfy real needs. To do this we must identify the project's stakeholders and their objectives. Ensuring that their objectives are met is the aim of project management. However, we cannot know that a project will meet its objectives in the future unless we know the present state of the project.

1.2 Why is Software Project Management Important?

This book is for students of software engineering and computer science and also those studying business information systems. More technically oriented students can be impatient at having to study something which keeps them away from their code. So why is it important to become familiar with project management?

The information in this paragraph comes from a National Audit Office report, *Improving IT Procurement*, November 2004.

First, there is the question of money. A lot of money is at stake with ICT projects. In the United Kingdom during the financial year 2002–2003, the central government spent more on contracts for ICT projects than on contracts related to roads (about £2.3 billion as opposed to £1.4 billion). The biggest departmental spender was the Department for Work and Pensions, who spent over £800 million on ICT. Mismanagement of ICT projects means that there is less to spend on good things such as hospitals.

There has been some debate about the precise validity of the Standish findings but the key point about the prevalence of IT project failings remains clear.

Unfortunately, projects are not always successful. In a report published in 2003, the Standish Group in the United States analysed 13,522 projects and concluded that only a third of projects were successful; 82% of projects were late and 43% exceeded their budget.

The reason for these project shortcomings is often the management of projects. The National Audit Office in the UK, for example, among other factors causing project failure identified '*lack of skills and proven approach to project management and risk management*'.

1.3 What is a Project?

Dictionary definitions of 'project' include: 'A specific plan or design' 'A planned undertaking' 'A large undertaking: e.g., a public works scheme', *Longman Concise English Dictionary*, 1982.

The dictionary definitions put a clear emphasis on the project being a *planned* activity.

The emphasis on being planned assumes we can determine how to carry out a task before we start. Yet with exploratory projects this might be difficult. Planning is in essence, thinking carefully about something before you do it – even with uncertain projects this is worth doing as long as the resulting plans are seen as provisional. Other activities, such as routine maintenance, will have been performed so many times that everyone knows exactly what to do. In these cases, planning hardly seems necessary, although procedures might be documented to ensure consistency and to help newcomers.

Programme management is often used to coordinate activities on concurrent jobs.

The activities that benefit most from conventional project management are likely to lie between these two extremes – see Figure 1.1.

There is a hazy boundary between the non-routine project and the routine job. The first time you do a routine task, it will be like a project. On the other hand, a project to develop a system similar to previous ones that you have developed will have a large element of the routine.

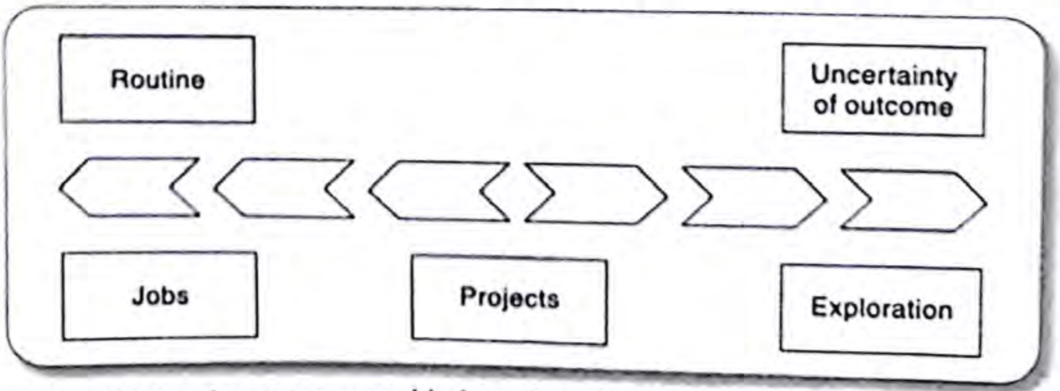

FIGURE 1.1 Activities most likely to benefit from project management

The following characteristics distinguish projects:

- Non-routine tasks are involved.
- Planning is required.
- Specific objectives are to be met or a specified product is to be created.
- The project has a predetermined time span.
- Work is carried out for someone other than yourself.
- Work involves several specialisms.
- People are formed into a temporary work group to carry out the task.
- Work is carried out in several phases.
- The resources that are available for use on the project are constrained.
- The project is large or complex.

The more, any of these factors apply to a task, the more difficult that task will be. Project size is particularly important. The project that employs 20 developers is likely to be disproportionately more difficult than one with only 10 staff because of the need for additional coordination. The examples and exercises used in this book usually relate to smaller projects in order to make the techniques easier to grasp. However, the techniques and issues discussed are of equal relevance to larger projects.

Exercise 1.1

Consider the following:

- Producing an edition of a newspaper
- Putting a robot vehicle on Mars to search for signs of life
- Getting married
- Amending a financial computer system to deal with a common European currency
- A research project into what makes a good human–computer interface
- An investigation into the reason why a user has a problem with a computer system
- A second-year programming assignment for a computing student
- Writing an operating system for a new computer
- Installing a new version of a word processing package in an organization

Some seem more like real projects than others. Put them into an order most closely matching your ideas of what constitutes a project. For each entry in the ordered list, describe the difference between it and the one above which makes it less worthy of the term 'project'.

There is no one correct answer to this exercise, but a possible solution to this and the other exercises you will come across may be found at the end of the book.

Some argue that projects are especially problematic as they are temporary sub-organizations. A group of people is brought together to carry out a task. The existence of this sub-organization cuts across the authority of the existing units within the organization. This has the advantage that a group containing various specialists is focused on a single important task. However, the project is likely to be seen as disruptive to

For example, see Rolf A. Lundin and Andres Sōderholm (1995) 'A theory of the temporary organization' *Scandinavian Journal of Management* 11(4) 437–55.

others. Also, expertise built up during the project may be lost when the team is eventually dispersed at the end of the project.

1.4 Software Projects versus Other Types of Project

F. P. Brooks (1987). 'No silver bullet: essence and accidents of software engineering'. This essay has been included in *The Mythical Man-Month*, Anniversary Edition, Addison Wesley, 1995.

Many techniques in general project management also apply to software project management, but Fred Brooks identified some characteristics of software projects which make them particularly difficult:

Invisibility When a physical artefact such as a bridge is constructed, the progress can actually be seen. With software, progress is not immediately visible. Software project management can be seen as the process of making the invisible visible.

Complexity Per dollar, pound or euro spent, software products contain more complexity than other engineered artefacts.

Conformity The 'traditional' engineer usually works with physical systems and materials like cement and steel. These physical systems have complexity, but are governed by consistent physical laws. Software developers have to conform to the requirements of human clients. It is not just that individuals can be inconsistent. Organizations, because of lapses in collective memory, in internal communication or in effective decision making, can exhibit remarkable 'organizational stupidity'.

Flexibility That software is easy to change is seen as a strength. However, where the software system interfaces with a physical or organizational system, it is expected that the software will change to accommodate the other components rather than *vice versa*. Thus, software systems are particularly subject to change.

1.5 Contract Management and Technical Project Management

In-house projects are where the users and the developers of new software work for the same organization. However, increasingly organizations contract out ICT development to outside developers. Here, the client organization will often appoint a 'project manager' to supervise the contract who will delegate many technically oriented decisions to the contractors. Thus, the project manager will not worry about estimating the effort needed to write individual software components as long as the overall project is within budget and on time. On the supplier side, there will need to be project managers who deal with the more technical issues. This book leans towards the concerns of these 'technical' project managers.

1.6 Activities Covered by Software Project Management

Chapter 4 on project analysis and technical planning looks at some alternative life cycles.

A software project is not only concerned with the actual writing of software. In fact, where a software application is bought 'off the shelf', there may be no software writing as such, but this is still fundamentally a software project because so many of the other activities associated with software will still be present.

Usually there are three successive processes that bring a new system into being – see Figure 1.2.

1. **The feasibility study** assesses whether a project is worth starting – that it has a valid *business case*. Information is gathered about the requirements of the proposed application. Requirements elicitation can, at least initially, be complex and difficult. The stakeholders may know the aims they wish to pursue, but not be sure about the means of achievement. The developmental and operational costs, and

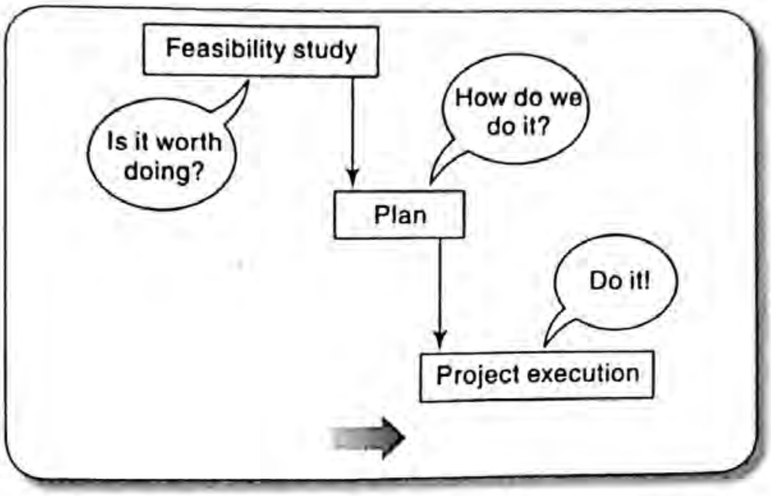

FIGURE 1.2 The feasibility study/plan/execution cycle

the value of the benefits of the new system, will also have to be estimated. With a large system, the feasibility study could be a project in its own right with its own plan. The study could be part of a strategic planning exercise examining a range of potential software developments. Sometimes an organization assesses a *programme* of development made up of a number of projects.

Chapter 2 explores some further aspects of programme management.

2. **Planning** If the feasibility study indicates that the prospective project appears viable, then project planning can start. For larger projects, we would not do all our detailed planning at the beginning. We create an outline plan for the whole project and a detailed one for the first stage. Because we will have more detailed and accurate project information after the earlier stages of the project have been completed, planning of the later stages is left to nearer their start.

The PRINCE2 method, which is described in Appendix A, takes this iterative approach to planning. Annex 1 to this chapter has an outline of the content of a plan.

3. **Project execution** The project can now be executed. The execution of a project often contains *design* and *implementation* sub-phases. Students new to project planning often find that the boundary between design and planning can be hazy. Design is making decisions about the form of the *products* to be created. This could relate to the external appearance of the software, that is, the user interface, or the internal architecture. The plan details the *activities* to be carried out to create these products. Planning and design can be confused because at the most detailed level, planning decisions are influenced by design decisions. Thus a software product with five major components is likely to require five sets of activities to create them.

Figure 1.3 shows the typical sequence of software development activities recommended in the international standard ISO 12207. Some activities are concerned with the *system* while others relate to *software*. The development of software will be only one part of a project. Software could be developed, for example, for a project which also requires the installation of an ICT infrastructure, the design of user jobs and user training.

Figure 1.3 suggests that these stages must be done strictly in sequence – we will see in Chapter 4 that other, iterative approaches can be adopted. However, the actual activities listed here would still be done.

- *Requirements analysis* starts with *requirements elicitation* or requirements gathering which establishes what the potential users and their managers require of the new system. It could relate to a *function* – that the system should do something. It could be a quality requirement – how well the functions must work. An example of this

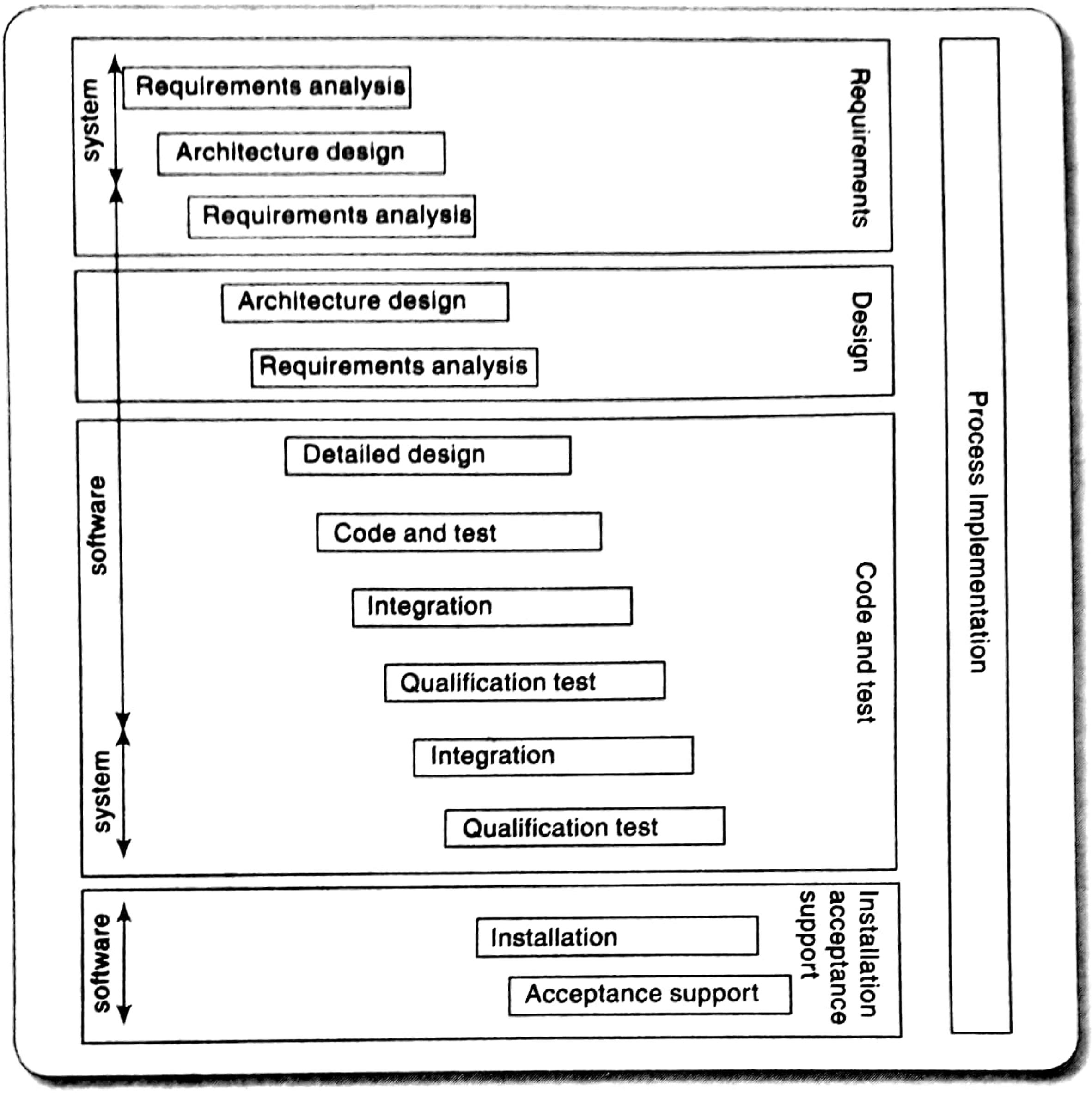

FIGURE 1.3 The ISO 12207 software development life cycle

is dispatching an ambulance in response to an emergency telephone call. In this case transaction time would be affected by hardware and software performance as well as the speed of human operation. Training to ensure that operators use the computer system efficiently is an example of a *system requirement* for the project, as opposed to a specifically *software requirement*. There would also be *resource requirements* that relate to application development costs.

- *Architecture design* The components of the new system that fulfil each requirement have to be identified. Existing components may be able to satisfy some requirements. In other cases, a new component will have to be made. These components are not only software: they could be new hardware or work processes. Although software developers are primarily concerned with software components, it is very rare that these can be developed in isolation. They will, for example, have to take account of existing legacy systems with which they will interoperate. The design of the *system architecture* is thus an input to the *software requirements*. A second architecture design process then takes place that maps the software requirements to *software components*.
- *Detailed design* Each software component is made up of a number of software units that can be separately coded and tested. The detailed design of these units is carried out separately.

- *Code and test* refers to writing code for each software unit. Initial testing to debug individual software units would be carried out at this stage.
- *Integration* The components are tested together to see if they meet the overall requirements. Integration could involve combining different software components, or combining and testing the software element of the system in conjunction with the hardware platforms and user interactions.
- *Qualification testing* The system, including the software components, has to be tested carefully to ensure that all the requirements have been fulfilled.
- *Installation* This is the process of making the new system operational. It would include activities such as setting up standing data (for example, the details for employees in a payroll system), setting system parameters, installing the software onto the hardware platforms and user training.
- *Acceptance support* This is the resolving of problems with the newly installed system, including the correction of any errors, and implementing agreed extensions and improvements. Software maintenance can be seen as a series of minor software projects. In many environments, most software development is in fact maintenance.

Exercise 1.2

Brightmouth College is a higher education institution which used to be managed by a local government authority but has now become autonomous. Its payroll is still administered by the local authority and pay slips and other outputs are produced in the local authority's computer centre. The authority now charges the college for this service. The college management are of the opinion that it would be cheaper to obtain an 'off-the shelf' payroll package and do the payroll processing themselves.

What would be the main stages of the project to convert to independent payroll processing by the college? Bearing in mind that an off-the-shelf package is to be used, how would this project differ from one where the software was to be written from scratch?

Exercise 1.3

Assume that a software organization development has been asked to carry out a feasibility study to develop the payroll package for Brightmouth College. The development organization plans to develop the software by customizing one of its existing products. What are the main steps through which the project manager of the organization would carry out the feasibility study?

1.7 Plans, Methods and Methodologies

A plan for an activity must be based on some idea of a *method* of work. For example, if you were asked to test some software, you may know nothing about the software to be tested, but you could assume that you would need to:

- Analyse the requirements for the software.

- Devise and write test cases that will check that each requirement has been satisfied.
- Create test scripts and expected results for each test case.
- Compare the actual results and the expected results and identify discrepancies.

While a *method* relates to a type of activity in general, a *plan* takes that method (and perhaps others) and converts it to real activities, identifying for each activity:

- Its start and end dates
- Who will carry it out
- What tools and materials – including information – will be needed

The output from one method might be the input to another. Groups of methods or techniques are often grouped into *methodologies* such as object-oriented design.

Exercise 1.4

This should ideally be done in groups of about four, but you can think about how you would go about this exercise on your own if need be. You are probably in a building that has more than one storey. From the point of view of this exercise, the bigger the building the better.

In a group of four, work out how you would obtain an accurate estimate of the height of the building. (If you happen to be in a single-storey building, you can estimate the floor area instead!) Plan how you would carry out any action needed to obtain your estimate. Spend 20 minutes on this – you must remain in the same room for this planning phase. Once planning is complete, implement your plan, timing how long it takes to produce your final figure.

If there is more than one group carrying out this exercise, after completion of the task you can compare answers and also the approach you used when coming up with your answer.

1.8 Some Ways of Categorizing Software Projects

Projects may differ because of the different technical products to be created. Thus we need to identify the characteristics of a project which could affect the way in which it should be planned and managed. Other factors are discussed below.

Changes to the characteristics of software projects

Over the last few decades, the characteristics of software projects have undergone drastic changes. For example, in the initial years of software development, almost every software was being entirely written from scratch. A possible reason for this could be that in those early days of software development, not many programs were available from which code could be reused in a new software development project. As a result, the entire code for every project had to be written from scratch. Further inhibiting code reuse was the fact that the programming paradigms that existed in those days hardly provided any support for code reuse. In contrast, at present, almost every programming language supports several ways of reusing existing code, including elegant ways of customizing and extending existing code, efficiently and dynamically linking library routines and support for frameworks.

A large number of projects that are being undertaken now are essentially customization of some existing software or development for a new release of an existing software. In these projects, much of the code of the developed software comes from reused code and only a small part of the code is actually written by the development team. Consequently, project durations have now shrunk to only a few months compared to multi-year projects that were being undertaken till about a few decades back. Further, in the past, customer participation in software projects was largely restricted to only the initial interactions for requirements, gathering, and specification and later, on completion of the project, taking delivery of the developed software. In contrast, at present, customer participation in almost every aspect of a project is being actively encouraged and often a few customer representatives are being included in the development team.

Compulsory versus voluntary users

In workplaces, there are systems that staff have to use if they want to do something, such as recording a sale. However, use of a system is increasingly voluntary, as in the case of computer games. Here it is difficult to elicit precise requirements from potential users as we could with a business system. What the game will do will thus depend much on the informed ingenuity of the developers, along with techniques such as market surveys, focus groups and prototype evaluation.

Information systems versus embedded systems

A traditional distinction has been between *information systems* which enable staff to carry out office processes and *embedded systems* which control machines. A stock control system would be an information system. An embedded, or process control, system might control the air conditioning equipment in a building. Some systems may have elements of both where, for example, the stock control system also controls an automated warehouse.

Embedded systems are also called real-time or industrial systems.

Exercise 1.5

Would an operating system on a computer be an information system or an embedded system?

Software products *versus* services

All types of software projects can broadly be classified into software product development projects and software services projects. These two broad classes of software projects can be further classified into subclasses, as shown in Figure 1.4. A software product development project concerns developing the software by keeping the requirements of the general customers in mind and the developed software is usually sold off-the-shelf to a large number of customers. A software product development project can further be classified depending on whether it concerns developing a generic product or a domain-specific product. A generic software product is sold to a broad spectrum of customers and is said to have a horizontal market. Examples of generic software products are Microsoft's Windows operating system and Oracle Corporation's Oracle 8i database management software. On the other hand, domain-specific software products are sold to specific categories of customers and are said to have a vertical market. Domain-specific software products target specific segments of customers (called verticals), such as, banking, telecommunication, finance and accounts and medical.. Examples of domain-specific software products are BANCS from TCS and FINACLE from Infosys in the banking domain and AspenPlus from Aspen corporation in the chemical process simulation.

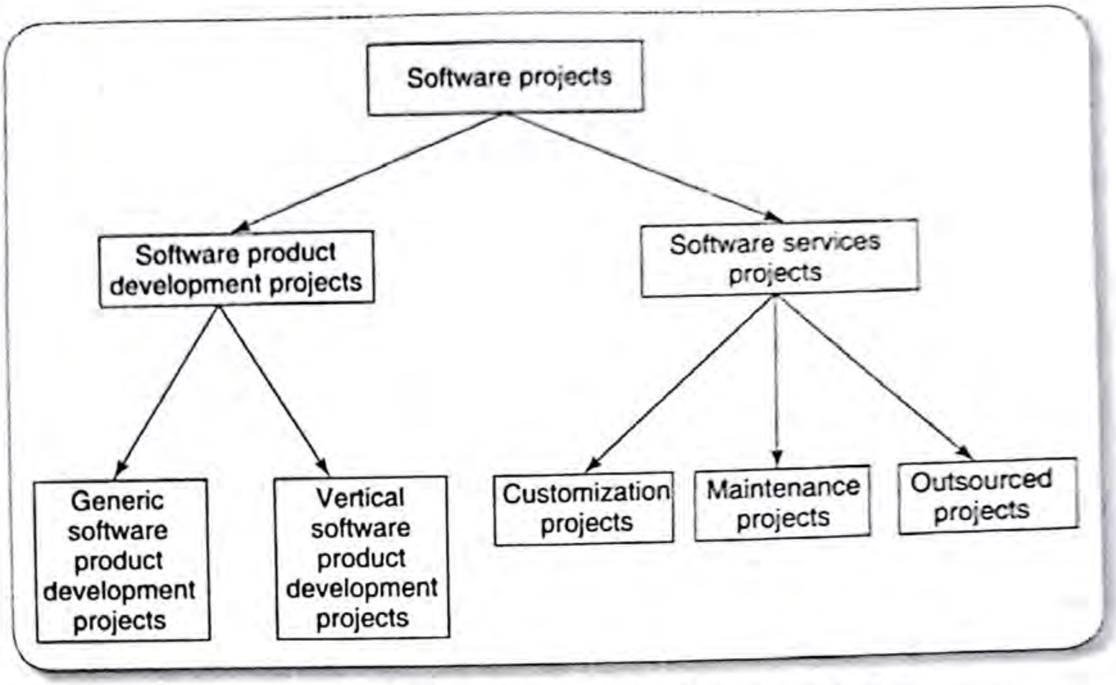
Software projects
Software product development projects
Software services projects
Generic software product development projects
Vertical software product development projects
Customization projects
Maintenance projects
Outsourced projects

FIGURE 1.4 A classification of software projects

Software services on the other hand, cover a large gamut of software projects such as customization, outsourcing, maintenance, testing and consultancy. At present, there is a rapid growth in the number of software services projects that are being undertaken world-wide and software services are poised to become the dominant type of software projects. One of the reasons behind this situation is the steep growth in the available code base. Over the past few decades, a large number of programs have already been developed. Available programs can therefore be modified to quickly fulfil the specific requirements of any customer. At present, there is hardly any software project in which the program code is written from scratch, and software is being mostly developed by customizing some existing software. For example, to develop a software to automate the payroll generation activities of an educational institute, the vendor may customize an existing software that might have been developed earlier for a different client's educational institute. Due to heavy reuse of code, it has now become possible to develop even large software systems in rather short period of time. Therefore, typical project durations are at present only a couple of months and multi-year projects have become very rare.

Outsourced projects

While developing a large project, sometimes, it makes good commercial sense for a company to outsource some parts of its work to other companies. There can be several reasons behind such a decision. For example, a company may consider outsourcing as a good option, if it feels that it does not have sufficient expertise to develop some specific parts of the product or if it determines that some parts can be developed cost-effectively by another company. Since an outsourced project is a small part of some project, it is usually small in size and needs to be completed within a few months. Considering these differences between an outsourced project and a conventional project, managing an outsourced project entails special challenges.

Indian software companies excel in executing outsourced software projects and have earned a fine reputation in this field all over the world. Of late, the Indian companies have slowly begun to focus on product development as well.

The type of development work being handled by a company can have an impact on its profitability. For example, a company that has developed a generic software product usually gets an uninterrupted stream of revenue over several years. However, outsourced projects fetch only one time revenue to any company.

Objective-driven development

Projects may be distinguished by whether their aim is to produce a *product* or to meet certain *objectives.*

A project might be to create a product, the details of which have been specified by the client. The client has the responsibility for justifying the product. On the other hand, the project requirement might be to meet certain objectives which could be met in a number of ways. An organization might have a problem and ask a specialist to recommend a solution.

Service level agreements are becoming increasingly important as organizations contract out functions to external service suppliers.

Many software projects have two stages. First is an objective-driven project resulting in recommendations. This might identify the need for a new software system. The next stage is a project actually to create the software product. This is useful where the technical work is being done by an external group and the user needs are unclear at the outset. The external group can produce a preliminary design at a fixed fee. If the design is acceptable the developers can then quote a price for the second, implementation, stage based on an agreed requirement.

Exercise 1.6

Would the project, to implement an independent payroll system at the Brightmouth College described in Exercise 1.2, above, be an objective-driven project or a product-driven project?

1.9 Project Charter

Project charter is an important high-level document that authorizes the starting of a project and use of the required resources. Besides, it outlines the project objectives, deliverables and the resources required. It also documents the aspects that are out of scope, and identifies the main stakeholders, their roles and responsibilities. A project charter document is usually developed for all types of projects, irrespective of whether it is an in-house project or a project undertaken on behalf of some customers. The project charter is signed and issued by a member of the top management of the company who also takes up the role of the sponsor of the project. The project sponsor champions the project, monitors the progress of the project and provides regular feedback to the project manager, and helps in removing any obstacles that the project manager may find difficult to overcome.

The project manager for a project is usually appointed before the project charter is issued and undertakes to write the project charter in consultation with the project sponsor. The project charter serves as a guiding document for all activities concerning the project. This is a document that is not expected to change throughout the project life cycle, unlike other project management documents such as project plan, risk management plan and work breakdown structure (WBS). The latter documents are dynamic in nature and change several times during the project duration. The project manager refers to the project charter while planning the project.

The project charter is usually a short document that is only a couple of pages long and typically contains the following:

- Overall objectives of the project and the broad items that are within the scope of the project and those that are out of scope.
- The time schedule in terms of the start date and the expected completion date of the project.
- The important stakeholders and their responsibilities towards the project.
- Overview of the resources that will be needed for the project and the overall budget.
- Major risks to the project and the broad strategies that can be adopted for overcoming those.

1.10 Stakeholders

These are people who have a stake or interest in the project. Their early identification is important as you need to set up adequate communication channels with them. Stakeholders can be categorized as:

- *Internal to the project team* This means that they will be under the direct managerial control of the project leader.
- *External to the project team but within the same organization* For example, the project leader might need the assistance of the users to carry out systems testing. Here the commitment of the people involved has to be negotiated.
- *External to both the project team and the organization* External stakeholders may be customers (or users) who will benefit from the system that the project implements. They may be contractors who will carry out work for the project. The relationship here is usually based on a contract.

B.W. Boehm and R. Ross, 'Theory W software project management: principles and examples', in B. W. Boehm (ed.) (1989) Software Risk Management, IEEE Computer Society Press.

Different types of stakeholders may have different objectives and one of the jobs of the project leader is to recognize these different interests and to be able to reconcile them. For example, end-users may be concerned with the ease of use of the new application, while their managers may be more focused on staff savings. The project leader therefore needs to be a good communicator and negotiator. Boehm and Ross proposed a 'Theory W' of software project management where the manager concentrates on creating situations where all parties benefit from a project and therefore have an interest in its success. (The 'W' stands for 'win–win'.)

The role and format of communication plans will be explained in greater detail in Chapter 11 on managing people in software environments.

Project managers can sometimes miss an important stakeholder group, especially in unfamiliar business contexts. These could be departments supplying important services that are taken for granted.

Given the importance of coordinating the efforts of stakeholders, the recommended practice is for a *communication plan* to be created at the start of a project.

Exercise 1.7

Identify the stakeholders in the Brightmouth College payroll project.

1.11 Setting Objectives

Among all these stakeholders are those who actually own the project. They control the financing of the project. They also set the objectives of the project. The objectives should define what the project team must achieve for project success. Although different stakeholders have different motivations, the project objectives identify the shared intentions for the project.

Objectives focus on the desired outcomes of the project rather than the tasks within it – they are the 'post-conditions' of the project. Informally the objectives could be written as a set of statements following the opening words '*the project will be a success if. . .*' Thus one statement in a set of objectives might be '*customers can order our products online*' rather than '*to build an e-commerce website*'. There is often more than one way to meet an objective and the more possible routes to success the better.

There may be several stakeholders, including users in different business areas, who might have some claim to project ownership. In such a case, a *project authority* needs to be explicitly identified with overall authority over the project.

This authority is often a *project steering committee* (or *project board* or *project management board*) with overall responsibility for setting, monitoring and modifying objectives. The project manager runs the project on a day-to-day basis, but regularly reports to the steering committee.

This committee is likely to contain user, development and management representatives.

Sub-objectives and goals

An effective objective for an individual must be something that is within the control of that individual. An objective might be that the software application produced must pay for itself by reducing staff costs. As an overall business objective this might be reasonable. For software developers it would be unreasonable as any reduction in operational staff costs depends not just on them but on the operational management of the delivered system. A more appropriate *goal* or sub-objective for the software developers would be to keep development costs within a certain budget.

Defining sub-objectives requires assumptions about how the main objective is to be achieved.

We can say that in order to achieve the objective we must achieve certain goals or sub-objectives first. These are steps on the way to achieving an objective, just as goals scored in a football match are steps towards the objective of winning the match. Informally this can be expressed as a set of statements following the words '*To reach objective. . ., the following must be in place. . .*'.

The mnemonic SMART is sometimes used to describe well-defined objectives:

- *Specific* Effective objectives are concrete and well defined. Vague aspirations such as '*to improve customer relations*' are unsatisfactory. Objectives should be defined so that it is obvious to all whether the project has been successful.
- *Measurable* Ideally there should be *measures of effectiveness* which tell us how successful the project has been. For example, '*to reduce customer complaints*' would be more satisfactory as an objective than '*to improve customer relations*'. The measure can, in some cases, be an answer to simple yes/no question, e.g. '*Did we install the new software by 1 June?*'
- *Achievable* It must be within the power of the individual or group to achieve the objective.

This still leaves a problem about the level at which the target should be set, e.g. why, say, a 50% reduction in complaints and not 40% or 60%?

- *Relevant* The objective must be relevant to the true purpose of the project.
- *Time constrained* There should be a defined point in time by which the objective should have been achieved.

Exercise 1.8

Bearing in mind the above discussion of objectives, comment on the appropriateness of the wording of each of the following 'objectives' for software developers:

(i) To implement the new application on time and within budget

(ii) To implement the new software application with the fewest possible software errors that might lead to operational failures

(iii) To design a system that is user-friendly

(iv) To produce full documentation for the new system

Measures of effectiveness

These concepts are explained more fully in Chapter 13 on software quality.

Measures of effectiveness provide practical methods of checking that an objective has been met. 'Mean time between failures' (mtbf) might, for example, be used to measure reliability. This is a *performance* measurement and, as such, can only be taken once the system is operational. Project managers want to get some idea of the performance of the completed system as it is being constructed. They will therefore seek *predictive* measures. For example, a large number of errors found during code inspections might indicate potential problems with reliability later.

Exercise 1.9

Identify the objectives and sub-objectives of the Brightmouth College payroll project. What measures of effectiveness could be used to check the success in achieving the objectives of the project?

1.12 The Business Case

The business case should be established at the time of the project's feasibility study. Chapter 2 explains the idea of a business case in more detail.

Most projects need to have a justification or business case: the effort and expense of pushing the project through must be seen to be worthwhile in terms of the benefits that will eventually be felt. A cost–benefit analysis will often be part of the project's feasibility study. This will itemize and quantify the project's costs and benefits. The benefits will be affected by the completion date: the sooner the project is completed, the sooner the benefits can be experienced. The quantification of benefits will often require the formulation of a *business model* which explains how the new application can generate the claimed benefits.

A simple example of a business model is that a new web-based application might allow customers from all over the world to order a firm's products via the internet, increasing sales and thus increasing revenue and profits.

Any project plan must ensure that the business case is kept intact. For example:

- that development costs are not allowed to rise to a level which threatens to exceed the value of benefits;
- that the features of the system are not reduced to a level where the expected benefits cannot be realized;
- that the delivery date is not delayed so that there is an unacceptable loss of benefits.

1.13 Project Success and Failure

The project plan should be designed to ensure project success by preserving the business case for the project. However, every non-trivial project will have problems, and at what stage do we say that a project is actually a failure? Because different stakeholders have different interests, some stakeholders in a project might see it as a success while others do not.

A good introduction to the issues discussed here can be found in A. J. Shenhar and O. Levy (1997) 'Mapping the dimensions of project success' *Project Management Journal* 28(2) 9–12.

Broadly speaking, we can distinguish between *project objectives* and *business objectives*. The project objectives are the targets that the project team is expected to achieve. In the case of software projects, they can usually be summarized as delivering:

- The agreed functionality
- The required level of quality
- On time
- Within budget

A project could meet these targets but the application, once delivered could fail to meet the business case. A computer game could be delivered on time and within budget, but might then not sell. A commercial website used for online sales could be created successfully, but customers might not use it to buy products, because they could buy the goods more cheaply elsewhere.

We have seen that in business terms it can generally be said that a project is a success if the value of benefits exceeds the costs. We have also seen that while project managers have considerable control over development costs, the value of the benefits of the project deliverables is dependent on external factors such as the number of customers. Project objectives still have some bearing on eventual business success. As we will see in Chapter 2, increasing development costs reduce the chances of the delivered product being profitable. A delay in completion reduces the amount of time during which benefits can be generated and diminishes the value of the project.

The assessment of the value of project benefits is explored in greater depth in Chapter 2.

A project can be a success on delivery but then be a business failure, On the other hand, a project could be late and over budget, but its deliverables could still, over time, generate benefits that outweigh the initial expenditure.

Some argue that the possible gap between project and business concerns can be reduced by having a broader view of projects that includes business issues. For example, the project management of an e-commerce website implementation could plan activities such as market surveys, competitor analysis, focus groups, prototyping, and evaluation by typical potential users – all designed to reduce business risks.

Because the focus of project management is, not unnaturally, on the immediate project, it may not be seen that the project is actually one of a sequence. Later projects benefit from the technical skills learnt on earlier projects. Technical learning will

For a wider discussion of the relationships between successive projects, see M. Engwall (2003) 'No project is an island: linking projects to history and context' Research Policy 32 789–808.

increase costs on the earlier projects, but later projects benefit as the learnt technologies can be deployed more quickly, cheaply and accurately. This expertise is often accompanied by additional software assets, for example, reusable code. Where software development is outsourced, there may be immediate savings, but these longer-term benefits of increased expertise will be lost. Astute managers may assess which areas of technical expertise it would be beneficial to develop.

Customer relationships can also be built up over a number of projects. If a client has trust in a supplier who has done satisfactory work in the past, they are more likely to use that company again, particularly if the new requirement builds on functionality already delivered. It is much more expensive to acquire new clients than it is to retain existing ones.

1.14 What is Management?

We have explored some of the special characteristics of software. We now look at the 'management' aspect of software project management. It has been suggested that management involves the following activities:

- Planning – deciding what is to be done
- Organizing – making arrangements
- Staffing – selecting the right people for the job etc.
- Directing – giving instructions
- Monitoring – checking on progress
- Controlling – taking action to remedy hold-ups
- Innovating – coming up with new solutions
- Representing – liaising with clients, users, developer, suppliers and other stakeholders

Exercise 1.10

Paul Duggan is the manager of a software development section. On Tuesday at 10.00 a.m. he and his fellow section heads have a meeting with their group manager about the staffing requirements for the coming year. Paul has already drafted a document 'bidding' for staff. This is based on the work planned for his section for the next year. The document is discussed at the meeting. At 2.00 p.m. Paul has a meeting with his senior staff about an important project his section is undertaking. One of the programming staff has just had a road accident and will be in hospital for some time. It is decided that the project can be kept on schedule by transferring another team member from less urgent work to this project. A temporary replacement is to be brought in to do the less urgent work but this may take a week or so to arrange. Paul has to phone both the human resources manager about getting a replacement and the user for whom the less urgent work is being done, explaining why it is likely to be delayed.

Identify which of the eight management responsibilities listed above Paul was responding to at different points during his day.

Much of the project manager's time is spent on only three of the eight identified activities, *viz.*, project planning, monitoring, and control. The time period during which these activities are carried out is indicated in Figure 1.5. It shows that project management is carried out over three well-defined stages or processes,

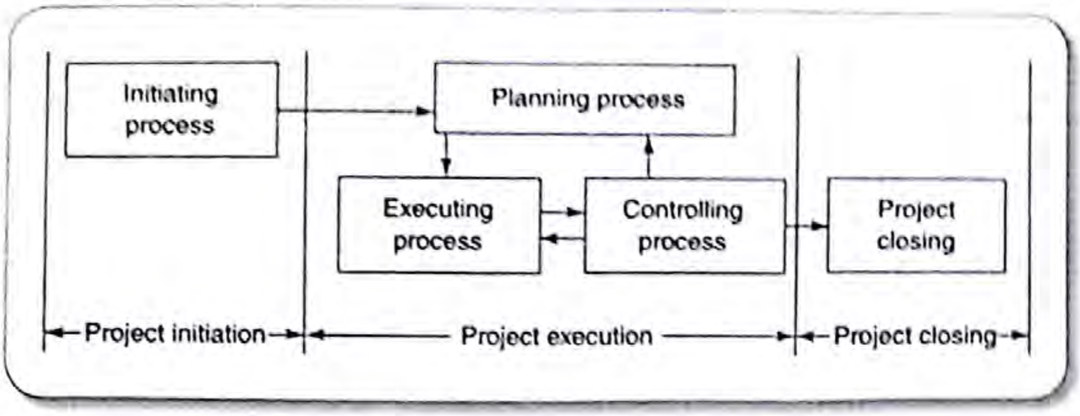

FIGURE 1.5 Principal project management processes

irrespective of the methodology used. In the project initiation stage, an initial plan is made. As the project starts, the project is monitored and controlled to proceed as planned. However, the initial plan is revised periodically to accommodate additional details and constraints about the project as they become available. Finally, the project is closed. In the project closing stage, all activities are logically completed and all contracts are formally closed.

Initial project planning is undertaken immediately after the feasibility study phase and before starting the requirements analysis and specification process. Figure 1.5 shows this project initiation period. Initial project planning involves estimating several characteristics of a project. Based on these estimates, all subsequent project activities are planned. The initial project plans are revised periodically as the project progresses and more project data becomes available. Once the project execution starts, monitoring and control activities are taken up to ensure that the project execution proceeds as planned. The monitoring activity involves monitoring the progress of the project. Control activities are initiated to minimize any significant variation in the plan.

Project planning is an important responsibility of the project manager. During project planning, the project manager needs to perform a few well-defined activities that have been outlined below. Note that we have given a very brief description of these activities in this chapter. We will discuss these activities in more detail in subsequent chapters. Several best practices have been proposed for software project planning activities. In Chapter 3, we will discuss Step Wise, which is based on the popular PRINCE2 (PRojects IN Controlled Environments) method. While PRINCE2 is used extensively in the UK and Europe, similar software project management best practices have been put forward in the USA by the Project Management Institute's 'PMBOK' which refers to their publication 'A Guide to the Project Management Body of Knowledge.'

- *Estimation* The following project attributes are estimated.
- *Cost* How much is it going to cost to complete the project?
- *Duration* How long is it going to take to complete the project?
- *Effort* How much effort would be necessary for completing the project?

The effectiveness of all activities such as scheduling and staffing, which are planned at a later stage, depends on the accuracy with which the above three project parameters have been estimated.

- *Scheduling* Based on estimations of effort and duration, the schedules for manpower and other resources are developed.
- *Staffing* Staff organization and staffing plans are made.

- *Risk Management* This activity includes risk identification, analysis, and abatement planning.
- *Miscellaneous Plans* This includes making several other plans such as quality assurance plan, configuration management plan, etc.

Project monitoring and control activities are undertaken after the initiation of development activities. The aim of project monitoring and control activities is to ensure that the software development proceeds as planned. While carrying out project monitoring and control activities, a project manager may sometimes find it necessary to change the plan to cope with specific situations and make the plan more accurate as more project data becomes available.

At the start of a project, the project manager does not have complete knowledge about the details of the project. As the project progresses through different development phases, the manager's information base gradually improves. The complexities of different project activities become clear, some of the anticipated risks get resolved, and new risks appear. The project parameters are re-estimated periodically incorporating new understanding and change in project parameters. By taking these developments into account, the project manager can plan subsequent activities more accurately with increasing levels of confidence. Figure 1.5 shows this aspect as iterations between monitoring and control, and the plan revision activities.

1.15 Management Control

Management, in general, involves setting objectives for a system and then monitoring the performance of the system. In Figure 1.6, the 'real world' is shown as being rather formless. Especially in the case of large undertakings, there will be a lot going on about which management should be aware.

Exercise 1.11

An ICT project is to replace locally held paper-based records with a centrally organized database. Staff in a large number of offices that are geographically dispersed need training and will then have to use the new ICT system to set up the backlog of manual records on the new database. The system cannot be properly operational until the last record has been transferred. The new system will only be successful if new transactions can be processed within certain time cycles.

Identify the data that you would collect to ensure that during execution of the project things were going to plan.

This will involve the local managers in *data collection*. Bare details, such as 'location X has processed 2000 documents', will not be very useful to higher management: *data processing* will be needed to transform this raw *data* into useful *information*. This might be in such forms as 'percentage of records processed', 'average documents processed per day per person' and 'estimated completion date'.

In our example, the project management might examine the 'estimated completion date' for completing data transfer for each branch. These can be checked against the overall target date for completion of this phase of the project. In effect they are comparing actual performance with one aspect of the overall project objectives. They might find that one or two branches will fail to complete the transfer of details in time. They would then need to consider what to do (this is represented in Figure 1.6 by the box *Making decisions/plans*). One possibility would be to move staff temporarily from one branch to another. If this is done, there

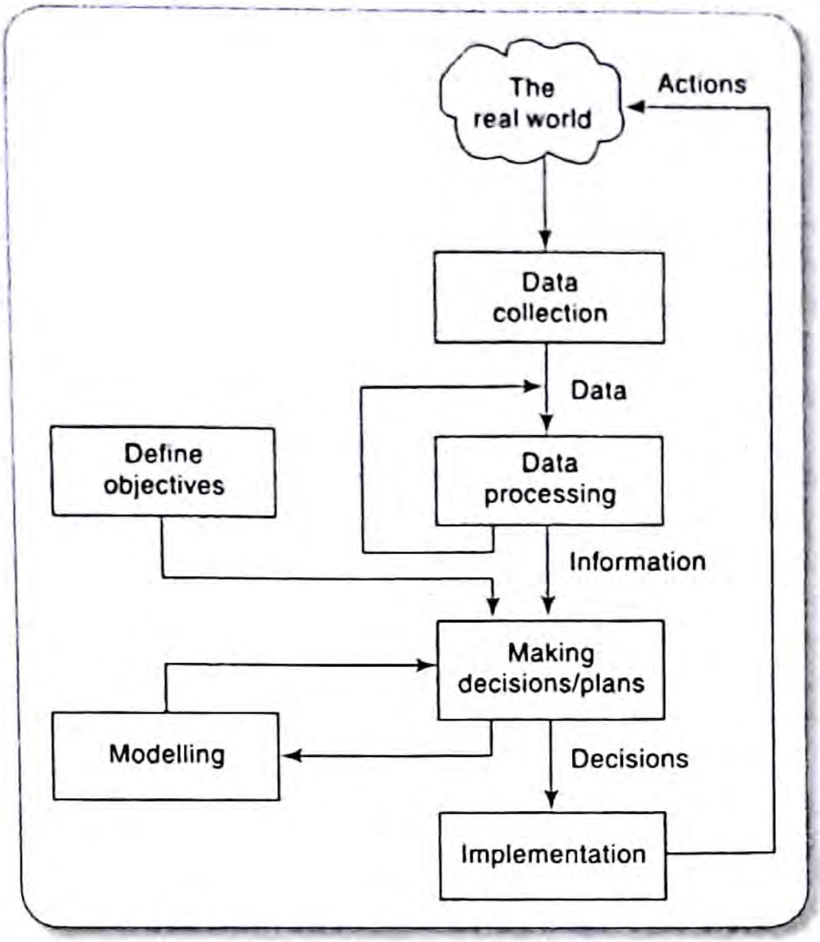

Figure 1.6 The project control cycle

is always the danger that while the completion date for the one branch is pulled back to before the overall target date, the date for the branch from which staff are being moved is pushed forward beyond that date. The project manager would need to calculate carefully what the impact would be in moving staff from particular branches. This is *modelling* the consequences of a potential solution. Several different proposals could be modelled in this way before one was chosen for *implementation.*

Having implemented the decision, the situation needs to be kept under review by collecting and processing further progress details. For instance, the next time that progress is reported, a branch to which staff have been transferred could still be behind in transferring details. This might be because the reason why the branch has got behind in transferring details is because the manual records are incomplete and another department, for whom the project has a low priority, has to be involved in providing the missing information. In this case, transferring extra staff to do data inputting will not have accelerated data transfer.

It can be seen that a project plan is dynamic and will need constant adjustment during the execution of the project. Courses and books on project management (such as this one) often focus considerable attention on project planning. While this is to be expected, with nearly all projects much more time is spent actually doing the project rather than planning it. A good plan provides a foundation for a good project, but is nothing without intelligent execution. The original plan will not be set in stone but will be modified to take account of changing circumstances.

Software development and project management life cycles

Software development life cycle denotes the stages through which a software is developed. In Figure 1.7, a software development life cycle (SDLC) is shown in terms of the set of activities that are undertaken during a typical software development project, their grouping into different phases and their sequencing. During the software development life cycle, starting from its conception, the developers carry out several processes (or development methodologies) till the software is fully developed and deployed at the client site. A few examples of the development processes undertaken by the development team include requirements gathering and analysis, requirements specification, architectural design, detailed design, coding and testing.

In contrast to the software development life cycle (SDLC), the project management life cycle typically starts well before the software development activities start and continues for the entire duration of the SDLC. This aspect has schematically been shown in Figure 1.7. As shown, during the software development life cycle, the software developers carry out several types of development processes. On the other hand, during the software project management life cycle, the software project manager carries out several project management processes (or project management methodologies) to perform the required software project management activities. A few examples of the project management processes carried out by a project manager include project initiation, planning, execution, monitoring, controlling, and closing. As shown in Figure 1.7, 'project life cycle' is a more generic term and is often used to denote both software development life cycle and project management life cycle.

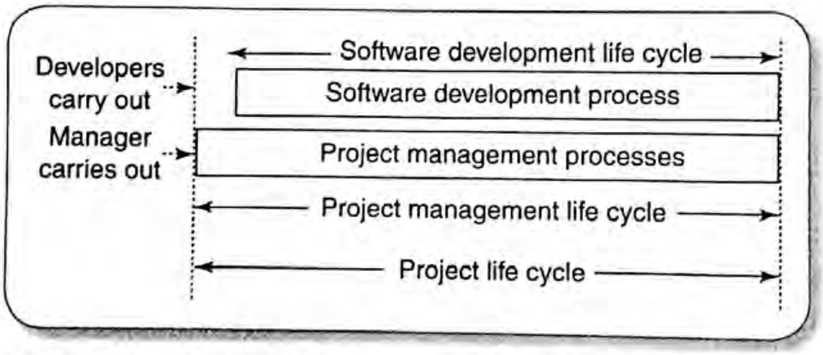
Developers carry out
Manager carries out
Software development life cycle
Software development process
Project management processes
Project management life cycle
Project life cycle

FIGURE 1.7 Project management life cycle versus software development life cycle

The activities carried out by the developers during software development life cycle as well as the project management life cycle are grouped into a number of phases. Typical sets of phases and their sequencing in the software development life cycle and the project management life cycle have been shown in Figure 1.8. As can be seen from Figure 1.8, the phases of the software development life cycle are requirements analysis, design, development, test and delivery. The different phases of the project management life cycle are initiation, planning, execution and closing. Further observe from Figure 1.8 that by the time the software development processes start, the initiation phase of the software project management life cycle is almost complete.

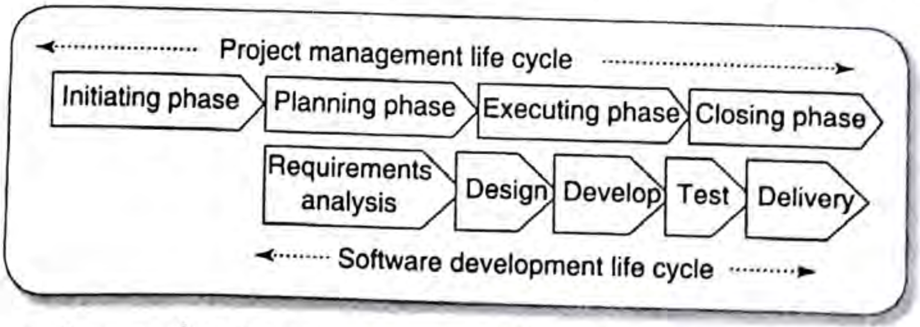

FIGURE 1.8 Different phases of project management life cycle and software development life cycle

1.16 Project Management Life Cycle

The different phases of the project management life cycle are shown in Figure 1.8. In the following, we discuss the main activities that are carried out in each phase.

Project Initiation

As shown in Figure 1.8, the software project management life cycle starts with project initiation. The project initiation phase usually starts with project concept development. During concept development the different characteristics of the software to be developed are thoroughly understood. The different aspects of the project that are investigated and understood include: the scope of the project, project constraints, the cost that would be incurred and the benefits that would accrue. Based on this understanding, a feasibility study is undertaken to determine whether the project would be financially and technically feasible. This is true for all types of projects, including the in-house product development projects as well as the outsourced projects. For example, an organization might feel a need for a software to automate some of its activities, possibly for more efficient operation. Based on the feasibility study, the business case is developed. Once the top management agrees to the business case, the project manager is appointed, the project charter is written, and finally the project team is formed. This sets the ground for the manager to start the project planning phase.

As has already been pointed out, during the project initiation phase it is crucial for the champions of the project to develop a thorough understanding of the important characteristics of the project. In his W5HH principle, Barry Boehm summarized the questions that need to be asked and answered in order to have an understanding of these project characteristics.

W5HH Principle: Boehm suggested that during project initiation, the project champions should have comprehensive answers to a set of key questions pertaining to the project. The answers to these questions would lead to the definition of key project characteristics. The name of this principle (W5HH) is an acronym constructed from the first letter of each question. This set of seven questions is the following:

- Why is the software being built?
- What will be done?
- When will it be done?
- Who is responsible for a function?
- Where are they organizationally located?
- How will the job be done technically and managerially?
- How much of each resource is needed?

Project bidding: Once an organization's top management is convinced by the business case, the project charter is developed. For some categories of projects, it may be necessary to have a formal bidding process to select a suitable vendor based on some cost-performance criteria. If the project involves automating some activities of an organization, the organization may either decide to develop it in-house or may get various software vendors to bid for the project. We briefly mention the different types of bidding techniques and their implications and applicability.

- *Request for quotation (RFQ)* An organization advertises an RFQ if it has good understanding of the project and the possible solutions. While publishing the RFQ, the organization would have to mention the scope of the work in a statement of work (SOW) document. Based on the RFQ different vendors can submit their quotations. The RFQ issuing organization can select a vendor based on the price quoted as well as the competency of the vendor. In government organizations, the term request for tender (RFT) is usually used in place of RFQ. RFT is similar to RFQ; however, in RFT the bidder needs to deposit a tender fee in order to participate in the bidding process.

- *Request for proposal (RFP)* Many times it so happens that an organization has reasonable understanding of the problem to be solved, however it does not have a good grasp of the solution aspects. That is, the organization may not have sufficient knowledge about the different features that are to be implemented, and may lack familiarity with the possible choices of the implementation environment, such as, databases, operating systems, client-server deployment, etc. In this case, the organization may solicit solution proposals from vendors. The vendors may submit a few alternative solutions and the approximate costs for each solution. In order to develop a better understanding, the requesting organization may ask the vendors to explain or demonstrate their solutions. It needs to be understood that the purpose of RFP is to get an understanding of the alternative solutions possible that can be deployed and not vendor selection. Based on the RFP process, the requesting organization can form a clear idea of the project solutions required, based on which it can form a statement work (SOW) for requesting RFQ from the vendors.
- *Request for Information (RFI)* An organization soliciting bids may publish an RFI. Based on the vendor response to the RFI, the organization can assess the competencies of the vendors and shortlist the vendors who can bid for the work. However, it must be noted that vendor selection is seldom done based on RFI, but the RFI response from the vendors may be used in conjunction with RFP and RFQ responses for vendor selection.

Project planning

An important outcome of the project initiation phase is the project charter. During the project planning phase, the project manager carries out several processes and creates the following documents:

- *Project plan* This document identifies the project tasks, and a schedule for the project tasks that assigns project resources and time frames to the tasks.
- *Resource plan* It lists the resources, manpower and equipment that would be required to execute the project.
- *Financial plan* It documents the plan for manpower, equipment and other costs.
- *Quality plan* Plan of quality targets and control plans are included in this document.
- *Risk plan* This document lists the identification of the potential risks, their prioritization and a plan for the actions that would be taken to contain the different risks.

Project execution

In this phase the tasks are executed as per the project plan developed during the planning phase. A series of management processes are undertaken to ensure that the tasks are executed as per plan. Monitoring and control processes are executed to ensure that the tasks are executed as per plan and corrective actions are initiated whenever any deviations from the plan are noticed. However, the project plan may have to be revised periodically to accommodate any changes to the project plan that may arise on account of change requests, risks and various events that occur during the project execution. Quality of the deliverables is ensured through execution of proper processes. Once all the deliverables are produced and accepted by the customer, the project execution phase completes and the project closure phase starts.

Project closure

Project closure involves completing the release of all the required deliverables to the customer along with the necessary documentation. Subsequently, all the project resources are released and supply agreements with the vendors are terminated and all the pending payments are completed. Finally, a postimplementation review is undertaken to analyse the project performance and to list the lessons learnt for use in future projects.

1.17 Traditional versus Modern Project Management Practices

Over the last two decades, the basic approach taken by the software industry to develop software has undergone a radical change. Hardly any software is being developed from scratch any more. Software development projects are increasingly being based on either tailoring some existing product or reusing certain pre-built libraries. In either case, two important goals of recent life cycle models are maximization of code reuse and compression of project durations. Other goals include facilitating and accommodating client feedbacks and customer participation in project development work, and incremental delivery of the product with evolving functionalities. Change requests from customers are encouraged, rather than circumvented. Clients on the other hand, are demanding further reductions in product delivery times and costs. These recent developments have changed project management practices in many significant ways. In the following section, we will discuss some important differences between modern project management practices and traditional practices.

- *Planning Incremental Delivery* Few decades ago, projects were much simpler and therefore more predictable than the present day projects. In those days, projects were planned with sufficient detail, much before the actual project execution started. After the project initiation, monitoring and control activities were carried out to ensure that the project execution proceeded as per plan. Now, projects are required to be completed over a much shorter duration, and rapid application development and deployment are considered key strategies. The traditional long-term planning has given way to adaptive short-term planning. Instead of making a long-term project completion plan, the project manager now plans all incremental deliveries with evolving functionalities. This type of project management is often called extreme project management. Extreme project management is a highly flexible approach to project management that concentrates on the human side of project management (e.g., managing project stakeholders), rather than formal and complex planning and monitoring techniques.
- *Quality Management* Of late, customer awareness about product quality has increased significantly. Tasks associated with quality management have become an important responsibility of the project manager. The key responsibilities of a project manager now include assessment of project progress and tracking the quality of all intermediate artifacts. We will discuss quality management issues in Chapter 13.
- *Change Management* Earlier, when the requirements were signed off by the customer, any changes to the requirements were rarely entertained. Customer suggestions are now actively being solicited and incorporated throughout the development process. To facilitate customer feedback, incremental delivery models are popularly being used. Product development is being carried out through a series of product versions implementing increasingly greater functionalities. Also customer feedback is solicited on each version for incorporation. This has made it necessary for an organization to keep track of the various versions and revisions through which the product develops. Another reason for the increased importance of keeping track of the versions and revisions is the following. Application development through customization has become a popular business model. Therefore, existence of a large number of versions of a product and the need to support these by a development organization has become common.

In this context, the project manager plays a key role in product base lining and version control. This has made change management a crucial responsibility of the project manager. Change management is also known as configuration management. We will discuss change management in Chapter 9.

- *Requirements Management* In modern software development practices, there is a conscious effort to develop software such that it would, to a large extent, meet the actual requirements of the customer. A basic premise of these modern development methodologies is that at the start of a project the customers are often unable to fully visualize their exact needs and are only able to determine their actual requirements after they start using the software. From this view point, modern software development practices advocate delivery of software in increments as and when the increments are completed by the development team, and actively soliciting change requests from the customer as they use the increments of the software delivered to them. In fact, a few customer representatives are included in the development team to foster close every day interactions with the customers. Contrast this with the practice followed in older development methodologies, where the requirements had to be identified upfront and these were then 'signed off' by the customer and 'frozen' before the development could start. Change requests from the customer after the start of the project were discouraged. Consequently, at present in most projects, the requirements change frequently during the development cycle. It has, therefore, become necessary to properly manage the requirements, so that as and when there is any change in requirements, the latest and up-to-date requirements become available to all. Requirements management has therefore become a systematic process of controlling changes, documenting, analysing, tracing, prioritizing requirements and then communicating the changes to the relevant stakeholders. By the term controlling changes, we mean that every change request is well managed, and problems such as accidental overwriting of a newer document with an older document are avoided.
- *Release Management* Release management concerns planning, prioritizing and controlling the different releases of a software. For almost every software, multiple releases are made during its life cycle. Starting with an initial release, releases are made each time the code changes. There are several reasons as to why the code needs to change. These reasons include functionality enhancements, bug fixes and improved execution speed. Further, modern development processes such as the agile development processes advocate frequent and regular releases of the software to be made to the customer during the software development. Starting with the release of the basic or core functionalities of the software, more complete functionalities are made available to the customers every couple of weeks. In this context, effective release management has become important.
- *Risk Management* In modern software project management practices, effective risk management is considered very important to the success of a project. A risk is any negative situation that may arise as the project progresses and may threaten the success of the project. Every project is susceptible to a host of risks that could usually be attributed to factors such as technology, personnel and customer. Unless proper risk management is practised, the progress of the project may get adversely affected. Risk management involves identification of risks, assessment of the impacts of various risks, prioritization of the risks and preparation of risk-containment plans. We discuss various aspects of project risk management in Chapter 7.
- *Scope Management* Once a project gets underway, many requirement change requests usually arise. Some of these can be attributed to the customers and the others to the development team. As we have already mentioned, modern development practices encourage the customer to come up with change requests. While all essential changes must be carried out, the superfluous and ornamental changes must be scrupulously avoided. However, while accepting change requests, it must be remembered that the three critical project parameters: scope, schedule and project cost are interdependent and are very

intricately related. If the scope is allowed to change extensively, while strictly maintaining the schedule and cost, then the quality of the work would be the major casualty. Therefore, for every scope change request, the project managers examine whether the change request is really necessary and whether the budget and time schedule would permit it. Often, the scope change requests are superfluous. For example, an overenthusiastic project team member may suggest to add features that are not required by the customer. Such scope change requests originated by the overenthusiastic team members are called *goldplating* and should be discouraged if the project is to succeed. The customer may also initiate scope change requests that are more ornamental or at best nonessential. These serve only to jeopardize the success of the project, while not adding any perceptible value to the delivered software. Such avoidable scope change requests originated by the customer are termed as scope creep. To ensure the success of the project, the project manager needs to guard against both gold plating and scope creep.

Exercise 1.12

Assume that the development of the pay roll package of Brightmouth College has been entrusted to an organization who would develop it by customizing one of its products. Discuss the main stages through which the organization could carry out project development?

Conclusion

This chapter has laid a foundation for the remainder of the book by defining what is meant by various terms such as 'software project' and 'management'. Among some of the more important points that have been made are the following:

- Projects are by definition non-routine and therefore more uncertain than normal undertakings.
- Software projects are similar to other projects but have some attributes that present particular difficulties, e.g., the relative invisibility of many of their products.
- A key factor in project success is having clear objectives. Different stakeholders in a project, however, are likely to have different objectives. This points to the need for a recognized overall project authority.
- For objectives to be effective there must be practical ways of testing that the objectives have been met.
- Where projects involve many different people, effective channels of information have to be established. Having objective measures of success helps unambiguous communication between the various parties to a project.

ANNEX 1 CONTENTS LIST FOR A PROJECT PLAN

- Introduction
- Background: including reference to the business case
- Project objectives
- Constraints – these could be included with project objectives
- Methods

The detail that goes into these sections will be explained in later chapters. For example, Chapter 7 relates to risk while Chapter 13 explains aspects of the management of quality.

- Project products: both deliverable products that the client will receive and intermediate products
- Activities to be carried out
- Resources to be used
- Risks to the project
- Management of the project, including
  - organizational responsibilities
  - management of quality
  - configuration management

Further Exercises

1. List the problems you experienced when you carried out a recent ICT-related assignment. Try to put these problems into some order of magnitude. For each problem consider whether there was some way in which the problem could have been reduced by better organization and planning by yourself.
2. Identify the main types of personnel employed in an information systems department. For each stage of a typical IS development project, list the types of personnel who are likely to be involved.
3. A public library is considering the implementation of a computer-based system to help administer book loans at libraries. Identify the stakeholders in such a project. What might be the objectives of such a project and how might the success of the project be measured in practical terms?
4. A software house has developed a customized order processing system for a client. You are an employee of the software house that has been asked to organize a training course for the end-users of the system. At present, a user handbook has been produced, but no specific training material. A plan is now needed for the project which will set up the delivery of the training courses. The project can be assumed to have been completed when the first training course starts. Among the things that will need to be considered are the following:
   - Training materials will need to be designed and created
   - A timetable will need to be drafted and agreed
   - Date(s) for the course will need to be arranged
   - The people attending the course will need to be identified and notified
   - Rooms and computer facilities for the course will need to be provided

   (a) Identify the main stakeholders for this project.

   (b) Draw up objectives for this project.

   (c) For the objectives, identify the measures of effectiveness.

   (d) For each objective, write down sub-objectives or goals and the stakeholders who will be responsible for their achievement.
5. A manager is in charge of a sub-project of a larger project. The sub-project requires the transfer of paper documents into a computer-based document retrieval system and their subsequent indexing so that they can be accessed via key-words. Optical character readers are to be used for the initial transfer but the text then needs to be clerically checked and corrected by staff. The project is currently scheduled to

take 12 months using permanent staff. A small budget is available to hire temporary staff in the case of staff absences through holidays, sickness or temporary transfer to other, more urgent, jobs. Discuss the control system that will need to be in place to control that sub-project.

6. The idea behind a project is that students should be able to access details of available placements via an intranet. When there is a placement opportunity for which they wish to be considered, they would be able to apply for it electronically. This would cause a copy of their CV, which would also be held online, to be sent to the potential employer.

   Details of interviews and placement offers would all be sent by e-mail. While some human intervention would be needed, the process would be automated as far as possible.

   You are required to produce a business case report for such an application, which justifies the potential development by showing that the value of its potential benefits outweighs its development and operational costs.

   Create lists of the main benefits and costs for the project. You do not have to specify actual figures, just the headings under which they would appear.
7. Distinguish between software product development and outsourced projects. Explain the key ways in which managing an outsourcing project differs from a product development project.
8. Identify the important characteristics of software development projects which make these harder to manage compared to other types of projects. Say for example, a building construction project.
9. What is the difference between a method and a methodology? What are the essential items that must be planned before carrying out a method or methodology?
10. Identify the main differences between managing the development of a conventional project and an outsourced project.
11. Identify the key aspects in which modern software project management practices differ from those of traditional software project management.
12. Explain the major activities carried out by a software project manager and the order in which these are carried out.
13. Identify the factors that make software projects much more difficult to manage, compared to many other types of projects such as a project to lay out a 100 km concrete road on an existing nonconcrete road.
14. What do you understand by the terms software development life cycle and software project management life cycle? Using a suitable schematic diagram explain the temporal relationship between the software development life cycle and the project management life cycle.
15. What are the different phases of the software development life cycle and software project management life cycle? Explain the sequencing of the phases in these two life cycles using a schematic diagram.
16. What do you understand by W5HH principle? Explain the significance of this principle.
17. What is a project charter? What purpose does it serve? Who usually writes this document and at which point in the project management life cycle is this document produced?
18. Differentiate between software product development projects and software services projects. What are the important differences between their characteristics? Why are software services projects becoming much more common?
19. Identify the important differences in the characteristics of the software development projects that are being undertaken now with those that were undertaken several decades back. What can be the possible reasons for the drastic shrinkage of the project durations from multi-year to a couple of months now?

20. Explain the important activities that are carried out during the initiation phase of a software development project.
21. Briefly explain the differences between different bidding processes: request for proposal (RFP), request for quotation (RFQ), request for information (RFI), and request for tender (RFT). Explain their applicability to specific project situations using suitable examples.
22. What is meant by the terms *gold plating* and *scope creep*? Explain the difference between these two and briefly mention why the project manager needs to guard against these.
23. What do you understand by *project scope management*? Why is this activity crucial to the success of a project?
24. What do you understand by the term *release management*? Why is this activity considered important?
25. Name the different types of plans prepared by a project manager during the project planning stage.
26. At what point in the project lifecycle should the business case be prepared?
27. For each of the following questions, exactly one option is correct. Select the appropriate option.

    (i) Which one of the following is not a characteristic of a software project?

    (a) A project can have nonroutine tasks that involve challenge

    (b) A project can have several routine tasks

    (c) The resources available for the project are usually constrained

    (d) Every software project has a predetermined starting point but may continue indefinitely

    (ii) Which one of the following statements concerning the business case for a project is false?

    (a) It provides the cost that would be incurred to complete the project.

    (b) It provides the benefits that are expected to accrue from undertaking the project.

    (c) It presents the cost-benefit analysis.

    (d) Once the business case is completed and approved by the project sponsor, the feasibility study is undertaken.

    (iii) Which one of the following is the most acceptable definition of a project?

    (a) A series of activities designed to accomplish some objective.

    (b) An attempt to perform something that has well-defined objectives, and requires both human and other types of resources and usually has to abide by several constraints.

    (c) A coordinated effort to accomplish a well-defined goal, but, in general, can be without any end points.

    (d) Any activity to which human and other resources must be allocated for it to proceed.

    (iv) Which one of the following is the most accurate definition of a project?

    (a) A planned sequence of activities.

    (b) An activity that requires planning, execution, controlling, and monitoring and is constrained by limited resources.

    (c) A temporary endeavour undertaken to create a unique product or service.

    (d) A planned effort with clear objectives.

    (v) Which one of the following constraints on a project is known as 'triple constraints'?

    (a) Quality, duration and effort

    (b) Cost, resources and duration

(c) Cost, duration and scope

(d) Cost, quality and product size

(vi) Which one of the following is true of a project charter?

(a) It is only used for in-house development projects

(b) It is also called the business case of the project

(c) It is a statement of the scope of the project

(d) It focuses on the project requirements and does not address the stakeholder's responsibilities

(vii) Which one of the following is usually not recognized as a phase of the software project management life cycle?

(a) Execution

(b) Initiation

(c) On-going maintenance

(d) Closing

(viii) Which one of the following is false of a project charter?

(a) It identifies the high-level time schedule for the project

(b) It provides an overview of the resource and budget for the project

(c) It authorizes the start of the project work

(d) It lists the responsibilities of the project sponsor

(ix) Which one of the following documents contains the statement of work?

(a) Request for quotation (RFQ)

(b) Business case

(c) Request for information (RFI)

(d) Request for proposal (RFP)

(x) An e-commerce company wishes to deploy customer relationship management (CRM) software. It makes a formal invitation from vendors to describe their solution and methodology along with the price for the same. The invitation from the organization is called which one of the following?

(a) Invitation to bid.

(b) Request for information.

(c) Request for proposal.

(d) Request for bid.

(xi) Which one of the following is not included in a project scope document?

(a) The deliverables for the project.

(b) The features and functions that are to be included in the software.

(c) The time schedule.

(d) The project plan.

(xii) One of your project team members insists on including a feature in the software being developed that he believes would be liked by the customer, though it is not part of the project scope. This feature can be an example of which one of the following?

(a) Scope creep

(b) An undocumented change

(c) Gold plating

(d) Scope enhancement

(xiii) Which one of the following most closely describes the sequence of phases of a project management life cycle?

(a) Initiation, planning, execution and closing.

(b) Concept, definition, development and closure.

(c) Initiation, definition, planning and monitoring.

(d) Concept, definition, implementation and maintenance.

(xiv) Which one of the following documents usually does not change during the duration of the project?

(a) Project plan

(b) Risk management plan

(c) Project charter

(d) Work breakdown structure (WBS)

(xv) In which phase of the project management life cycle, most of the project funding is likely to be spent?

(a) Initiating

(b) Executing

(c) Planning

(d) Closeout

(xvi) Which one of the following documents is not developed during the project initiation phase?

(a) Project charter

(b) Project feasibility report

(c) Business case

(d) Project plan

2 Project Evaluation and Programme Management

Learning Objectives

- Describe the contents of a typical business plan
- Explain project portfolio management
- Carry out an evaluation and selection of projects against strategic, technical and economic criteria
- Use a variety of cost-benefit evaluation techniques for choosing among competing project proposals
- Evaluate the business risk involved in a project
- Explain how individual projects can be grouped into programmes
- Explain how the implementation of programmes and projects can be managed so that the planned benefits are achieved

2.1 Introduction

The first that many developers hear of an ICT project is when they are allocated to the project team. However, new projects do not appear out of thin air. There will be some process – varying in sophistication between organizations – that decides that the project is worth doing.

As we saw in Chapter 1, sometimes managers justify a commitment to a single project as the benefits will exceed the costs of the implementation and operation of the new application. In other cases, managers would not approve a project on its own, but can see that it enables the fulfilment of strategic objectives when combined with other projects.

Thus a project to establish an ICT infrastructure within an organization might not deliver a direct financial benefit, but could provide a platform for subsequent projects to do so.

It might not be possible to measure the benefits of a project in financial terms. If you create a system which allows the more accurate recording of data concerning the medical condition of patients, it might contribute to the alleviation of pain and the preservation of life, but it would be difficult to put a money value on these.

The last chapter emphasized that an ICT or software project needed a business case. In this chapter, we explain what such a document might contain. A business case may be presented for several potential projects, but there may be money or staff time for only some of the projects. Managers need some way of deciding which projects to select. This is part of *portfolio management*. This chapter will discuss some ways in which projects can be evaluated and compared for inclusion in a project portfolio. The chapter finishes by discussing the way groups of projects which together contribute to a common business objective can be managed as *programmes* of projects.

2.2 Business Case

The section on the business case draws on B. Hughes (2008) *Exploiting IT for business benefit*. British Computer Society.

Organizations may have different titles such as a *feasibility study* or a *project justification* for what we call the business case. Its objective is to provide a rationale for the project by showing that the benefits of the project outcomes will exceed the costs of development, implementation and operation (or production).

Typically a business case document might contain:

1. Introduction and background to the proposal
2. The proposed project
3. The market
4. Organizational and operational infrastructure
5. The benefits
6. Outline implementation plan
7. Costs
8. The financial case
9. Risks
10. Management plan

These sections will now be described in more detail.

Introduction and background

This is a description of the current environment of the proposed project. A problem to be solved or an opportunity to be exploited is identified.

The proposed project

A brief outline of the proposed project is provided.

In Section 2.3, we will explore further the difference between new product development and renewal projects.

The market

This is needed when the project is to create new product or a new service capability. This would contain information like the estimated demand for the product or service and any likely competitors.

Organizational and operational infrastructure

This describes how the structure of the organization will be affected by the implementation of the project. This is of most relevance where the project is implementing or modifying an information system as part of a broader business change project. It would also be relevant if a tailored production or distribution system has to be set up when a new product is designed.

Benefits

Where possible, a financial value should be put on the benefits of the implemented project. For commercial organizations this could be related to increased profits caused either by increasing income or by making savings on costs. For not-for-profit organizations we would try to quantify the benefits even if we cannot quote a precise financial value. In an example we used earlier relating to an IT system that improved the diagnosis of a particular disease, an increase in the rate of diagnosis might be quoted.

Outline implementation plan

In addition to the ICT aspects of the project, activities such as marketing, promotion and operational and maintenance infrastructures need to be considered. One consideration will be which project activities can be outsourced, and which are best kept in-house.

This will also detail the management of the implementation. The responsibilities are allocated for the tasks identified in the outline implementation plan. Key decision points or milestones, where a health-check on the state of the implementation is taken, should be identified. As we will see, for a large implementation a number of projects may be needed which can be managed as a programme.

Costs

Having outlined the steps needed to set up the operations needed by the proposal, a schedule of expected costs associated with the planned approach can now be presented.

There will clearly be some uncertainties about some of the costs, especially as the details of the requirements have not yet been worked out.

The financial case

There are a number of ways in which the information on income and costs can be analysed and these will be the subject of the section on evaluation techniques later in this chapter.

Risks

Once again a more detailed discussion of risks will follow in a later section. We note here that many estimates of costs and, more particularly, benefits of the project will be speculative at this stage and the section on risk should take account of this. In the last chapter we distinguished between project and business objectives. We can similarly distinguish project risk – relating to threats to successful project execution – from business risk – relating to factors threatening the benefits of the delivered project. In the business case the main focus is on business risk.

2.3 Project Portfolio Management

Quite a good introduction to the concepts of portfolios can be found in B. De Reyck *et al.* 'The impact of project portfolio management on information technology projects' (2005) *International Journal of Project Management* 23 524–37.

Portfolio project management provides an overview of all the projects that an organization is undertaking or is considering. It prioritizes the allocation of resources to projects and decides which new projects should be accepted and which existing ones should be dropped.

The concerns of project portfolio management include:

- Identifying which project proposals are worth implementation.
- Assessing the amount of risk of failure that a potential project has.
- Deciding how to share limited resources, including staff time and finance, between projects – one problem can be that too many projects are started given the resources available so that inevitably some projects will miss planned completion dates.
- Being aware of the dependencies between projects, especially where several projects need to be completed for an organization to reap benefits.
- Ensuring that projects do not duplicate work.
- Ensuring that necessary developments have not been inadvertently been missed.

The three key aspects of project portfolio management are *portfolio definition, portfolio management* and *portfolio optimization*. An organization would undertake portfolio definition before adopting portfolio management and then proceeding to optimization.

Project portfolio definition

Warren McFarlan's (1981) 'Portfolio approach to information systems' *Harvard Business Review* 59(5) 142–50 introduced the portfolio concept to information systems.

An organization should record in a single repository details of all current projects. A decision will be needed about whether projects of all types are to be included. Should just ICT projects be included in the repository, or should other projects such as the setting up of a new warehouse also be included? One problem for many organizations is that projects can be divided into *new product developments* (NPD) where the project deliverable is a product, such as a computer game, that is sold to customers, and *renewal* projects which improve the way an organization operates – information systems projects are often like this. The distinction is not always clear-cut. For example, a new information system could be used to provide a customer service such as recording the details of people buying a new insurance product.

NPD projects are often more frequent in organizations which have a continuous development of new goods and services. Renewal projects may be less frequent and thus inherently more risky as there is less experience of these types of project. NPD projects find attracting funding easier with their clear relationship between the project and income. Where both types of project call upon the same pools of resources, including finance, the argument for a common portfolio is strong.

Project portfolio management

Once the portfolio has been established, more detailed costings of projects can be recorded. The value that managers hope will be generated by each project can also be recorded. Actual performance of projects on these performance indicators can then be tracked. This information can be the basis for the more rigorous screening of new projects.

Project portfolio optimization

The performance of the portfolio can be tracked by high-level managers on a regular basis. A better balance of projects may be achieved. Some projects could potentially be very profitable but could also be risky. In the case of an e-commerce site, for example, sales may not be as great as hoped because established competitors reduce prices. Other projects could have modest benefits, such as those cutting costs by automating processes, but have fewer risks. The portfolio ought to have a carefully thought-out balance between the two types of project.

Some problems with project portfolio management

An important role of project portfolio management is sharing resources between projects. There can be problems because while apparently full-time staff are allocated to a project, they may effectively be part-time because they still have routine work to do. This is particularly so with users, and with developers who may on occasion be called away from project work to deal with support tasks.

The official project portfolio may not accurately reflect organizational activity if some projects are excluded. A formal decision may be made that only projects over a certain level of cost will be recorded in the portfolio.

The 'below the line' projects could in fact consume substantial staff effort and bleed away effort from the official projects. It can be argued that all projects should be included in the official portfolio.

Interesting insights into the practical problems of portfolios can be found in B. S. Blichfeldt and P. Eskerod (2008) 'Project portfolio management – there's more to it than management enacts' *International Journal of Project Management* 26: 357–65.

However, there are advantages in allowing these tasks. It allows small *ad hoc* tasks to be done, such as quick fixes to systems to deal with externally imposed changes. They reduce work for higher management by saving them from having to process a large number of small work requests. Developers may find these small tasks rewarding: dealing with these small requests is an easy way to keep users happy. Thus, when allocating resources to projects, a margin should be set to allow first-line managers some judgement in accepting non-planned work.

2.4 Evaluation of Individual Projects

We will now look more closely at how the feasibility of an individual project can be evaluated.

Technical assessment

Technical assessment of a proposed system consists of evaluating whether the required functionality can be achieved with current affordable technologies. Organizational policy, aimed at providing a consistent hardware/software infrastructure, is likely to limit the technical solutions considered. The costs of the technology adopted must be taken into account in the cost–benefit analysis.

Cost–benefit analysis

Even where the estimated benefits will exceed the estimated costs, it is often necessary to decide if the proposed project is the best of several options. Not all projects can be undertaken at any one time and, in any case, the most valuable projects should get most resources.

Any project aiming at a return on investment must, as a minimum, provide a greater benefit than putting that investment in, say, a bank.

Cost–benefit analysis comprises two steps:

- *Identifying all of the costs and benefits of carrying out the project and operating the delivered application* These include the development costs, the operating costs, and the benefits expected from the new system. Where the proposed system is a replacement, these estimates should reflect the change in costs and benefits due to the new system. A new sales order processing system, for example, could only claim to benefit an organization by the increase in sales due to the use of the new system.
- *Expressing these costs and benefits in common units* We must express each cost and benefit – and the *net benefit* which is the difference between the two – in money.

Most direct costs are easy to quantify in monetary terms and can be categorized as:

The different types of benefits will be discussed in greater detail in the context of benefits to management later in this chapter.

- *Development costs*, including development staff costs.
- *Setup costs*, consisting of the costs of putting the system into place, mainly of any new hardware but also including the costs of file conversion, recruitment and staff training.
- *Operational costs* relating to operating the system after installation.

Exercise 2.1

Brightmouth College is considering the replacement of the existing payroll service, operated by a third party, with a tailored, off-the-shelf computer-based system. List some of the costs it might consider under the headings of:

- Development costs
- Setup costs
- Operational costs

List some of the benefits under the headings:

- Quantified and valued benefits
- Quantified but not valued
- Identified but not easily valued

For each cost or benefit, explain how, in principle, it might be measured in monetary terms.

Cash flow forecasting

Typically products generate a negative cash flow during their development followed by a positive cash flow over their operating life. There might be decommissioning costs at the end of a product's life.

As important as estimating the overall costs and benefits of a project is producing a cash flow forecast which indicates when expenditure and income will take place (Figure 2.1).

We need to spend money, such as staff wages, during a project's development. Such expenditure cannot wait until income is received (either from using software developed in-house use or from selling it). We need to know that we can fund this development expenditure either from the company's own resources or by borrowing. A forecast is needed of when expenditure, such as the payment of salaries, and any income are to be expected.

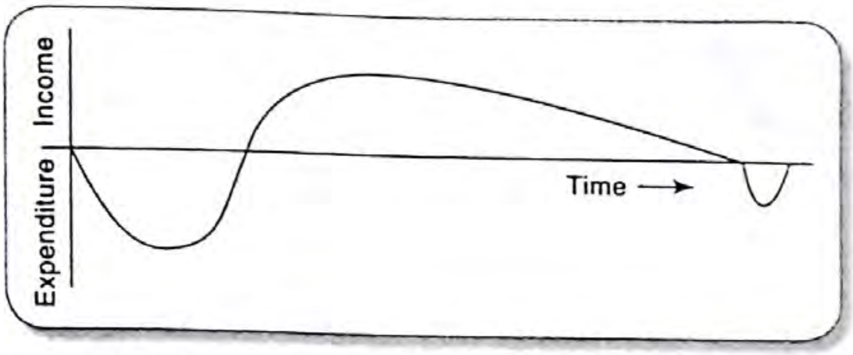

FIGURE 2.1 Typical product life cycle cash flow

Accurate cash flow forecasting is difficult, as it is done early in the project's life cycle (at least before any significant expenditure is committed) and many items to be estimated (particularly the benefits of using software) might be some years in the future.

When estimating future cash flows, it is usual to ignore the effects of inflation. Forecasts of inflation rates tend to be uncertain. Moreover, if expenditure is increased due to inflation it is likely that income will increase proportionately.

The difficulty and importance of cash flow forecasting is evidenced by the number of companies that suffer bankruptcy because, although they are developing profitable products or services, they cannot sustain an unplanned negative cash flow.

2.5 Cost–benefit Evaluation Techniques

We now take a look at some methods for comparing projects on the basis of their cash flow forecasts.

Table 2.1 illustrates cash flow forecasts for four projects. In each case, it is assumed that the cash flows take place at the end of each year. For short-term projects or where there are significant seasonal cash flow patterns, quarterly, or even monthly, cash flow forecasts could be appropriate.

TABLE 2.1 Four project cash flow projections – figures are end of year totals (£)

Year	Project 1	Project 2	Project 3	Project 4
0	–100,000	–1,000,000	–100,000	–120,000
1	10,000	200,000	30,000	30,000
2	10,000	200,000	30,000	30,000
3	10,000	200,000	30,000	30,000
4	20,000	200,000	30,000	30,000
5	100,000	300,000	30,000	75,000
Net profit	50,000	100,000	50,000	75,000

Exercise 2.2

Consider the project cash flow estimates for four projects at JOE shown in Table 2.1. Negative values represent expenditure and positive values income.

Rank the four projects in order of financial desirability and make a note of your reasons for ranking them in that way before reading further.

Net profit → 2

The net profit of a project is the difference between the total costs and the total income over the life of the project. Project 2 in Table 2.1 shows the greatest net profit but this is at the expense of a large investment. Indeed, if we had £1 m to invest, we might undertake all of the other three projects and obtain an even greater net profit. Note also that all projects contain an element of risk and we might not be prepared to risk £1 m. We shall look at the effects of risk and investment later in this chapter.

Cash flows take place at the end of each year. The year 0 represents the initial investment made at the start of the project.

Moreover, the simple net profit takes no account of the timing of the cash flows. Projects 1 and 3 each have a net profit of £50,000 and therefore, according to this selection criterion, would be equally preferable. The bulk of the income occurs late in the life of project 1, whereas project 3 returns a steady income throughout its life. Having to wait for a return has the disadvantage that the investment must be funded for longer. Add to that the fact that, other things being equal, estimates in the more distant future are less reliable than short-term estimates and we can see that the two projects are not equally preferable.

Payback period → 3*, 4

The *payback period* is the time taken to break even or pay back the initial investment. Normally, the project with the shortest payback period will be chosen on the basis that an organization will wish to minimize the time that a project is 'in debt'.

Exercise 2.3

Consider the four project cash flows given in Table 2.1 and calculate the payback period for each of them.

The advantage of the payback period is that it is simple to calculate and is not particularly sensitive to small forecasting errors. Its disadvantage as a selection technique is that it ignores the overall profitability of the project – in fact, it totally ignores any income (or expenditure) once the project has broken even. Thus the fact that projects 2 and 4 are, overall, more profitable than project 3 is ignored.

Return on investment → 4

The *return on investment* (ROI), also known as the *accounting rate of return* (ARR), provides a way of comparing the net profitability to the investment required. There are some variations on the formula used to calculate the return on investment but a straightforward common version is:

$$\text{ROI} = \frac{\textit{average annual profit}}{\textit{total investment}} \times 100$$

Exercise 2.4

Calculating the ROI for project 1, the net profit is £50,000 and the total investment is £100,000. The return on investment is therefore calculated as

$$ROI = \frac{\textit{average annual profit}}{\textit{total investment}} \times 100$$

$$= \frac{50{,}000/5}{100{,}000} \times 100 = 10\%$$

1. 10%
2. 2%
3. 10%.
4. 12.5%

Calculate the ROI for each of the other projects shown in Table 2.1 and decide which, on the basis of this criterion, is the most worthwhile.

The return on investment provides a simple, easy-to-calculate measure of return on capital. Unfortunately, it suffers from two severe disadvantages. Like the net profitability, it takes no account of the timing of the cash flows. More importantly, this rate of return bears no relationship to the interest rates offered or charged by banks (or any other normal interest rate) since it takes no account of the timing of the cash flows or of the compounding of interest. It is therefore, potentially, very misleading.

Net present value

The calculation of *net present value* is a project evaluation technique that takes into account the profitability of a project and the timing of the cash flows that are produced. This is based on the view that receiving £100 today is better than having to wait until next year to receive it. We could, for example, invest the £100 in a bank today and have £100 plus the interest in a year's time. If we say that the *present value* of £100 in a year's time is £91, we mean that £100 in a year's time is the equivalent of £91 now.

Net present value (NPV) and internal rate of return (IRR) are collectively known as discounted cash flow (DCF) techniques.

The equivalence of £91 now and £100 in a year's time means we are discounting the future income by approximately 10%. If we received £91 now and invested it for a year at an annual interest rate of 10%, it would be worth £100 in a year's time. The annual rate by which we discount future earnings is known as the *discount rate* – 10% in the above example.

Note that this example uses approximate figures.

Similarly, £100 received in two years' time would have a present value of approximately £83 – in other words, £83 invested at an interest rate of 10% would yield approximately £100 in two years' time.

A rate of 10% may be unrealistic but is used here for ease of calculation.

The present value of any future cash flow may be obtained by applying the following formula

$$\textit{Present value} = \frac{\textit{value in year } t}{(1+r)^t}$$

where r is the discount rate, expressed as a decimal value, and t is the number of years into the future that the cash flow occurs.

$1yr = \frac{1}{(1+0.10)} = 0.9091$ $2yr = \frac{1}{(1+0.10)^2} = 0.826$

More extensive or detailed tables may be constructed using the formula *discount factor* $\frac{1}{(1+r)^t}$ for various values of *r* (the discount rate) and *t* (the number of years from now).

Alternatively, and rather more easily, the present value of a cash flow may be calculated by multiplying the cash flow by the appropriate discount factor. A small table of discount factors is given in Table 2.2.

The NPV for a project is obtained by discounting each cash flow (both negative and positive) and summing the discounted values. It is normally assumed that any initial investment takes place immediately (indicated as year 0) and is not discounted. Later cash flows are normally assumed to take place at the end of each year and are discounted by the appropriate amount.

TABLE 2.2 NPV discount factors

	Discount rate (%)					
Year	**5**	**6**	**8**	**10**	**12**	**15**
1	0.9524	0.9434	0.9259	0.9091	0.8929	0.8696
2	0.9070	0.8900	0.8573	0.8264	0.7972	0.7561
3	0.8638	0.8396	0.7938	0.7513	0.7118	0.6575
4	0.8227	0.7921	0.7350	0.6830	0.6355	0.5718
5	0.7835	0.7473	0.6806	0.6209	0.5674	0.4972
6	0.7462	0.7050	0.6302	0.5645	0.5066	0.4323
7	0.7107	0.6651	0.5835	0.5132	0.4523	0.3759
8	0.6768	0.6274	0.5403	0.4665	0.4039	0.3269
9	0.6446	0.5919	0.5002	0.4241	0.3606	0.2843
10	0.6139	0.5584	0.4632	0.3855	0.3220	0.2472
15	0.4810	0.4173	0.3152	0.2394	0.1827	0.1229
20	0.3769	0.3118	0.2145	0.1486	0.1037	0.0611
25	0.2953	0.2330	0.1460	0.0923	0.0588	0.0304

Exercise 2.5

Assuming a 10% discount rate, the NPV for project 1 (Table 2.1) would be calculated as in Table 2.3. The net present value for project 1, using a 10% discount rate, is therefore £618. Using a 10% discount rate, calculate the net present values for projects 2, 3 and 4 and decide which, on the basis of this, is the most beneficial to pursue.

Table 2.3 Applying the discount factors to project 1

Year	Project 1 cash flow (£)		Discount factor @ 10%	Discounted cash flow (£)	
0	–100,000	-100,000	1.0000	–100,000	-100000
1	10,000	30 000	0.9091	9,091	27273
2	10,000	30000	0.8264	8,264	24792
3	10,000	30000	0.7513	7,513	22539
4	20,000	30000	0.6830	13,660	20490
5	100,000	30000	0.6209	62,090	18627
Net Profit	£50,000		NPV: £618		13721

It is interesting to note that the net present values for projects 1 and 3 are significantly different – even though they both yield the same net profit and both have the same return on investment. The difference in NPV reflects the fact that, with project 1, we must wait longer for the bulk of the income.

The main difficulty with NPV for deciding between projects is selecting an appropriate discount rate. Some organizations have a standard rate but, where this is not the case, then the discount rate should be chosen to reflect available interest rates (borrowing costs where the project must be funded from loans) plus some premium to reflect the fact that software projects are normally more risky than lending money to a bank. The exact discount rate is normally less important than ensuring that the same discount rate is used for all projects being compared. However, it is important to check that the ranking of projects is not sensitive to small changes in the discount rate – have a look at the following exercise.

Exercise 2.6

Calculate the net present value for each of the projects A, B and C shown in Table 2.4 using each of the discount rates 8%, 10% and 12%.

For each of the discount rates, decide which is the best project. What can you conclude from these results?

Table 2.4 Three estimated project cash flows

Year	Project A (£)	Project B (£)	Project C (£)
0	–8,000	–8,000	–10,000
1	4,000	1,000	2,000
2	4,000	2,000	2,000

(Contd)

3	2,000	4,000	6,000
4	1,000	3,000	2,000
5	500	9,000	2,000
6	500	-6,000	2,000
Net Profit	4,000	5,000	6,000

Alternatively, the discount rate can be thought of as a target rate of return. If, for example, we set a target rate of return of 15% we would reject any project that did not display a positive net present value using a 15% discount rate. Any project that displayed a positive NPV would be considered for selection – perhaps by using an additional set of criteria where candidate projects were competing for resources.

Internal rate of return

One disadvantage of NPV as a measure of profitability is that, although it may be used to compare projects, it might not be directly comparable with earnings from other investments or the costs of borrowing capital. Such costs are usually quoted as a percentage interest rate. The internal rate of return (IRR) attempts to provide a profitability measure as a percentage return that is directly comparable with interest rates. Thus, a project that showed an estimated IRR of 10% would be worthwhile if the capital could be borrowed for less than 10% or if the capital could not be invested elsewhere for a return greater than 10%.

The IRR is calculated as that percentage discount rate that would produce an NPV of zero. It is most easily calculated using a spreadsheet or other computer program that provides functions for calculating the IRR. Microsoft Excel, for example, provides IRR functions which, provided with an initial guess or seed value (which may be zero), will search for and return an IRR.

One deficiency of the IRR is that it does not indicate the absolute size of the return. A project with an NPV of £100,000 and an IRR of 15% can be more attractive than one with an NPV of £10,000 and an IRR of 18% – the return on capital is lower but the net benefits greater.

Another objection to the internal rate of return is that, under certain conditions, it is possible to find more than one rate that will produce a zero NPV. However, if there are multiple solutions, it is always appropriate to take the lowest value and ignore the others.

NPV and IRR are not, however, a complete answer to economic project evaluation.

- A total evaluation must also take into account the problems of funding the cash flows – will we, for example, be able to repay the interest on any borrowed money at the appropriate time?
- While a project's IRR might indicate a profitable project, future earnings from a relatively risky project might be far less reliable than earnings from, say, investing with a bank. We might undertake a more detailed risk analysis as described below.
- We must also consider any one project within the financial and economic framework of the organization as a whole – if we fund this one, will we also be able to fund other worthy projects?

1 → 10.17%
2 → 3.08%
3 → 15.24%

Exercise 2.7

Check if the projects *A*, *B*, and *C* shown in Table 2.4 are worth taking up when the rate of interest on borrowed capital is 15%.

2.6 Risk Evaluation

Every project involves risk. We have already noted that *project* risks, which prevent the project from being completed successfully, are different from the *business* risk that the delivered products are not profitable. Project risks will be discussed in Chapter 7. Here we focus on business risk.

Risk identification and ranking

In any project evaluation we should identify the risks and quantify their effects. One approach is to construct a project risk matrix utilizing a checklist of possible risks and classifying risks according to their relative importance and likelihood. Importance and likelihood need to be separately assessed – we might be less concerned with something that, although serious, is very unlikely to occur than with something less serious that is almost certain. Table 2.5 illustrates a basic project risk matrix listing some of the business risks for a project, with their importance and likelihood classified as high (H), medium (M), low (L) or exceedingly unlikely (—). So that projects may be compared, the list of risks must be the same for each project assessed. It is likely, in reality, that it would be longer than shown and more precise.

The project risk matrix may be used as a way of evaluating projects (those with high risks being less favoured) or as a means of identifying and ranking the risks for a specific project.

Table 2.5 A fragment of a basic project/business risk matrix for an e-commerce application

Risk	Importance	Likelihood
Client rejects proposed look and feel of site	H	—
Competitors undercut prices	H	M
Warehouse unable to deal with increased demand	M	L
Online payment has security problems	M	M
Maintenance costs higher than estimated	L	L
Response times deter purchasers	M	M

Risk and net present value

Where a project is relatively risky, it is a common practice to use a higher discount rate to calculate net present value. This risk premium might, for example, be an additional 2% for a reasonably safe project or 5% for a fairly risky one. Projects may be categorized as high, medium, or low risk using a scoring method and risk premiums designated for each category. The premiums, even if arbitrary, provide a consistent method of taking risk into account.

Cost–benefit analysis

A rather more sophisticated approach to the evaluation of risk is to consider each possible outcome and estimate the probability of its occurring and the corresponding value of the outcome. Rather than a single cash flow forecast for a project, we will then have a set of cash flow forecasts, each with an associated probability of occurring. The value of the project is then obtained by summing the cost or benefit for each possible outcome weighted by its corresponding probability. Exercise 2.8 illustrates how this may be done

Exercise 2.8

BuyRight, a software house, is considering developing a payroll application for use in academic institutions and is currently engaged in a cost–benefit analysis. Study of the market has shown that, if BuyRight can target it efficiently and no competing products become available, it will obtain a high level of sales generating an annual income of £800,000. It estimates that there is a 1 in 10 chances of this happening. However, a competitor might launch a competing application before its own launch date and then sales might generate only £100,000 per year. It estimates that there is a 30% chance of this happening. The most likely outcome, it believes, is somewhere in between these two extremes – it will gain a market lead by launching before any competing product becomes available and achieve an annual income of £650,000. BuyRight has therefore calculated its expected sales income as in Table 2.6.

TABLE 2.6 BuyRight's income forecasts

Sales	Annual sales income (£)	Probability	Expected value (£)
	i	p	$i \times p$
High	800,000	0.1	80,000
Medium	650,000	0.6	390,000
Low	100,000	0.3	30,000
Expected Income			500,000

Development costs are estimated at £750,000. Sales levels are expected to be constant for at least four years. Annual costs of marketing and product maintenance are estimated at £200,000, irrespective of the market share. Would you advise going ahead with the project?

This approach is frequently used to evaluate large projects such as the building of motorways, where variables such as traffic volumes, and hence the total benefit of shorter journey times, are uncertain. The technique, of course, relies on being able to assign probabilities of occurrence to each scenario, which requires extensive research.

When used to evaluate a single major project, the cost–benefit approach, by 'averaging out' the negative and positive outcomes of the different scenarios, does not take full account of 'worst-case scenarios'. Because of this, it is more appropriate for the evaluation of a portfolio of projects where overall profitability is the primary concern, more successful projects can offset the impact of less successful ones.

Risk profile analysis

An approach which attempts to overcome some of the objections to cost–benefit averaging is the construction of risk profiles using sensitivity analysis.

This involves varying each of the parameters that affect the project's cost or benefits to ascertain how sensitive the project's profitability is to each factor. We might, for example, vary one of our original estimates by plus or minus 5% and recalculate the expected costs and benefits for the project. By repeating this exercise for each of our estimates in turn we can evaluate the sensitivity of the project to each factor.

By studying the results of a sensitivity analysis we can identify those factors that are most important to the success of the project. We then need to decide whether we can exercise greater control over them or otherwise mitigate their effects. If neither is the case, then we must live with the risk or abandon the project.

Using decision trees

The approaches to risk analysis discussed previously rather assume that we are passive bystanders allowing nature to take its own course – the best we can do is to reject over-risky projects or choose those with the best risk profile. There are many situations, however, where we can evaluate whether a risk is important and, if it is, decide a suitable course of action.

Such decisions will limit or affect future options and, at any point, it is important to be able to assess how a decision will affect the future profitability of the project.

As an example, say a successful company is considering when to replace its sales order processing system. The decision largely rests upon the rate at which its business expands – if its market share significantly increases (which it believes will happen if rumours of a competitor's imminent bankruptcy are fulfilled) the existing system might need to be replaced within two years. Not replacing the system in time could be an expensive option as it could lead to lost revenue if it cannot cope with increased sales. Replacing the system immediately will, however, be expensive as it will mean deferring other projects already scheduled.

It is calculated that extending the existing system will have an NPV of £75,000, although if the market expands significantly, this will be turned into a loss with an NPV of –£1 00,000 due to lost revenue. If the market does expand, replacing the system now has an NPV of £250,000 due to the benefits of being able to handle increased sales and other benefits such as improved management information. If sales do not increase, however, the benefits will be severely reduced and the project will suffer a loss with an NPV of –£50,000.

The company estimate the likelihood of the market increasing significantly at 20% – and, hence, the probability that it will not increase at 80%. This scenario can be represented as a tree structure as shown in Figure 2.2.

The analysis of a decision tree consists of evaluating the expected benefit of taking each path from a decision point (denoted by D in Figure 2.2). The expected value of each path is the sum of the value of each possible outcome multiplied by its probability of occurrence. The expected value of extending the system is therefore £40,000 (75,000 × 0.8 – 100,000 × 0.2) and the expected value of replacing the system £10,000 (250,000 × 0.2 – 50,000 × 0.8). The company should therefore choose the option of extending the existing system.

✓

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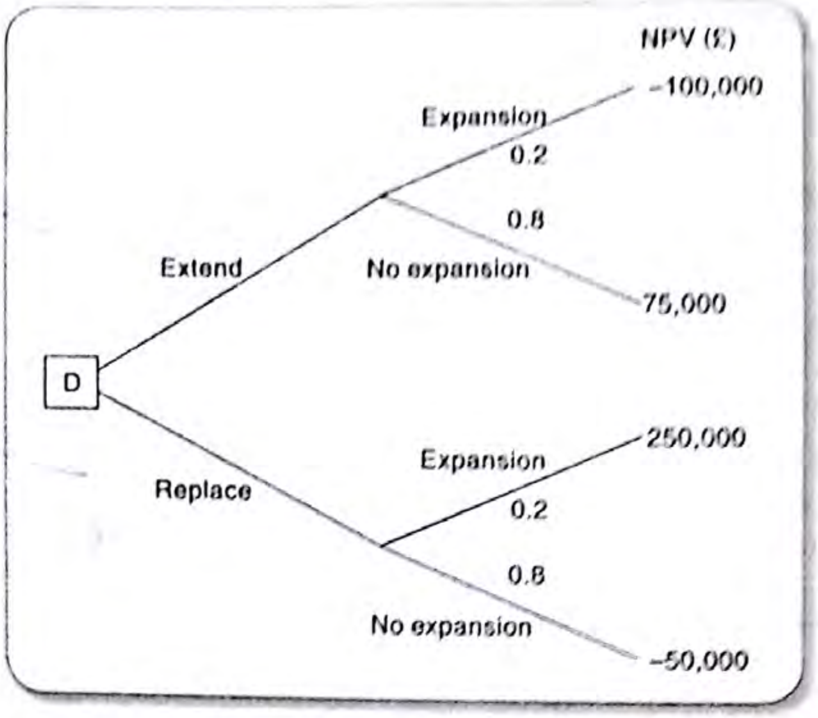


FIGURE 2.2 A decision tree

2.7 Programme Management

Fems' paper appeared in the *International Journal of Project Management* August 1991.

It should now have been made clear that there will be an element of risk with any single project. Even where projects produce real financial benefits, the precise size of those benefits will often be uncertain at the start of the project. This makes it important for organizations to take a broad view of all its projects to ensure that while some projects may disappoint, organizational developments overall will generate substantial benefits.

We introduced project portfolios in Section 2.3. We will now examine how careful management of programmes of projects can provide benefits. D. C. Ferns defined a programme as '*a group of projects that are managed in a coordinated way to gain benefits that would not be possible were the projects to be managed independently*'.

Programmes can exist in different forms, as can be seen below.

Business cycle programmes

The collection of projects that an organization undertakes within a particular planning cycle has already been discussed under the topic of project portfolios. We have seen that many organizations have a fixed budget for ICT development. Decisions have to be made about which projects to implement within that budget within the accounting period, which often coincides with the financial year.

Strategic programmes

Several projects together can implement a single strategy. For example, the merging of two organizations' computer systems could require several projects each dealing with a particular application area. Each activity could be treated as a distinct project, but would be coordinated as a programme.

Infrastructure programmes

Organizations can have various departments which carry out distinct, relatively self-contained, activities. In a local authority, one department might have responsibilities for the maintenance of highways, another for refuse collection, and another for education. These distinct activities will probably require distinct databases and information systems. In such a situation, the central ICT function would have responsibility for setting up and maintaining the ICT infrastructure, including the networks, workstations and servers upon which these distinct applications run. In these circumstances, an infrastructure programme could refer to the activities of identifying a common ICT infrastructure and its implementation and maintenance.

Research and development programmes

Truly innovative companies, especially those that are trying to develop new products for the market, are well aware that projects will vary in terms of their risk of failure and the potential returns that they might eventually reap. Some development projects will be relatively safe, and result in the final planned product, but that product might not be radically different from existing ones on the market. Other projects might be extremely risky, but the end result, if successful, could be a revolutionary technological breakthrough that meets some pressing but previously unsatisfied need.

Alan Webb (2001) 'When project management doesn't work' *Project Management Today* May.

A successful portfolio would need to be a mixture of 'safe projects' with relatively low returns and some riskier projects that might fail, but if successful would generate handsome profits which will offset the losses on the failures.

Innovative partnerships

Companies sometimes come together to work collaboratively on new technologies in a 'pre-competitive' phase. Separate projects in different organizations need to be coordinated and this might be done as a programme.

2.8 Managing the Allocation of Resources within Programmes

We are now going to examine in more detail, programmes, where resources have to be shared between concurrent projects. Typically, an ICT department has pools of particular types of expertise, such as software developers, database designers and network support staff, and these might be called upon to participate in a number of concurrent projects.

In these circumstances, programme managers will have concerns about the optimal use of specialist staff. These concerns can be contrasted with those of project managers – see Table 2.7.

The comparison is based on G. Reiss (1996) *Programme Management Demystified*, Chapman & Hall.

The project managers are said to have an 'impersonal relationship' with resource types because, essentially, they require, for example, a competent systems analyst and who fills that role does not matter. The programme manager has a number of individual systems analysts under his or her control whose deployment has to be planned.

When a project is planned, at the stage of allocating resources, programme management will be involved. Some activities in the project might have to be delayed until the requisite technical staff are freed from work on other projects. Where expensive technical staff are employed full-time, then you would want to avoid them

TABLE 2.7 Programme managers *versus* project managers

Programme manager	Project manager
Many simultaneous projects	One project at a time
Personal relationship with skilled resources	Impersonal relationship with resource type
Need to maximize utilization of resources	Need to minimize demand for resources
Projects tend to be similar	Projects tend to be dissimilar

having short periods of intense activity interspersed with long periods of idleness, during which they are still being paid. It is most economic when the demand for work is evenly spread from month to month.

As will be seen in Chapter 9 on monitoring and control, when a project is executed, activities can take longer (or sometimes even less time) than planned. Delays can mean that specialist staff are prevented from moving on to their next project. Hence, it can be seen that programme management needs continually to monitor the progress of projects and the use of resources.

2.9 Strategic Programme Management

A different form of programme management is where a portfolio of projects all contribute to a common objective. Take, for example, a business which carries out maintenance work for clients. A customer's experience of the organization might be found to be very variable and inconsistent. The employee who records the customer's requirements is different from the people who actually carry out the work and different again from the clerk who deals with the accounts. Often a customer has to explain to one company employee a problem that has already been discussed at length with some other employee. A business objective might be to present a consistent and uniform front to the client. This objective might require changes to a number of different systems which until now have been largely self-contained. The work to reorganize each individual area could be treated as a separate project, coordinated at a higher level as a programme.

These types of programme are most often needed by large organizations which have a large and complicated organizational structure. Government departments are typical examples and it is not surprising that the OGC, the United Kingdom government agency which was responsible (as the CCTA) for the introduction of PRINCE2 project management standards, has directed its attention to guidelines for effective programme management. The approach now described is based on the OGC guidelines.

Recall that OGC is the Office of Government Commerce which was formerly the Central Computing and Telecommunications Agency or CCTA.

2.10 Creating a Programme

Programme mandate

The OGC envisages that the planning of a programme will be triggered by the creation of an agreed *programme mandate*. Ideally this should be a formal document describing:

- The new services or capabilities the programme should deliver
- How the organization will be improved by use of the new services or capability
- How the programme fits with corporate goals and any other initiatives

At this point, a *programme director* ought to be appointed to provide initial leadership for the programme. To be successful, the programme needs a champion who is in a prominent position within the organization. This will signal the seriousness with which the organization takes the programme.

Programme brief

A *programme brief* is now produced which outlines the business case for the programme. It will have sections setting out:

- A preliminary *vision statement* which describes the new capacity that the organization seeks – it is described as 'preliminary' because this will later be elaborated
- The *benefits* that the programme should create – including when they are likely to be generated and how they might be measured
- Risks and issues
- Estimated costs, timescales and effort

Vision statement

The programme brief should give the sponsors enough information to decide whether to request a more detailed definition of the programme. This stage would justify the setting up of a small team. A *programme manager* with day-to-day responsibility for the programme would be appointed.

This group takes the vision statement from the project brief and refines and expands it. It should describe in detail the new capability that the programme will give the organization. If estimates for costs, performance and service levels cannot be provided, then there should at least be an indication of how they might be measured; for example, one might be able to say that repeat business will be increased, even if the precise size of the increase cannot be provided.

Blueprint

The achievement of the improved capability described in the vision statement can come only through changes to the structure and operations of the organization. These are detailed in the *blueprint*. This should contain:

- Business models outlining the new processes required
- Organizational structure – including the numbers of staff required in the new systems and the skills they will need
- The information systems, equipment and other, non-staff, resources that will be needed
- Data and information requirements
- Costs, performance and service level requirements

To return to the example of the organization which wants to present a consistent interface to its customers: while this aspiration might be stated in the vision statement, the way that it is to be achieved would have to be stated in the blueprint. This might, for example, suggest:

- The appointment of 'account managers' who could act as a point of contact for the client throughout their business transactions with the company.
- A common computer interface allowing the account manager to have access to all the information relating to a particular client or job, regardless of the computer system from which it originates.

The blueprint is supported by *benefit profiles* which estimate when the expected benefits will be experienced following implementation of the enhanced capability. One principle is that a programme should deliver tangible benefits. Being provided with a capability does not guarantee that it will be used to obtain the benefits envisaged. For example, as a part of the programme above, the marketing department might be provided with sales and demographic information which allows them to target potential customers more accurately. This should improve the ratio of sales revenue to advertising costs. However, just because this information is available does not mean that the marketing staff will necessarily make effective use of it. Hence the need for evidence of actual business benefits. The timing of the benefits needs to be carefully considered. Thus marketing campaigns that target particular customers might take time to plan and organize and the benefits in increased sales and/or lower advertising costs could take some months to become apparent.

The management structure needed to drive this programme forward would also need to be planned and organized.

A preliminary list of the projects needed to achieve the programme objectives will be created with estimated timescales. This *programme portfolio* will be presented to the programme sponsors.

Communication plans are considered in more detail in Chapter 12.

A major risk is that some of those whose work will be affected by the programme will not be drawn into the programme effectively. A *stakeholder map* identifying the groups of people with an interest in the project and its outcomes and their particular interests could be drawn up. This can be used to write a *communications strategy* and *plan* showing how the appropriate information flows between stakeholders can be set up and maintained.

We noted back in Chapter 1 that with conventional project planning, it is not usually possible to plan all the phases of a project at the outset, as much of the information needed to produce the detailed plans will not be available. This is more so with programmes. However, at the initial programme planning stage, a preliminary plan can be produced containing:

- The project portfolio
- Cost estimates for each project
- The benefits expected (including the appropriate benefits profile)
- Risks identified
- The resources needed to manage, support and monitor the programme

This information allows a *financial plan* to be created. This enables higher management to put in place the budget arrangements to meet the expected costs at identified points in time. These will be tied to points in the programme when higher management review progress and authorize further expenditure.

2.11 Aids to Programme Management

Dependency diagrams

There will often be physical and technical dependencies between projects. For example, a project to relocate staff from one building to another cannot start until the project to construct the new building has been completed. Dependency diagrams, which are very similar to activity networks at project level, can show these dependencies. However, where projects run concurrently in a programme and products interchange, the dependency diagrams could become quite complicated.

Figure 2.3 shows a dependency diagram for a programme to merge two organizations, the constituent parts of which are explained below.

A *Systems study/design* A project is carried out which examines the various existing IT applications in the two old organizations, analyses their functionality, and makes recommendations about how they are to be combined.

B *Corporate image design* Independently of Project A, this project is designing the corporate image for the new organization. This would include design of the new logo to be put on company documents.

C *Build common systems* Once Project A has been completed, work can be triggered on the construction of the new common ICT applications.

There will be interdependencies between C and D that will need to be managed.

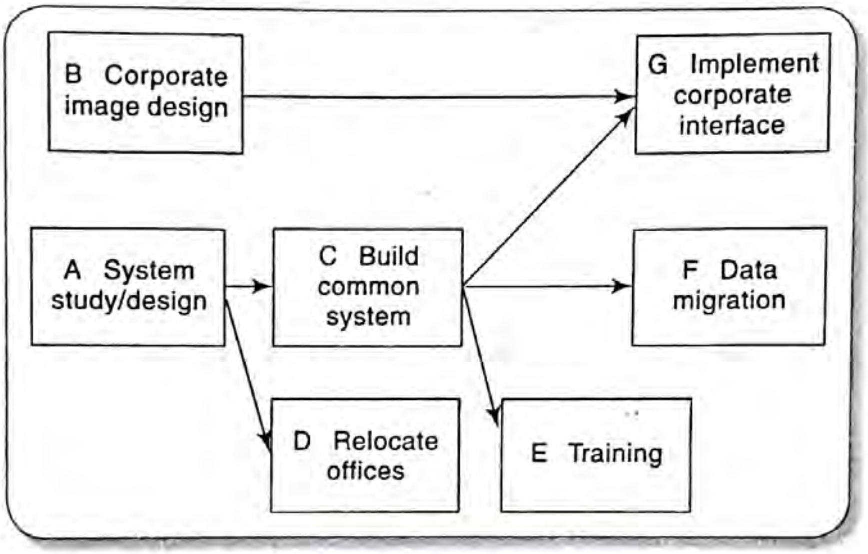


FIGURE 2.3 An example of a dependency diagram

D *Relocate offices* This is the project that plans and carries out the physical co-location of the staff in the two former organizations. In this scenario, this has to wait until the completion of Project A because that project has examined how the two sets of applications for the previous organizations could be brought together, and this has repercussions on the departmental structure of the new merged organization.

E *Training* Once staff have been brought together, perhaps with some staff being made redundant, training in the use of the new systems can begin.

F *Data migration* When the new, joint, applications have been developed and staff have been trained in their use, data can be migrated from existing databases to the new consolidated database.

G *Implement corporate interface* Before the new applications can 'go live', the interfaces, including the documentation generated for external customers, must be modified to conform to the new company image.

Delivery planning

The creation of a delivery dependency diagram would typically lead to the definition of *tranches* of projects. A tranche is a group of projects that will deliver their products as one step in the programme. The projects in a tranche should combine to provide a coherent new capability or set of benefits for the client. A consideration in scheduling a tranche will be the need to avoid contention for scarce resources.

Figure 2.4 shows how the programme's portfolio of projects can be organized into tranches, each of which delivers some tangible benefits to the user.

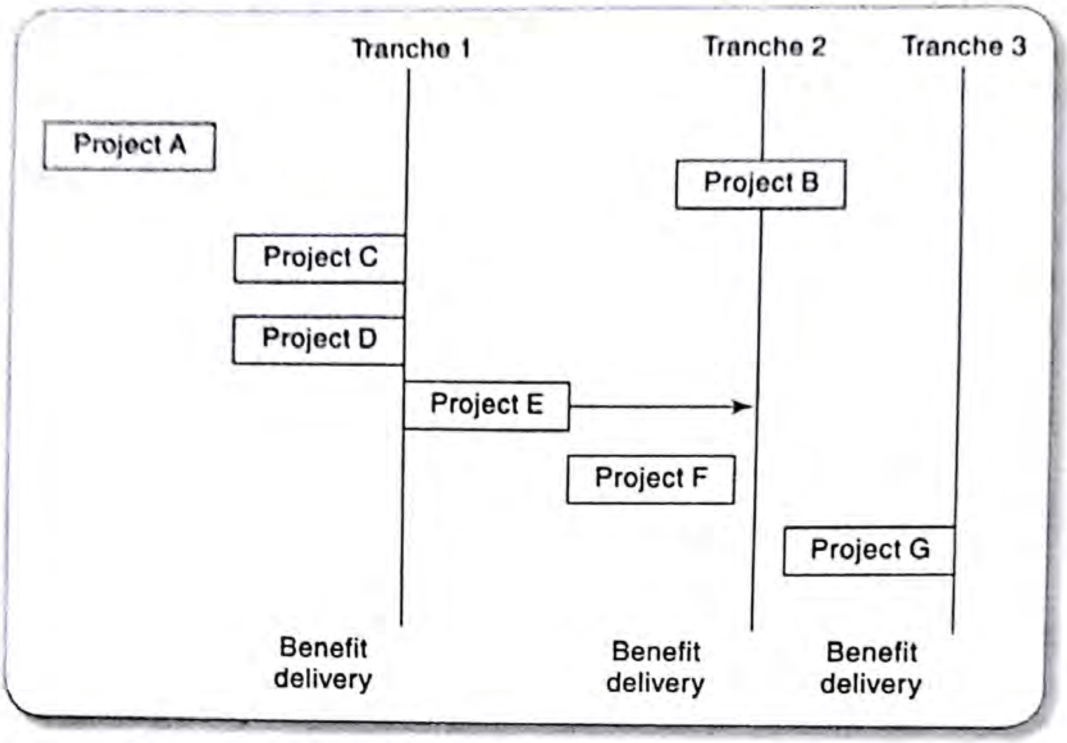


FIGURE 2.4 Delivering tranches of project deliverables

At this point, the planning of individual projects can be considered. This could be initiated by the writing of *project briefs*, defining the scope and objectives of each project.

2.12 Some Reservations about Programme Management

Some writers on project management have expressed reservations about the way they see the ideas of programme management being presented. It is argued that approaches like the one we have described above focus on *structure* – for example, who reports to whom – at the expense of *process* – for example, the basis on which decisions are made.

The main concern is that the programme may be seen as some kind of 'super-project'. This could lead to two problems: first, that programme management may exert an unnecessary control over the subordinate projects, leading to bureaucratic obstruction. The second is that programmes should be seen as the means by which the objectives of the business are converted into action at the level of projects. The business environment is constantly changing and as a consequence programmes need to evolve and be modified during the course of their execution. If the super-project idea predominates then too much planning at the beginning plus a reluctance to change the scope of the programme may lead to inflexibility.

As we have seen in the case of the company merger programme, the projects within a programme may be very different from one another. Also, some programmes – for example where engineering integration is important – may need to be quite tightly coordinated, whereas other programmes could afford a more flexible regime.

The main lessons here seem to be:

- programme management is *not* simply a scaled-up project management;
- different forms of programme management may be appropriate for different types of project.

2.13 Benefits Management

We have already noted that providing a capability does not guarantee that the capability will be used to deliver the planned benefits. Businesses have become aware of the lack of evidence of some investments in ICT increasing the productivity of organizations. Even with *business process re-engineering* (BPR), the radical reorganization of businesses to deliver improvements in efficiency and effectiveness, there are many reported cases where the expected benefits have not materialized.

Thomas K. Landauer (1995) *The Trouble with Computers: Usefulness, Usability and Productivity*, MIT Press, explores the issues of the 'productivity paradox' in IT.

Benefits management is an attempt to remedy this. It encompasses the identification, optimization and tracking of the expected benefits from a business change in order to ensure that they are actually achieved.

To do this, you must:

- Define the expected benefits from the programme
- Analyse the balance between costs and benefits
- Plan how the benefits will be achieved and measured
- Allocate responsibilities for the successful delivery of the benefits
- Monitor the realization of the benefits

Benefits can be of many different types, including:

- *Mandatory compliance* Governmental or European legislation might make certain changes mandatory.
- *Quality of service* An insurance company, for example, might want to settle claims by customers more quickly.
- *Productivity* The same, or even more, work can be done at less cost in staff time.
- *More motivated work force* This might be because of an improved rewards system, or through job enlargement or job enrichment.
- *Internal management bènefits* (for instance, better decision making) To take an insurance example again, better analysis of insurance claims could pinpoint those categories of business which are most risky and allow an insurance company to adjust premiums to cover this.

Job enlargement and enrichment will be discussed in Chapter 11.

- *Risk reduction* The insurance example might also be applicable here, but measures to protect an organization's networks and databases from intrusion and external malicious attack would be even more pertinent.
- *Economy* The reduction of costs, other than those related to staff – procurement policies might be put in place which encourage the consolidation of purchasing in order to take advantage of bulk-buying at discount.
- *Revenue enhancement/acceleration* The sooner bills reach customers, the sooner they can pay them.
- *Strategic fit* A change might not directly benefit a particular group within the organization but has to be made in order to obtain some strategic advantage for the organization as a whole.

A change could have more than one of these types of benefit. In fact, benefits are often inter-linked. An example of this is an insurance company which introduced a facility whereby when settling claims for damage to property, they directly arranged for contractors to carry out the remedial work. This improved quality of service for customers as it saved them the trouble of locating a reputable contractor, reduced costs to the insurance company because they could take advantage of the bulk purchase of services, and improved staff morale because of the goodwill generated between the insurance company's front-line staff and the customer.

Quantifying benefits

We have already seen that benefits can be:

- Quantified and valued – that is, a direct financial benefit is experienced
- Quantified but not valued – for example, a decrease in the number of customer complaints
- Identified but not easily quantified – for example, public approval of the organization in the locality where it is based

A particular activity might also have *disbenefits*. For example, increased sales might mean that more money has to be spent on expensive overtime working.

There can be controversy over whether a business change will lead to the particular benefits claimed for it, for example that a new company logo will improve staff morale. Some key tests have been suggested in order to sound out whether a putative benefit is likely to be genuine:

- Can you explain in precise terms why this benefit should result from this business change?
- Can you identify the ways in which we will be able to see the consequences of this benefit?
- If the required outcomes do occur, can they be attributed directly to the change, or could other factors explain them?
- Is there any way in which the benefits can be measured?

We mentioned earlier the need for *benefit profiles* that estimate when and how benefits will be experienced. Specific staff have to be allocated responsibility for ensuring that the planned benefits actually materialize. These will often be *business change managers*.

Benefits cannot normally be monitored in a purely project environment because the project will almost certainly have been officially closed before the benefits start to filter through.

In our view, benefits management brings to the fore the powerful idea that developers and users are *jointly* responsible for ensuring the delivery of the benefits of projects.

Conclusion

Some of the key points in this chapter are:

- Projects must be evaluated on strategic, technical and economic grounds.
- Many projects are not justifiable on their own, but are as part of a broader programme of projects that implement an organization's strategy.
- Not all benefits can be precisely quantified in financial values.

- Economic assessment involves the identification of all costs and income over the lifetime of the system, including its development and operation and checking that the total value of benefits exceeds total expenditure.
- Money received in the future is worth less than the same amount of money in hand now, which may be invested to earn interest.
- The uncertainty surrounding estimates of future returns lowers their real value measured now.
- Discounted cash flow techniques may be used to evaluate the present value of future cash flows taking account of interest rates and uncertainty.
- Cost–benefit analysis techniques and decision trees provide tools for evaluating expected outcomes and choosing between alternative strategies.

Further Exercises

1. Identify the major risks that could affect the success of the Brightmouth College payroll project and try to rank them in order of importance.
2. Explain why discounted cash flow techniques provide better criteria for project selection than net profit or return on investment.
3. An insurance company has examined the way that it settles house insurance claims. It decides to introduce a new computer-based claims settlement system which will reduce the time taken to settle claims. This reduction in effort is partly achieved by enabling the claims clerk to obtain the information needed directly, rather than having to go through other departments. Also, as part of the new process, new repair work will be allocated by the insurance company to authorized builders, decorators, plumbers etc., rather than the claimant having to make arrangements to get estimates, and so on.

   (a) Explain the possible benefits and disbenefits that might be generated by this application. Note that the benefits could come under the following headings:

   Mandatory compliance
   Quality of service
   Productivity
   More motivated work force
   Internal management benefits
   Risk reduction
   Economy
   Revenue enhancement/acceleration
   Strategic fit

   How could the actual benefit be assessed in each case?

   (b) When the application is implemented, some of the claims staff at the insurance company complain about the additional stress of dealing with irate customers grumbling about tradespeople being slow to do repair work or about poor quality workmanship. Also, in some places there are shortages of qualified repair people leading to delays in getting work done.

   Which projected benefits are being affected by these developments?

   How would you deal with these problems?

   How would you assess your success in dealing with these problems?

4. Suppose Brightmouth College has the option of either buying payroll software off-the-shelf at £50,000 or employing a programmer for six months at a salary of £5000 to develop the software. Perform cost-benefit analysis for the two options. You can make suitable assumptions regarding any factor that has not been mentioned in this problem statement.

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

(i) Which one of the following is typically not a concern of a project portfolio manager?

(a) Dependency among projects

(b) Duplication of work among projects

(c) Monitoring and control of projects

(d) Prioritization of projects for resource allocation

(ii) Which one of the following best defines a project portfolio of a software development organization?

(a) All projects that are being carried out within an organization.

(b) All projects being carried out by the organization for a specific customer.

(c) All projects that have been started in the same financial year.

(d) A range of products and services offered by the organization.

(iii) Consider that the cost for a project has been estimated to be £100,000. This amount needs to be invested upfront. The project duration is expected to be 1 year and the contracted sale value of the project outcome is £120,000. The bank interest rate is 10 percent. What is the internal rate of return (IRR) of the project?

(a) 17.3 percent (b) 18.2 percent

(c) 19.1 percent (d) 20.8 percent

(iv) Suppose the feasibility study of a software project shows that the project would cost £150,000 to complete and the expected profit per year after project completion is £15,000. What would be the annual return on investment (ROI) if the project is undertaken?

(a) 1 percent (b) 10 percent

(c) 15 percent (d) 20 percent

(v) Which one of the following financial parameters for a project indicates the time period at the end of which the total costs incurred would exactly equal the accrued benefits?

(a) Return on investment (ROI) (b) Payback period

(c) Internal rate of return (IRR) (d) Net present value (NPV)

(vi) Which one of the following is true regarding NPV (Net Present Value)?

(a) NPV assumes computation of the present value at the cost of capital

(b) NPV assumes computation of the present value using the rate of return from the best available investment option

(c) NPV assumes computation of the present value using the prevailing rate of interest

(d) NPV assumes computation of the present value using the rate of interest that may prevail from year to year

(vii) Suppose a software development company has undertaken a project that is expected to cost £160,000 to execute, and the expected inflow is £25,000 per quarter for the first year, £30,000 per quarter thereafter. What is the payback period for the project?

(a) 18 months (b) 19 months

(c) 24 months (d) 25 months

(viii) What would be the impact of an increase of the discount rate on the IRR of a project?

(a) IRR would increase (b) IRR would decrease

(c) IRR would be unaffected (d) IRR may increase or decrease

(ix) When the IRR is equal to the discount rate, what can be said about the NPV?

(a) It would be positive

(b) It would be equal to zero

(c) It would be negative

(d) It cannot be determined without knowing the exact discount rate

Answer the following two questions (x) and (xi) using the following information. A company is conducting the feasibility study of a project. The software has to be given free to the customer and also has to be deployed at the customer site free of charge. However, there is a maintenance contract for 5 years and the cash flow that will accrue in this regard has been shown in the following. The cost of development is shown as a negative cash accrual.

Year	Cash Flow
0	(£100,000)
1	£20,000
2	£30,000
3	£40,000
4	£50,000
5	£50,000

(x) What is the payback period of the proposed project?

(a) 3 years (b) 4 years

(c) 4.2 years (d) 5 years

(xi) What is the net present value of the proposed project if the discount rate is 10 percent?

(a) £82,823 (b) £93,472

(c) £17,187 (d) £15,832

(xii) Which one of the following is not true regarding ROI (Return on Investment)?

(a) It computes the discounted net income from an investment at a given point in time.

(b) It computes the net income per unit of investment.

(c) It quantifies the total profit accruing from an investment.

(d) It computes the time period at the end of which the discounted income equals the investment.

3 An Overview of Project Planning

Learning Objectives

- Approach project planning in an organized step-by-step manner
- See where the techniques described in other chapters fit into an overall planning approach
- Repeat the planning process in more detail for sets of activities within a project as the time comes to execute them

3.1 Introduction to Step Wise Project Planning

This chapter describes a framework of basic steps in project planning upon which the following chapters build. Many different techniques can be used in project planning and this chapter gives an overview of the points at which these techniques can be applied during project planning. Chapter 4 will illustrate how different projects may need different technical approaches, but the overall framework should always apply to the planning process.

The OGC was previously the CCTA (Central Computing and Telecommunications Agency).

The framework described is called the Step Wise method to help to distinguish it from other methods such as PRINCE2. PRINCE2 is a set of project management standards that were originally sponsored by what is now the Office of Government Commerce (OGC) for use on British government ICT and business change projects. The standards are now also widely used on non-government projects in the United Kingdom. Step Wise should be compatible with PRINCE2. It should be noted, however, that Step Wise covers only the planning stages of a project and not monitoring and control.

Appendix A adds some further details about the PRINCE2 approach.

It should be clearly understood that the Step Wise method discussed in this chapter aims to introduce the standardization of the project planning method brought about by PRINCE. PRINCE stands for PRojects IN Controlled Environments. PRINCE2 is in the public domain, and offers non-proprietary best practice guidance on project management. It is a *de facto* standard used extensively in UK and also internationally.

In contrast, the traditional project planning approach discussed in many other text books, and practised in many industries allows considerable flexibility in the steps to be carried out, and the manner in which they are carried out. However, it should be clearly understood that all our discussions in the subsequent chapters can be used in a traditional project management situation without any loss of generality.

In order to illustrate the Step Wise approach and how it might have to be adapted to deal with different circumstances, two parallel examples are used. Let us assume that there are two former Computing and Information Systems students who now have several years of software development experience under their belts.

Case Study

Example A: A Brightmouth College Payroll

Brigette has been working for the Management Services department of a local authority when she sees an advertisement for the position of Information Systems Development Officer at Brightmouth College. She is attracted to the idea of being her own boss, working in a relatively small organization and helping them to set up appropriate information systems from scratch. She applies for the job and gets it. One of the first tasks that confronts her is the implementation of independent payroll processing. (This scenario has already been used as the basis of some examples in Chapter 1.)

Case Study

Example B: International Office Equipment Annual Maintenance Contracts

Amanda works for International Office Equipment (IOE), which assembles, supplies, installs and services various items of high-technology office equipment. An expanding area of their work is the maintenance of ICT equipment. They have now started to undertake maintenance of equipment of which they were not the original suppliers. An existing application built by the in-house ICT department allows sales staff to input and generate invoices for completed work. A large organization might have to call out IOE several times during a month to deal with problems with equipment. Each month a batch run of the system generates monthly statements for customers so that only one payment a month needs to be made. The management of IOE would like to provide a service where for a single annual payment customers would get free servicing and problem resolution for a pre-specified set of equipment. Amanda has been given her first project management role, the task of implementing this extension to the IOE maintenance jobs billing system.

The enhanced application will need a means of recording the details of the items of equipment to be covered by a customer's annual maintenance contract. The annual fee will depend on the numbers of each type of equipment item that is to be covered. Even though the jobs done under this contract will not be charged for, the work will be recorded to allow for an analysis of costs and the profitability of each customer and each type of equipment. This will provide information which will allow IOE to set future contract prices at an optimally profitable level. At the moment, job details are only recorded after job completion so that invoices can be generated. The new system will allow a central coordinator to allocate jobs to engineers and the system to notify engineers of urgent jobs automatically via their mobile phones.

In Table 3.1 we outline the general approach that might be taken to planning these projects. Figure 3.1 provides an outline of the main planning activities. Steps 1 and 2 'Identify project scope and objectives' and 'Identify project infrastructure' could be tackled in parallel in some cases. Steps 5 and 6 will need to be repeated for each activity in the project.

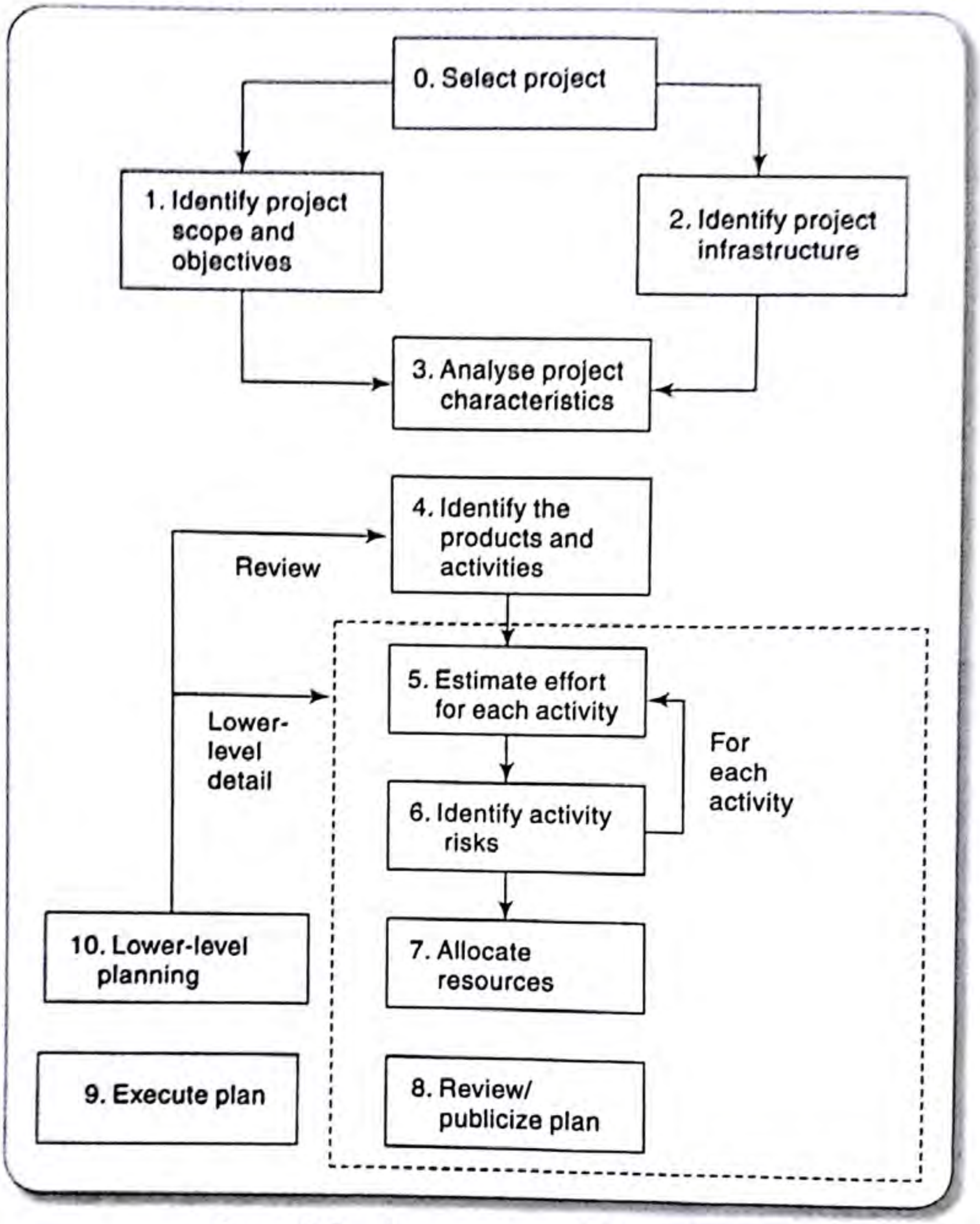

0. Select project
1. Identify project scope and objectives
2. Identify project infrastructure
3. Analyse project characteristics
4. Identify the products and activities
Review
5. Estimate effort for each activity
Lower-level detail
For each activity
6. Identify activity risks
7. Allocate resources
10. Lower-level planning
9. Execute plan
8. Review/ publicize plan

FIGURE 3.1 An overview of Step Wise

A major principle of project planning is to plan in outline first and then in more detail as the time to carry out an activity approaches. Hence the lists of products and activities that are the result of Step 4 will be reviewed when the tasks connected with a particular phase of a project are considered in more detail. This will be followed by a more detailed iteration of Steps 5 to 8 for the phase under consideration.

3.2 Step 0: Select Project

This is called Step 0 because in a way it is outside the main project planning process. Proposed projects do not appear out of thin air – some process must decide to initiate this project rather than some other. While a

TABLE 3.1 An outline of Step Wise planning activities

Step	Activities within step
0	Select project
1	Identify project scope and objectives 1.1 Identify objectives and measures of effectiveness in meeting them 1.2 Establish a project authority 1.3 Identify stakeholders 1.4 Modify objectives in the light of stakeholder analysis 1.5 Establish methods of communication with all parties
2	Identify project infrastructure 2.1 Establish relationship between project and strategic planning 2.2 Identify installation standards and procedures 2.3 Identify project team organization
3	Analyse project characteristics 3.1 Distinguish the project as either objective- or product-driven 3.2 Analyse other project characteristics 3.3 Identify high-level project risks 3.4 Take into account user requirements concerning implementation 3.5 Select general life-cycle approach 3.6 Review overall resource estimates
4	Identify project products and activities 4.1 Identify and describe project products (including quality criteria) 4.2 Document generic product flows 4.3 Recognize product instances 4.4 Produce ideal activity network 4.5 Modify ideal to take into account need for stages and checkpoints
5	Estimate effort for each activity 5.1 Carry out bottom-up estimates 5.2 Revise plan to create controllable activities
6	Identify activity risks 6.1 Identify and quantify activity-based risks 6.2 Plan risk reduction and contingency measures where appropriate 6.3 Adjust plans and estimates to take account of risks
7	Allocate resources 7.1 Identify and allocate resources 7.2 Revise plans and estimates to take account of resource constraints
8	Review/publicize plan 8.1 Review quality aspects of project plan 8.2 Document plans and obtain agreement
9/10	Execute plan/lower levels of planning This may require the reiteration of the planning process at a lower level

Chapter 2 has already discussed these issues in some detail.

feasibility study might suggest that there is a business case for the project, it would still need to be established that it should have priority over other projects. This evaluation of the merits of projects could be part of project portfolio management.

3.3 Step 1: Identify Project Scope and Objectives

The activities in this step ensure that all the parties to the project agree on the objectives and are committed to the success of the project. We have already looked at the importance of the correct definition of objectives in Chapter 1.

Step 1.1: Identify objectives and practical measures of the effectiveness in meeting those objectives

Case Study **Examples: Project Objectives**

The project objectives for the Brightmouth College payroll project have already been discussed in Exercise 1.8.

Amanda at JOE has the objectives clearly laid down for her in the recommendations of a business case report which have been accepted by JOE management. The main objectives are to allow:

- details of annual maintenance contracts to be recorded;
- details of maintenance work covered by these contracts to be recorded;
- analysis of costs to be carried out so that the optimal level of maintenance contract fees may be identified;
- recording of job requests and notification of jobs to engineers via mobile phones.

Other objectives are laid down that refer to expected timescales and the resources that might be used.

Step 1.2: Establish a project authority

We have already noted in Chapter 1 that a single overall project authority needs to be established so that there is unity of purpose among all those concerned.

Step 1.3: Stakeholder analysis – identify all stakeholders in the project and their interests

Recall that this was the basis of a discussion in Chapter 1. Essentially all the parties who have an interest in the project need to be identified. In that chapter we listed as an example the stakeholders in the Brightmouth College payroll project.

Exercise 3.1

What important stakeholders outside the IOE organization might be considered in the case of the IOE annual maintenance contracts system?

Case Study — Examples: Project Authorities

Amanda finds that her manager and the main user management have already set up a Project Board which will have overall direction of the project. She is a little concerned as the equipment maintenance staff are organized with different sections dealing with different types of equipment. This means that a customer could have work done by several different sections. Not all the sections are represented on the Project Board and Amanda is aware that there are some differences of opinion between some sections. It is left to the user representatives on the board to resolve those differences and to present an agreed policy to the systems developers.

Throughout the text we use capitalized initial letters to indicate a term that has a precise meaning in the PRINCE2 standards, e.g. Project Board.

Brigette finds that effectively she has two different clients for the payroll system: the finance and human resources departments. To help resolve conflicts, it is agreed that the managers of both departments should attend a monthly meeting with the vice-principal which Brigette has arranged in order to steer the project.

Step 1.4: Modify objectives in the light of stakeholder analysis

In order to gain the full cooperation of all concerned, it might be necessary to modify the project objectives. This could mean adding new features to the system which give a benefit to some stakeholders as a means of assuring their commitment to the project. This is potentially dangerous as the system size may be increased and the original objectives obscured. Because of these dangers, it is suggested that this process be done consciously and in a controlled manner.

Compare this with the 'Theory W' of Boehm and Ross mentioned in Chapter 1.

Case Study — Examples: Modified Project Objectives

The IOE maintenance staff are to be given the extra task of entering data about completed jobs. As no customer charges are generated by visits under annual maintenance contracts, engineers may feel that completing cost details is unnecessary bureaucracy, and start to do this in a careless and inaccurate manner. To give some benefit to the engineers, the system is to be extended to reorder spare parts automatically when required. It will also automatically capture timesheet details which previously had to be completed by hand.

At Brightmouth College, the human resources department has a lot of work preparing payroll details for finance. It would be tactful to agree to produce some management information reports for human resources from the payroll details held on the computer.

Step 1.5: Establish methods of communication with all parties

For internal staff this should be fairly straightforward, but a project leader implementing a payroll system would need to find a contact point with BACS (Bankers Automated Clearing Scheme), for instance. This step could lead to the first draft of a *communications plan* – to read more about these, see Chapter 12.

3.4 Step 2: Identify Project Infrastructure

Projects are never carried out in a vacuum. There is usually some kind of existing infrastructure into which the project must fit. Where project managers are new to the organization, they must find out the precise nature of this infrastructure. This could be the case where the project manager works for an outside organization carrying out the work for a client.

Step 2.1: Identify relationship between the project and strategic planning

B. Iyer and R. Gottlieb (2004) 'The Four-Domain Architecture: an approach to support enterprise architecture design' *IBM Systems Journal* 43(3) 587–97 provides a good introduction to enterprise architecture concepts.

We saw in Chapter 2 how project portfolio management supported the selection of the projects to be carried out by an organization. Also, how programme management can ensure that a group of projects contribute to a common organizational strategy. There is also a technical framework within which the proposed new systems are to fit. Hardware and software standards, for example, are needed so that various systems can communicate with each other. These technical strategic decisions should be documented as part of an *enterprise architecture* process. Compliance with the enterprise architecture should ensure that successive ICT projects create software and other components compatible with those created by previous projects and also with the existing hardware and software platforms.

Case Study

Examples: Role of Existing Strategic Plans

Enterprise Resource Planning (ERP) systems are integrated software applications usually acquired as off-the-shelf packages that require considerable customization. They integrate all the standard financial and trading applications common to most businesses.

Amanda finds at IOE that there is a well-defined rolling strategic plan which has identified her annual maintenance contracts subsystem as an important required development. Because it is an extension of an existing system, the hardware and software platforms upon which the application are to run are dictated.

Brigette at Brightmouth College finds that there is an overall College strategic plan which describes new courses to be developed, and so on, and mentions in passing the need for 'appropriate administrative procedures' to be in place. There is a recommendation in a consultant's report concerning the implications of financial autonomy that independent payroll processing be implemented as just one module in an ERP system which would cover all the college's financial processing needs. Although the college has quite a lot of ICT equipment for teaching purposes, there is no machine set aside for payroll processing and the intention is that the hardware to run the payroll will be acquired at the same time as the software.

Step 2.2: Identify installation standards and procedures

Any organization that develops software should define their development procedures. As a minimum, the normal stages in the software life cycle to be carried out should be documented along with the products created at each stage.

See discussion of the ISO/IEC 12207 standard in Chapter 1.

Change control and *configuration management* standards should be in place to ensure that changes to requirements are implemented in a safe and orderly way.

The procedural standards may lay down the quality checks that need to be done at each point of the project life cycle or these may be documented in a separate *quality standards and procedures* manual.

See Chapter 9 on monitoring and control.

The organization, as part of its monitoring and control policy, may have a *measurement programme* in place which dictates that certain statistics have to be collected at various stages of a project.

Finally the project manager should be aware of any *project planning and control standards*. These will relate to how the project is controlled: for example, the way that the hours spent by team members on individual tasks are recorded on timesheets.

Case Study — Examples: Identifying Standards

Amanda at IOE finds that there is a very weighty volume of development standards which, among other things, specifies that a specific structured systems analysis and design method be used. She finds that a separate document has been prepared which lays down quality procedures. This specifies when the reviews of work will be carried out and describes detailed procedures governing how the reviews are to be done. Amanda also finds a set of project management guidelines modelled on PRINCE2.

Brigette finds no documents of the nature that Amanda found at IOE except for some handouts for students that have been produced by different lecturers at different times and which seem to contradict each other.

As a stop-gap measure, Brigette writes a brief document which states what the main stages of a 'project' (perhaps 'job for the user' would be a better term in this context) should be. This happens to be very similar to the list given in Chapter 1. She stresses that:

- no job of work to change a system or implement a new one is to be done without there being a detailed specification first;
- the users must record agreement to each specification in writing before the work is carried out.

She draws up a simple procedure for recording all changes to user requirements.

Brigette, of course, has no organizational quality procedures, but she dictates that each person in the group (including herself) has to get someone else to check through their work when they finish a major task and that, before any new or amended software is handed over to the users, someone other than the original developer should test it. She sets up a simple system to record errors found in system testing and their resolution. She also creates a log file of reported user problems with operational systems.

Brigette does not worry about timesheets but arranges an informal meeting with her colleagues each Monday morning to discuss how things are going and also arranges to see the vice-principal, who is her official boss, and the heads of the finance and human resources sections each month to review progress in general terms.

Step 2.3: Identify project team organization

Some of these issues will be discussed in Chapter 12 on working in teams.

Project leaders, especially in the case of large projects, might have some control over the way that their project team is to be organized. Often, though, the organizational structure will be dictated to them. For example, a high-level managerial decision might have been taken that software developers and business analysts will be in different groups, or that the development of business-to-consumer web applications will be done within a separate group from that responsible for 'traditional' database applications.

If the project leader does have some control over the project team organization then this would best be considered at a later stage (see Step 7: Allocate resources).

Case Study

Examples: Project Organization

At IOE, there are groups of business analysts set up as teams which deal with individual user departments. Hence the users always know whom they should contact within the information systems department if they have a problem. Software developers, however, work in a 'pool' and are allocated to specific projects on an ad hoc basis.

At Brightmouth College, a software developer has been seconded to Brigette from the technicians supporting the computing courses in the college. She is also allowed to recruit a trainee analyst/programmer. She is not unduly worried about the organizational structure needed.

3.5 Step 3: Analyse Project Characteristics

Chapter 4 elaborates on the process of analysing project characteristics.

The general purpose of this part of the planning operation is to ensure that the appropriate methods are used for the project.

Step 3.1: Distinguish the project as either objective- or product-driven

This has already been discussed in the first chapter. As development of a system advances it tends to become more product-driven, although the underlying objectives always remain and must be respected.

Step 3.2: Analyse other project characteristics (including quality-based ones)

For example, is an information system to be developed or a process control system, or will there be elements of both? Will the system be safety critical, where human life could be threatened by a malfunction?

Step 3.3: Identify high-level project risks

Consideration must be given to the risks that threaten the successful outcome of the project. Generally speaking, most risks can be attributed to the operational or development environment, the technical nature of the project or the type of product being created.

Case Study — **Examples: High-Level Risks**

We have already noted that Amanda has raised concerns about the possibility that engineers lack the motivation to complete with due care and attention the cost details for jobs done under annual contracts. Another risk relates to the software functionality which will produce cost analysis reports used for the future pricing of annual contracts. If the analysis is incorrect IOE could suffer financially. Amanda decides therefore that the analysis functionality will be produced using an iterative approach where an IOE marketing analyst will look at versions of the reports produced and suggest improvements to the methods of calculation and presentation before the system is finally made operational.

Brigette at Brightmouth College considers the application area to be very well defined. There is a risk, however, that there may be no package on the market that caters for the way that things are done at the moment. Brigette, therefore, decides that an early task in the project is to obtain information about the features of the main payroll packages that are available.

Step 3.4: Take into account user requirements concerning implementation

The clients may have their own procedural requirements. For example, an organization might mandate the use of a particular development method.

Step 3.5: Select development methodology and life-cycle approach

The development methodology and project life cycle to be used for the project will be influenced by the issues raised above. The idea of a methodology, that is, the group of methods to be used in a project, was discussed in Chapter 1. For many software developers, the choice of methods will seem obvious: they will use the ones that they have always used in the past. In Chapter 4 we recommend caution in assuming that the current project is really similar to previous ones.

Chapter 4 discusses life cycles in more detail.

As well as the methods to be used, there are generic ways of structuring projects, such as the use of the waterfall life cycle outlined in Chapter 4, that need to be considered. While the setting of objectives involves identifying the problems to be solved, this part of planning is working out the ways in which these problems are to be solved. For a project that is novel to the planner, some research into the methods typically used in the problem domain is worthwhile. For example, sometimes, as part of a project, a questionnaire survey has to be conducted. There are lots of books on the techniques used in such surveys and a wise move would be to look at one or two of them at the planning stage.

Chapter 5 goes into more detail on this topic. Function points are an attempt to measure system size without using lines of code.

Step 3.6: Review overall resource estimates

Once the major risks have been identified and the broad project approach has been decided upon, this would be a good point at which to re-estimate the effort and other resources required to implement the project. Where enough information is available an estimate based on function points might be appropriate.

3.6 Step 4: Identify Project Products and Activities

The more detailed planning of the individual activities now takes place. The longer-term planning is broad and in outline, while the more immediate tasks are planned in some detail.

Step 4.1: Identify and describe project products (or deliverables)

In general, there can be no project products that do not have activities that create them. Wherever possible, we ought also to ensure the reverse: that there are no activities that do not produce a tangible product. Identifying all the things the project is to create helps us to ensure that all the activities we need to carry out are accounted for. Some of these products will be handed over to the client at the end of the project – these are *deliverables*. Other products might not be in the final configuration, but are needed as *intermediate* products used in the process of creating the deliverables.

These products will include a large number of *technical* products, such as training material and operating instructions. There will also be products to do with the *management* and the *quality* of the project. Planning documents would, for example, be management products.

The products will form a hierarchy. The main products will have sets of component products which in turn may have sub-component products, and so on. These relationships can be documented in a Product Breakdown Structure (PBS) – see Figure 3.2. In this example the products have been grouped into those relating to the system as a whole, and those related to individual modules. A third 'group', which happens to have only one product, is called 'management products' and consists of progress reports. The asterisk in the progress reports indicates that there will be new instances of the entity 'progress report' created repeatedly throughout the project.

PRINCE2 suggests that the PBS be presented as a hierarchy diagram. In practice it may be more convenient to produce a structured list.

Note that in Figure 3.2 the only boxes that represent tangible products are those at the bottom of the hierarchy that are not further subdivided. Thus there are only six individual product types shown in the diagram. The boxes that are higher up – for example 'module products' – are simply the names of groups of items.

Some products are created from scratch, for example new software components. A product could quite easily be a document, such as a software design document. It

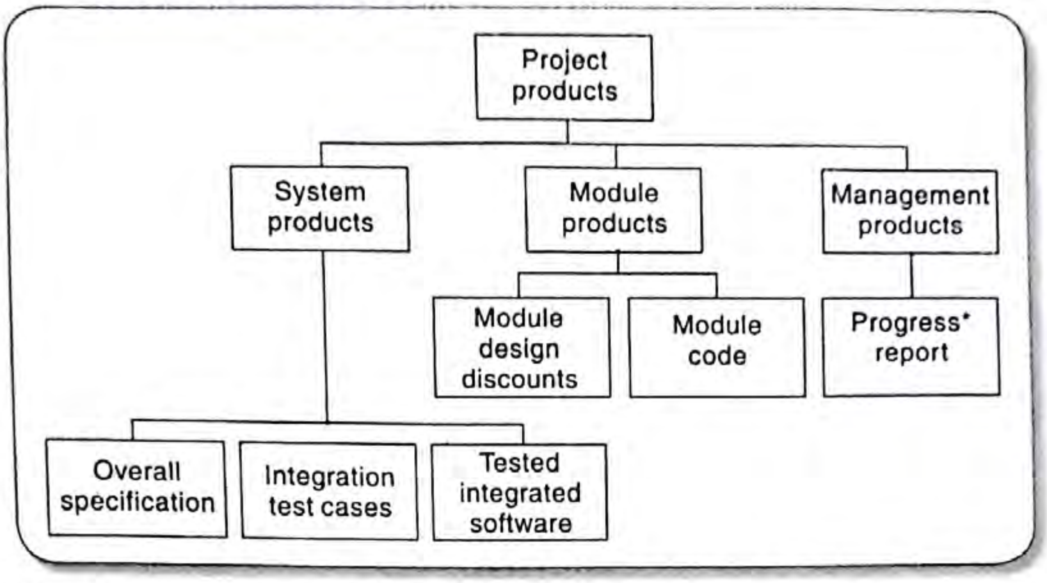


FIGURE 3.2 A fragment of a Product Breakdown Structure for a system development task (* indicates that further progress reports can be added during the course of the project.)

might be a modified version of something that already exists, such as an amended piece of code. A product could even be a person, such as a 'trained user', a product of the process of training. Always remember that a product is the result of an activity. A common error is to identify as products things that are really activities, such as 'training', 'design' and 'testing'. Specifying 'documentation' as a product should also be avoided – by itself this term is just too vague.

This part of the planning process draws heavily on the standards laid down in PRINCE2. These specify that products at the bottom of the PBS should be documented by *Product Descriptions* which contain:

- *Name/identity* of the product
- *Purpose* of the product
- *Derivation* of the product (that is, the other products from which it is derived)
- *Composition* of the product
- *Form* of the product
- Relevant *standards*
- *Quality* criteria that define whether the product is acceptable

Exercise 3.2

At Brightmouth College, Brigette has decided that the finance department at the college should carry out acceptance testing of the new payroll system. This type of testing ensures that the application has been set up in a way that allows the users to carry out their jobs accurately using the new system. As the finance department staff are not sure what test case documents should look like, Brigette draws up a product description of a test case. Write the content for this product description.

Case Study — Examples: Product Breakdown Structures

At IOE, Amanda finds that there is a standard PBS that she can use as a checklist for her own project.

Brigette at Brightmouth College has no installation standard PBS, although she can, of course, refer to various books for standard checklists. She decides that one part of the PBS should contain the products needed to help select the appropriate hardware and software for the payroll application (Figure 3.3).

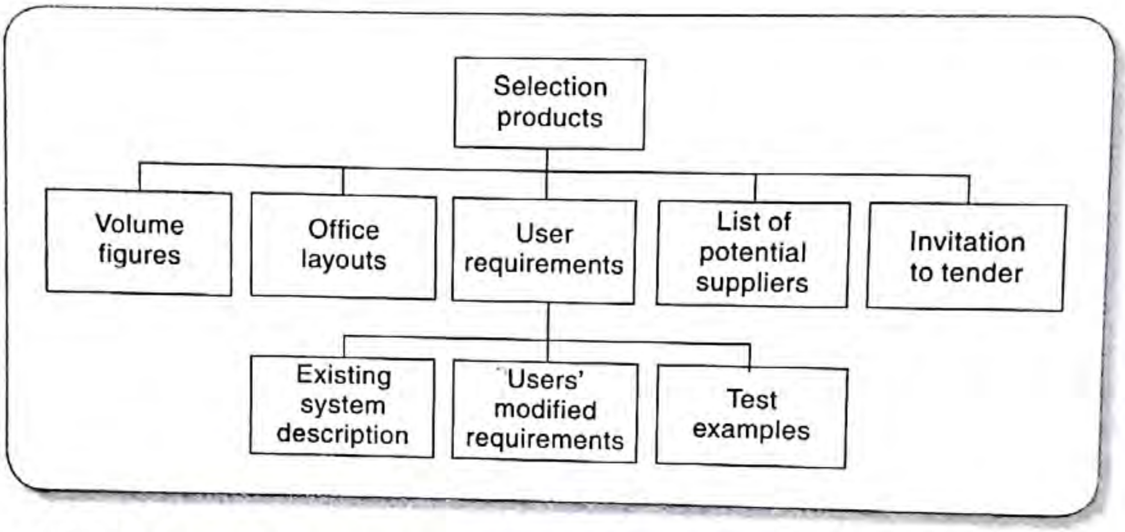


FIGURE 3.3 A Product Breakdown Structure (PBS) for the products needed to produce an invitation to tender (ITT)

Exercise 3.3

What would be the product breakdown structure of the deliverables of the vendor who would develop the Brightmouth College payroll software by customizing one of his existing products?

Step 4.2: Document generic product flows

The PFD effectively documents, in outline, the method (see Chapter 1) for the project.

Some products will need one or more other products to exist first before they can be created. For example, a program design must be created before the program can be written and the program specification must exist before the design can be commenced. These relationships can be portrayed in a *Product Flow Diagram* (PFD). Figure 3.4 gives an example. Note that the 'flow' in the diagram is assumed to be from top to bottom and left to right. In the example in Figure 3.4, 'user requirements' is in an oval which means that it is used by the project but is not created by it. It is often convenient to identify an overall product at the bottom of the diagram, in this case 'integrated/tested software', into which all the other products feed.

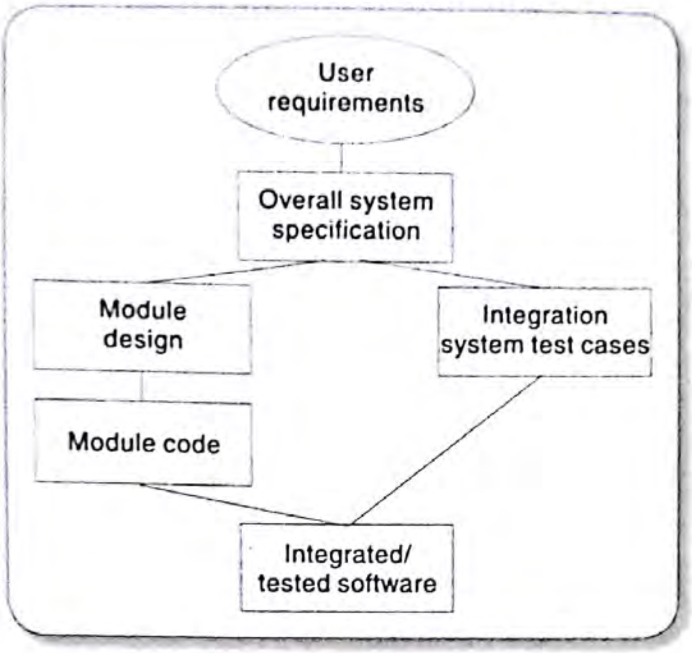

User requirements
Overall system specification
Module design
Integration system test cases
Module code
Integrated/ tested software

Figure 3.4 A fragment of a Product Flow Diagram (PFD) for a software development task

PFDs should not have links between products which loop back iteratively. This is emphatically *not* because iterations are not recognized. On the contrary, the PFD allows for looping back at any point. For example, in the PFD shown in Figure 3.4, say that during integration testing it was found that a user requirement had been missed in the overall system specification. If we go back to overall system specification and change it we can see from the PFD that all the products that follow it might need to be reworked. A new module might need to be designed and coded, test cases would need to be added to check that the new requirements had been successfully incorporated, and the integration testing would need to be repeated.

The form that a PFD takes will depend on assumptions and decisions about how the project is to be carried out. These decisions may not be obvious from the PFD and so a textual description explaining the reasons for the structure can be helpful.

Case Study **Examples: IOE Has Standard PFD**

At IOE, Amanda has an installation standard PFD for software development projects. This is because a recognized software development method is used which lays down a sequence of documents that have to be produced. This sequence of products can be straightforwardly documented as a PFD.

Exercise 3.4

Draw up a possible Product Flow Diagram (PFD) based on the Product Breakdown Structure (PBS) shown in Figure 3.3. This identifies some of the products of the Brightmouth payroll project, particularly those generated when gathering information to be presented to potential suppliers of the hardware as part of an 'invitation to tender'. The volume figures are such things as the number of employees for whom records will have to be maintained.

Step 4.3: Recognize product instances

This may be delayed to later in the project when more information is known.

Where the same generic PFD fragment relates to more than one instance of a particular type of product, an attempt should be made to identify each of those instances. In the example in Figure 3.2, it could be that in fact there are just two component software modules in the software to be built.

Step 4.4: Produce ideal activity network

In order to generate one product from another there must be one or more activities that carry out the transformation. By identifying these activities we can create an activity network which shows the tasks that have to be carried out and the order in which they have to be executed.

Case Study

Examples: Activity Network for IOE Maintenance Accounts

Part of the initial activity network developed from the PFD in Figure 3.4 for the software development task might look like Figure 3.5.

Exercise 3.5

Draw up an activity network for the Product Flow Diagram that you created in Exercise 3.4 (or the PFD given in the solution if you prefer!).

The activity networks are 'ideal' in the sense that no account has been taken of resource constraints. For example, in Figure 3.5, it is assumed that resources are available for both software modules to be developed in parallel. A good rule is that activity networks are never amended to take account of resource constraints.

Step 4.5: Modify the ideal to take into account need for stages and checkpoints

The approach to sequencing activities described above encourages the formulation of a plan which will minimize the overall duration, or 'elapsed time', for the project. It assumes that an activity will start as soon as the preceding ones upon which it depends have been completed.

There might, however, be a need to modify this by dividing the project into stages and introducing checkpoint activities. These are activities which draw together the products of preceding activities to check that they are compatible. This could potentially delay work on some elements of the project – there has to be a trade-off between efficiency and quality.

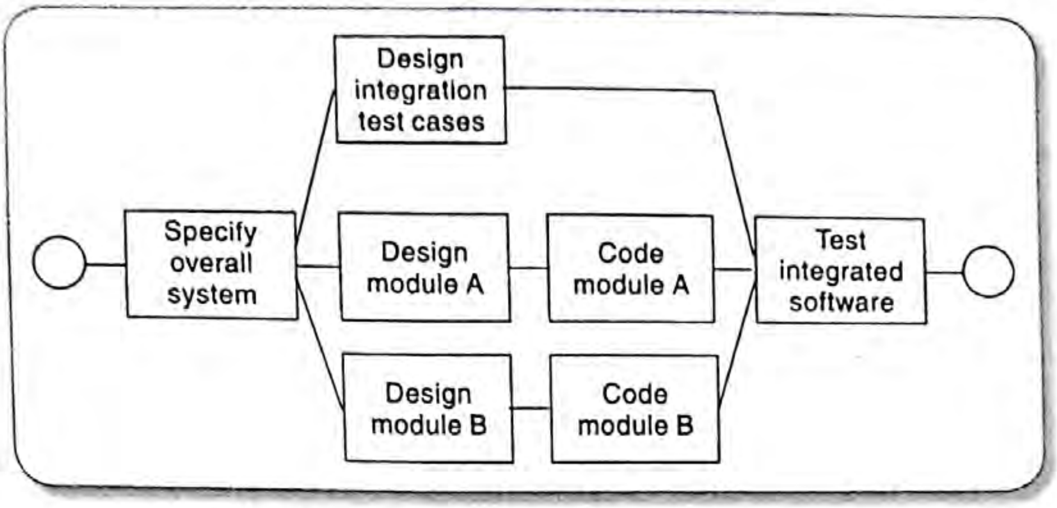


Figure 3.5 An example of an activity network

The people to whom the project manager reports could decide to leave the routine monitoring of activities to the project manager. However, there could be some key activities, or *milestones*, which represent the completion of important stages of the project of which they would want to take particular note. Checkpoint activities are often useful milestones.

Strictly, a milestone is a dummy activity with no duration that indicates the start or end of a group of activities. The milestone would therefore be *after* the checkpoint activity.

Exercise 3.6

In the example in Figure 3.5, it has been decided that the designs for modules A and B are to be checked for consistency by 'dry-running' them against the integration test cases before committing staff to software coding. Redraw the activity network to reflect this.

3.7 Step 5: Estimate Effort for Each Activity

Step 5.1: Carry out bottom-up estimates

Some overall estimates of effort, cost and duration will already have been done (see Step 3.6).

At this point, estimates of the staff effort required, the probable elapsed time and the non-staff resources needed for each activity will need to be produced. The method of arriving at each of these estimates will vary depending on the type of activity.

Chapter 5 on software effort estimation deals with this topic in more detail.

The difference between *elapsed time* and *effort* should be noted. Effort is the amount of work that needs to be done. If a task requires three members of staff to work for two full days each, the effort expended is six days. Elapsed time is the time between the start and end of a task. In our example above, if the three members of staff start and finish at the same time then the elapsed time for the activity would be two days.

The individual activity estimates of effort should be summed to get an overall bottom-up estimate which can be reconciled with the previous top-down estimate.

The activities on the activity network can be annotated with their elapsed times so that the overall duration of the project can be calculated.

Step 5.2: Revise plan to create controllable activities

The estimates for individual activities could reveal that some are going to take quite a long time. Long activities make a project difficult to control. If an activity involving system testing is to take 12 weeks, it would be difficult after six weeks to judge accurately whether 50 per cent of the work is completed. It would be better to break this down into a series of smaller subtasks.

Case Study — **Examples: IOE Annual Maintenance Contracts – Carry Out Bottom-Up Estimates**

At IOE, Amanda has to estimate the lines of code for each of the software modules. She looks at programs that have been coded for similar types of application at IOE in the past to get some idea of the size of the new modules. She then refers to some conversion tables that the information systems development department at IOE have produced which convert the lines of code into estimates of effort. Other tables allow her to allocate the estimated effort to the various stages of the project.

Although Brigette is aware that some additional programs might have to be written to deal with local requirements, the main software is to be obtained 'off the shelf' and so estimating based on lines of code would clearly be inappropriate. Instead, she looks at each individual task and allocates a time. She realizes that in many cases these represent 'targets' as she is uncertain at the moment how long these tasks will really take (see Step 6 below).

There might be a number of activities that are important, but individually take up very little time. For a training course, there might be a need to book rooms and equipment, notify those attending, register students on the training system, order refreshments, copy training materials, and so on. In a situation like this, it would be easier to bundle the activities into a single merged activity 'make training course arrangements' which could be supplemented with a checklist.

In general, try to make activities about the length of the reporting period used for monitoring and controlling the project. If you have a progress meeting every two weeks, then it would convenient to have activities of two weeks' duration on average, so that progress meetings would normally be made aware of completed tasks each time they are held.

3.8 Step 6: Identify Activity Risks

Step 6.1: Identify and quantify activity-based risks

Chapter 7 on risk touches on this topic in more detail.

Risks inherent in the overall nature of the project have already been considered in Step 3. We now want to look at each activity in turn and assess the risks to its successful outcome. Any plan is always based on certain assumptions. Say the design of a component is planned to take five days. This is based on the assumption that the client's requirement is clear and unambiguous. If it is not then additional effort to clarify the requirement would be needed. The possibility that an assumption upon which a plan is based is incorrect, constitutes a risk. In this example, one way of expressing the uncertainty would be to express the estimate of effort as a range of values.

As will be seen in Chapter 7, a simple way of dealing with uncertainty is to have a 'most likely' estimate for where everything works with no problems (such as users changing their requirements) and a second estimate that includes a safety margin so that it has an estimated 95 per cent chance of being met.

A project plan will be based on a huge number of assumptions, and so some way of picking out the risks that are most important is needed. The damage that each risk could cause and the likelihood of it occurring have to be gauged. This assessment can draw attention to the most serious risks. The usual effect if a problem materializes is to make the task longer or more costly.

Step 6.2: Plan risk reduction and contingency measures where appropriate

It may be possible to avoid or at least reduce some of the identified risks. On the other hand, *contingency plans* specify action that is to be taken if a risk materializes. For example, a contingency plan could be to use contract staff if a member of the project team is unavailable at a key time because of serious illness.

Step 6.3: Adjust overall plans and estimates to take account of risks

We may change our plans, perhaps by adding new activities which reduce risks. For example, a new programming language might mean we schedule training courses and time for the programmers to practise their new programming skills on some non-essential work.

Case Study | **Examples: Identifying Risks**

As well as the new software modules that will have to be written, Amanda has identified several existing modules that will need to be amended. The ease with which the modules can be amended will depend upon the way that they were originally written. There is therefore a risk that they may take longer than expected to modify.

Amanda takes no risk reduction measures as such but notes a pessimistic elapsed time for the amendment activity.

Brigette identifies as a risk the possible absence of key staff when investigating the user requirements, as this activity will take place over the holiday period. To reduce this risk, she adds a new activity, 'arrange user interviews', at the beginning of the project. This will give her advance notice of any likely problems of this nature.

3.9 Step 7: Allocate Resources

Step 7.1: Identify and allocate resources

The type of staff needed for each activity is recorded. The staff available for the project are identified and are provisionally allocated to tasks.

Chapter 8 on resource allocation covers this topic in more detail.

Step 7.2: Revise plans and estimates to take into account resource constraints

Some staff may be needed for more than one task at the same time and, in this case, an order of priority is established. The decisions made here may have an effect on the overall duration of the project when some tasks are delayed while waiting for staff to become free.

Ensuring someone is available to start work on an activity as soon as the preceding activities have been completed might mean that they are idle while waiting for the job to start and are therefore used inefficiently.

Gantt charts are named after Henry Gantt and 'Gantt' should therefore not be written in capital letters as if it stood for something!

The product of Steps 7.1 and 7.2 would typically be a Gantt chart – see Figure 3.6. The Gantt chart gives a clear picture of when activities will actually take place and highlights which ones will be executed at the same time. Activity networks can be misleading in this respect.

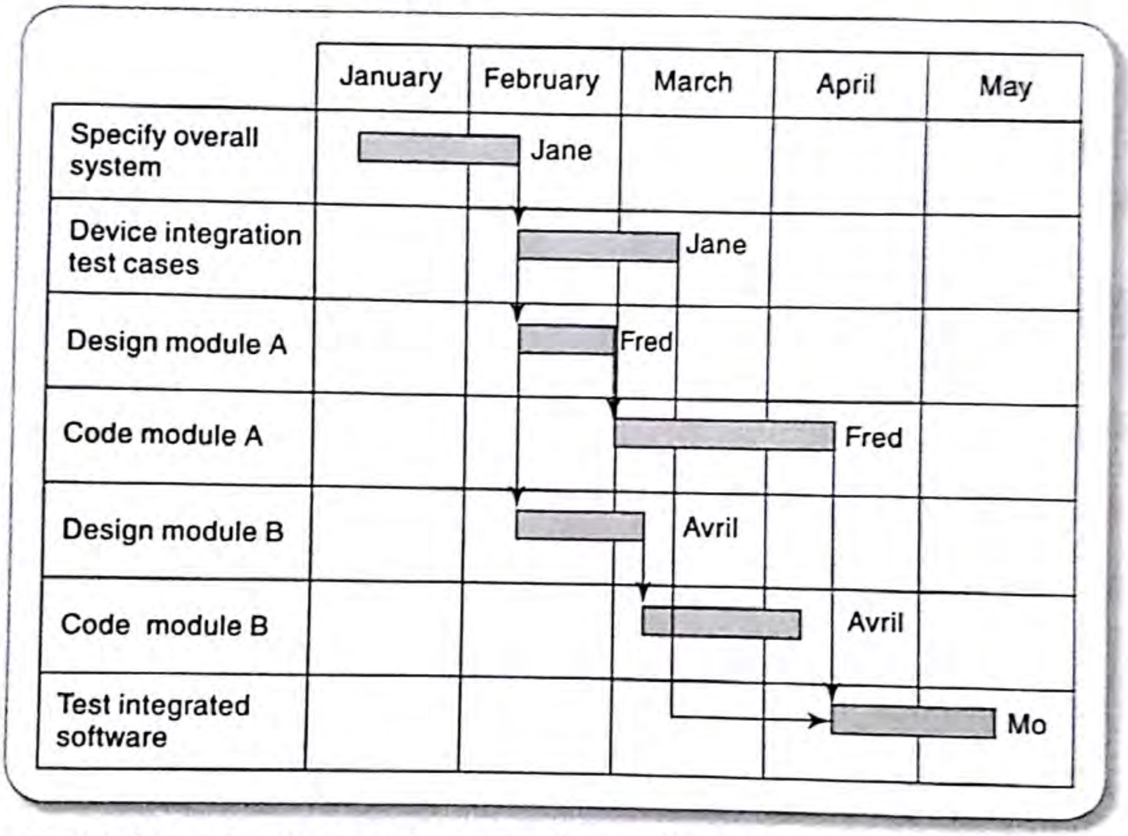


FIGURE 3.6 Gantt chart showing when staff will be carrying out tasks

Case Study

Examples: Taking Resource Constraints into Account

Amanda has now identified three new major software modules plus an existing software module that will need extensive amendment. At IOE the specification of modules is carried out by the lead systems analyst for the project (who in this case is Amanda) assisted by junior analyst/designers. Four analyst/programmers are available to carry out the design, coding and unit testing of the individual modules. After careful consideration and discussion with her manager, Amanda decides to use only three analyst/

programmers so as to minimize the risk of staff waiting between tasks and thus reduce staff costs. It is accepted that this decision, while reducing the cost of the project, will delay its end.

Brigette finds that she herself will have to carry out many important activities. She can reduce the workload on herself by delegating some work to her two colleagues, but she realizes that she will have to devote more time to specifying exactly what they will have to do and to checking their work. She adjusts her plan accordingly.

3.10 Step 8: Review/Publicize Plan

Step 8.1: Review quality aspects of the project plan

A danger when controlling any project is that an activity can reveal that an earlier activity was not properly completed and needs to be reworked. This, at a stroke, can transform a project that appears to be progressing satisfactorily into one that is badly out of control. It is important to know that when a task is reported as completed, it really is – hence the importance of quality reviews. Each task should have *quality criteria*. These are quality checks that have to be passed before the activity can be 'signed off' as completed.

Case Study **Examples: IOE Existing Quality Standards**

Amanda finds that at IOE, the Quality Standards and Procedures Manual lays down quality criteria for each type of task. For example, all module design documentation for any group of modules that interact with one another has to be reviewed by a group of colleagues before the coding can commence. This is to reduce the likelihood of integration problems when the components are finally executed together. Amanda adds an activity to her plan to deal with this.

Exercise 3.7

Brigette has no installation standards to help her apart from the minimal ones she has written herself. What quality checks might Brigette introduce to ensure that she has understood the users' requirements properly?

Step 8.2: Document plans and obtain agreement

It is important that the plans be carefully documented and that all the parties to the project understand and agree to the commitments required of them in the plan. This may sound obvious, but it is amazing how often this is not done. Chapter 12 describes the use of a *communications plan* to ensure appropriate communications between stakeholders at the right points in the project.

Exercise 3.8

At the end of Chapter 1 the main sections of a project plan document were listed. Draw up a table showing which Step Wise activities provide material for which sections of the project plan.

3.11 Steps 9 and 10: Execute Plan/Lower Levels of Planning

Once the project is underway, plans will need to be drawn up in greater detail for each activity as it becomes due. Detailed planning of the later stages will need to be delayed because more information will be available nearer the start of the stage. Of course, it is necessary to make provisional plans for the more distant tasks, because thinking about what needs to be done can help unearth potential problems, but sight should not be lost of the fact that these plans are provisional.

Case Study — Examples: Lower-Level Planning

While work is going on with the specification of the individual modules, Amanda has some time to start planning the integration tests in some detail. She finds that one of the modules – the one that deals with recording job requests – does not actually communicate directly with the other new modules and can therefore be reviewed independently of the others. She schedules an earlier review of this module as this allows coding of the module to be started earlier.

When Brigette comes to consider the activity 'draft invitation to tender', she has to familiarize herself with the detailed institutional rules and procedures that govern this process. She finds that in order to draft this document she will need to obtain some additional pieces of information from the users.

Conclusion

This chapter has presented a framework into which the techniques described in the other parts of the book should slot. It is suggested that any planning approach should have the following elements:

- Establishment of project objectives
- Analysis of the characteristics of the project
- Establishment of an infrastructure consisting of an appropriate organization and set of standards, methods and tools
- Identification of the products of the project and the activities needed to generate those products
- Allocation of resources to activities
- Establishment of quality controls

Project planning is an iterative process. As the time approaches for particular activities to be carried out they should be replanned in more detail.

Further Exercises

1. List the products created by the Step Wise planning process.
2. What products must exist before the activity 'test program' can take place? What products does this activity create?
3. An employee of a training organization has the task of creating case study exercises and solutions for a training course which teaches a new systems analysis and design method. The person's work plan has a three-week task 'learn new method'. A colleague suggests that this is unsatisfactory as a task as there are no concrete deliverables or products from the activity. What can be done about this?
4. In order to carry out usability tests for a new word processing package, the software has to be written and debugged. User instructions have to be available describing how the package is to be used. These have to be scrutinized in order to plan and design the tests. Subjects who will use the package in the tests will need to be selected. As part of this selection process, they will have to complete a questionnaire giving details of their past experience of, and training in, typing and using word processing packages. The subjects will carry out the required tasks using the word processing package. The tasks will be timed and any problems the subjects encounter with the package will be noted. After the test, the subjects will complete another questionnaire about what they felt about the package. All the data from the tests will be analysed and a report containing recommendations for changes to the package will be drawn up. Draw up a Product Breakdown Structure, a Product Flow Diagram and a preliminary activity network for the above.
5. Question 4 in the further exercises for Chapter 1 refers to a scenario relating to a training exercise. Using that scenario, draw up a Product Breakdown Structure, a Product Flow Diagram and a preliminary activity network.
6. Brightmouth College intends to automate the routine activities of its library including issuing books to users, return of books, handling fine collection, and querying availability of books. The library has around 10,000 books. At present, the activities of the library are being carried out manually by the four member library staff. The college intends to allot the development of the software to a vendor. The software would have to be transferred to the library in a fully operational mode. To speed up the delivery of software, the vendor would have to create the operational database during the development of the software. This would involve entering details of the existing books into a CSV (comma separated values) file. After the development of the software, the CSV data will have to be imported into the software. After alpha testing, the software would have to be tested in the operational environment. For this, the software would have to be run along side the manual system at the library for a week. During this time, user training would also have to be conducted.
   (a) Identify and represent the deliverables using a product breakdown structure (PBS)
   (b) Develop the product flow diagram
   (c) Develop an activity network

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

   (i) Which one of the following is usually not true?

   (a) Product breakdown structure helps identify the activities

   (b) Product breakdown structure helps to identify the deliverables

   (c) Lowest level of product breakdown structure are work items

   (d) Some items documented in the product breakdown structure may not be deliverable to the customer

   (ii) Which one of the following is an appropriate sequence of steps in project planning?

   (a) Develop product breakdown structure, develop activity network, estimate effort and allocate resource.

   (b) Develop activity network, develop product breakdown structure, estimate effort and allocate resource.

   (c) Develop product breakdown structure, estimate effort, develop activity network and allocate resource.

   (d) Allocate resource, develop product breakdown structure, develop activity network and estimate effort.

4 Selection of an Appropriate Project Approach

Learning Objectives

- Evaluate situations where software applications could be acquired off-the-shelf rather than being built specially
- Take account of the characteristics of the system to be developed when planning a project
- Select an appropriate process model
- Make best use of the waterfall process model where appropriate
- Reduce some risks by the creation of appropriate prototypes
- Reduce other risks by implementing the project in increments
- Identify where unnecessary organizational obstacles can be removed by using agile development methods

4.1 Introduction

The development of software in-house usually means that:

- The developers and the users belong to the same organization.
- The application will slot into a portfolio of existing computer-based systems.
- The methodologies and technologies are largely dictated by organizational standards and policies, including the existing enterprise architecture.

However, a software supplier could carry out successive development projects for a variety of external customers. They would need to review the methodologies and technologies to be used for each individual project. This decision-making process has been called *technical planning* by some, although here we use the term *project analysis*. Other terms for this process are *methods engineering* and *methods tailoring*. Even where development is in-house, any characteristics of the new project requiring a different approach from previous projects need to be considered. A wide range of system development methods exists, but many organizations get along without using any of the recognized approaches. Where methods are used, 'means–end inversion' can happen: developers focus on the means – the procedures and intermediate products of a prescribed method – at the expense of the 'end', the actual required outcomes of the work. These issues are the subject of this chapter.

B. Fitzgerald, N. L. Russo and T. O'Kane (2003). 'Software development method tailoring at Motorola' *Communications of the ACM* 46(4) 65–70 provides a good insight into how method tailoring works in practice.

The relevant part of the Step Wise approach is Step 3: *Analyse project characteristics.* The selection of a particular process model could add new products to the Project Breakdown Structure or new activities to the activity network. This will generate inputs for Step 4: Identify the products and activities of the project (see Figure 4.1).

In the remainder of this chapter we will look at how the characteristics of a project's environment and the application to be delivered influence the shape of the plan of

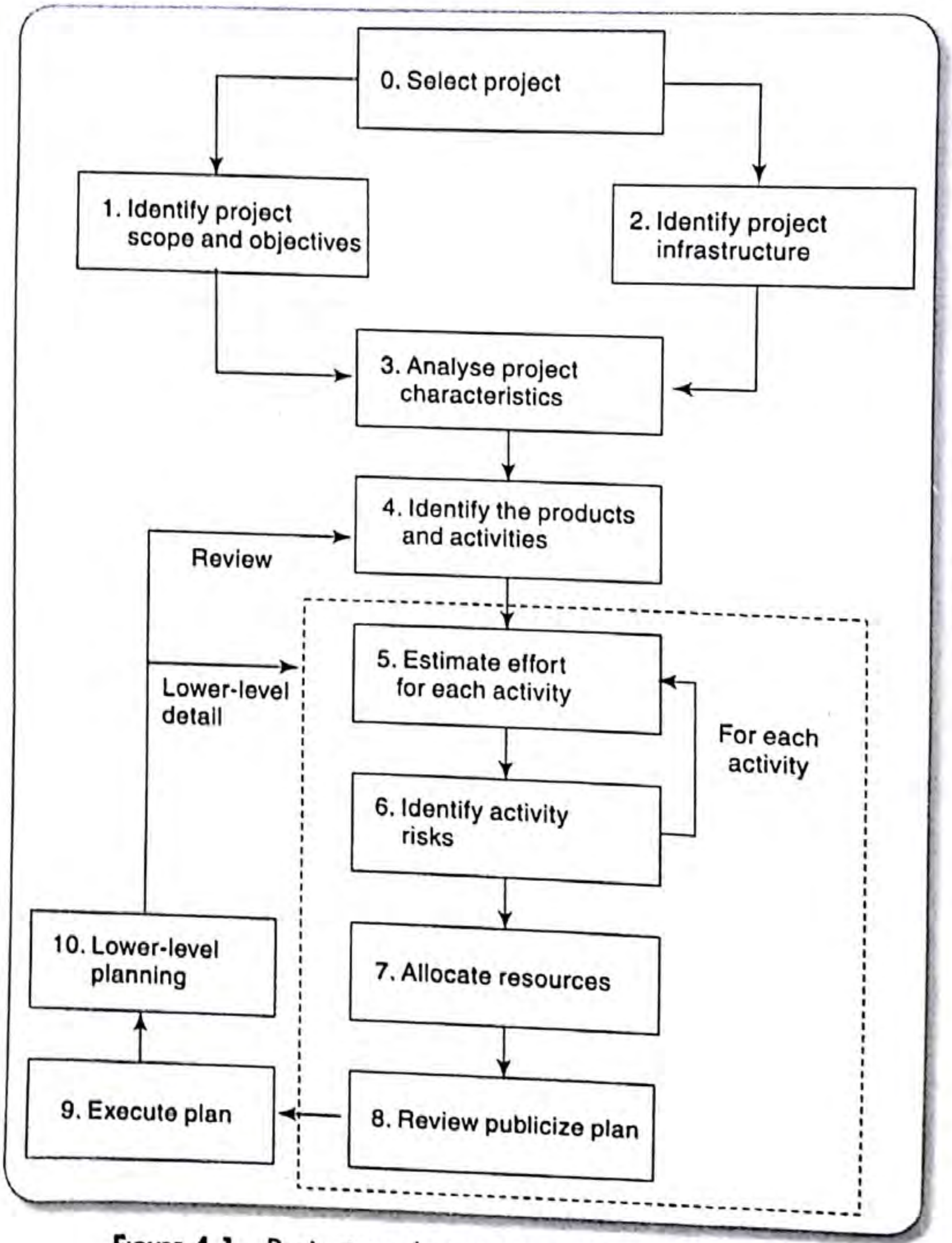

0. Select project
1. Identify project scope and objectives
2. Identify project infrastructure
3. Analyse project characteristics
4. Identify the products and activities
Review
Lower-level detail
5. Estimate effort for each activity
For each activity
6. Identify activity risks
7. Allocate resources
8. Review publicize plan
9. Execute plan
10. Lower-level planning

FIGURE 4.1 Project analysis is the subject of Step 3

a project. We will then look at some of the most common *process models*, namely the waterfall approach, prototyping and incremental delivery. Some of the ideas of prototyping and incremental delivery have been further developed and made part of *agile methods*. We will have a look at how these *lightweight* processes have been designed to remove what have been seen as the bureaucratic obstacles created by more formal, *heavyweight* methods.

4.2 Build or Buy?

Software development can be seen from two differing viewpoints: that of the developers and that of the clients or users. With *in-house development*, the developers and the users are in the same organization. Where the development is *outsourced*, they are in different organizations. In these days of global system development, the different organizations could be on different continents. These factors will affect the way that a project is organized.

The communication challenges of geographically dispersed projects are discussed in Chapter 12 on working in teams.

The development of a new IT application within an organization would often require the recruitment of technical staff who, once the project has been completed, will no longer be required. Because this project is a unique new development for the client organization there may be a lack of executives qualified to lead the effort. Contracting the project out to an external IT development company may be attractive in these circumstances. The contracting company will have technical and project expertise not readily available to the client. However, there would still be considerable management effort needed by the client to establish and manage the contract and this is the subject of Chapter 10 on managing contracts.

Whether in-house or outsourced, software development is still involved. An option which is increasingly taken – as in the case of the Brightmouth College payroll scenario – is to obtain a licence to run off-the-shelf OTS software. The advantages of such an approach include:

- The supplier of the application can spread the cost of development over a large number of customers and thus the cost per customer should be reduced.
- The software already exists and so
  - It can be examined and perhaps even trialed before acquisition
  - There is no delay while the software is being built
- Where lots of people have already used the software, most of the bugs are likely to have been reported and removed, leading to more reliable software.

However, there are disadvantages, which include the following.

- As you have the same application as everyone else, there is no competitive advantage.
- Modern off-the-shelf software tends to be very customizable: the characteristics of the application can be changed by means of various parameter tables. However, this flexibility has limits and you may end up having to change your office procedures in order to fit in with the computer system.
- You will not own the software code. This may rule out making modifications to the application in response to changes in the organization or its environment.
- Once you have acquired your off-the-shelf system, your organization may come to be very reliant upon it. This may create a considerable barrier to moving to a different application. The supplier may be in a position to charge inflated licence fees because you are effectively a captive customer.

We will explore these issues further in Chapter 10 on managing contracts. In the remainder of this chapter we focus on situations where new software is being developed, whether in-house or outsourced.

4.3 Choosing Methodologies and Technologies

Strictly speaking, methodology should refer to the 'study of methods'.

In the context of ICT system development and software engineering, the term *methodology* describes a collection of *methods*. We introduced 'method' in Chapter 1 as a general way of carrying out a specific task that could be applicable to any project needing to do that task. *Techniques* and methods are sometimes distinguished. Techniques tend to involve the application of scientific, mathematical or logical principles to resolve a particular kind of problem. They often require the practice of particular personal skills (the word 'technique' is derived from the Greek for skilful) – software design is a good example. Methods often involve the creation of *models*. A model is a representation of a system which abstracts certain features but ignores others. For example, an entity relationship diagram (ERD) is a model of the structure of the data used by a system. What can be confusing is that a software development life cycle itself is a type of system. Features of life cycles can therefore be abstracted and represented as 'models' as we will see later in this chapter. Some of these models can thus start to look a bit like methods.

Project analysis should select the most appropriate methodologies and technologies for a project. Methodologies include approaches like the Unified Software Development Process (USDP), Structured Systems Analysis and Design Method (SSADM) and Human-Centred Design, while technologies might include appropriate application-building and automated testing environments. The analysis identifies the methodology, but also selects the methods within the methodology that are to be deployed.

As well as the products and activities, the chosen methods and technologies will affect:

- The training requirements for development staff
- The types of staff to be recruited
- The development environment – both hardware and software
- System maintenance arrangements

We are now going to describe some of the steps of project analysis.

Identify project as either objective-driven or product-driven

The soft systems approach is described in P. Checkland and J. Scholes (1999) *Soft Systems Methodology in Action*, John Wiley and Sons.

In Chapter 1 we distinguished between *objective-driven* and *product-driven* projects. A product-driven project creates products defined before the start of the project. An objective-driven project will often have come first which will have defined the general software solution that is to be implemented.

The project manager's dream is to have well-defined objectives but as much freedom as possible about how those objectives are to be satisfied. An objective might be to pay staff in a start-up company reliably, accurately and with low administrative costs. The company does not have to specify the use of a particular packaged software solution at the outset – but as we will see, there can be exceptions to this.

Sometimes the objectives of the project are uncertain or are the subject of disagreement. People might be experiencing problems but no one knows exactly how to solve these problems. ICT specialists might provide help with some problems but assistance from other specialists might be needed with others. In these kinds of situation a *soft systems* approach might be considered.

Analyse other project characteristics

The following questions can be usefully asked.

- *Is a data-oriented or process-oriented system to be implemented?* *Data-oriented* systems generally mean information systems that will have a substantial database. *Process-oriented* systems refer to embedded control systems. It is not uncommon to have systems with elements of both. Some writers suggest that the OO approach is more suitable for process-oriented systems where control is important than for systems dominated by a relational database.

We first introduced the difference between information systems and embedded systems in Chapter 1.

- *Will the software that is to be produced be a general tool or application specific?* An example of a general tool would be a spreadsheet or a word processing package. An application-specific package could be, for example, an airline seat reservation system.
- *Are there specific tools available for implementing the particular type of application?* For example:
  - *Does it involve concurrent processing?* – the use of techniques appropriate to the analysis and design of such systems would be considered;
  - *Will the system to be created be knowledge-based?* – expert systems have rules which result in some 'expert advice' when applied to a problem, and specific methods and tools exist for developing such systems; or
  - *Will the system to be produced make heavy use of computer graphics?*

Note that here we are talking about writing the software tool, not its use.

- *Is the system to be created safety critical?* For instance, could a malfunction in the system endanger human life? If so, among other things, testing would become very important.
- *Is the system designed primarily to carry out predefined services or to be engaging and entertaining?* With software designed for entertainment, design and evaluation will need to be carried out differently from more conventional software products.
- *What is the nature of the hardware/software environment in which the system will operate?* The environment in which the final software will operate could be different from that in which it is to be developed. Embedded software might be developed on a large development machine which has lots of supporting software tools such as compilers, debuggers and static analysers, but then be downloaded to a small processor in the target configuration. A standalone desktop application needs a different approach to one for a mainframe or a client–server environment.

Exercise 4.1

How would you categorize each of the following systems according to the classification above?

(a) A payroll system

(b) A system to control a bottling plant

(c) A system which holds details of the plans of plant used by a water company to supply water to consumers

(d) A software package to support project managers

(e) A system used by lawyers to access case law relating to company taxation

Identify high-level project risks

Chapter 2 has already touched on some aspects of risk which are developed further in Chapter 7.

At the beginning of a project, some managers might expect elaborate plans even though we are ignorant of many important factors affecting the project. For example, until we have analysed the users' requirements in detail we cannot estimate the effort needed to build a system to meet those requirements. The greater the uncertainties at the beginning, the greater the risk that the project will be unsuccessful. Once we recognize an area of uncertainty we can, however, take steps to reduce its uncertainty.

One suggestion is that uncertainty can be associated with the *products, processes*, or *resources* of a project.

- *Product uncertainty* How well are the requirements understood? The users themselves could be uncertain about what a proposed information system is to do. The government, say, might introduce a new form of taxation but its detailed operation might not be known until case law has been built up. Some environments change so quickly that a seemingly precise and valid statement of requirements rapidly becomes out of date.

Extreme programming will be discussed in Section 4.15.

- *Process uncertainty* The project under consideration might be the first where an organization is using an approach like extreme programming (XP) or a new application-building tool. Any change in the way that the systems are developed introduces uncertainty.

Of course, some risk factors can increase both uncertainty and complexity.

- *Resource uncertainty* The main area of uncertainty here is likely to be the availability of staff of the right ability and experience. The larger the number of resources needed or the longer the duration of the project, the more inherently risky it will be.

Some factors – such as continually changing requirements – increase *uncertainty*, while others – for instance, software size – increase *complexity*. Different strategies are needed to deal with the two distinct types of risks.

Exercise 4.2

At IOE, Amanda has identified possible user resistance as a risk to the annual maintenance contracts project. Would you classify this as a product, process or resource risk? It may be that it does not fit into any of these categories and some other is needed.

Brigette at Brightmouth College has identified as a risk the possibility that no suitable payroll package would be available on the market. What other risks might be inherent in the Brightmouth College payroll project?

Take into account user requirements concerning implementation

Chapter 13 on software quality discusses BS EN ISO 9001.

We suggested earlier that staff planning a project should try to ensure that unnecessary constraints are not imposed on the way that a project's objectives are to be met. The example given was the specification of the exact payroll package to be deployed. Sometimes, such constraints are unavoidable. International conglomerates have found that imposing uniform applications and technologies throughout all their component parts can save time and money. Obtaining IT services for the whole organization from a single supplier can mean that large discounts can be negotiated.

A client organization often lays down standards that have to be adopted by any contractor providing software for them. Sometimes organizations specify that suppliers of software have BS EN ISO 9001 : 2000 or TickIT accreditation. This will affect the way projects are conducted.

Select general life-cycle approach

- *Control systems* A real-time system will need to be implemented using an appropriate methodology. Real-time systems that employ concurrent processing may have to use techniques such as Petri nets.
- *Information systems* Similarly, an information system will need a methodology, such as SSADM or Information Engineering, that matches that type of environment. SSADM would be especially appropriate where the project employs a large number of development staff whose work will need to be coordinated: the method lays down in detail the activities and products needed at each step. Team members would therefore know exactly what is expected.

SSADM as a named methodology is now rarely used, but many of methods within it are still in wide use – sometimes under the general name of business system development (BSD) techniques.

- *Availability of users* Where the software is for the general market rather than application and user specific, then a methodology which assumes that identifiable users exist who can be quizzed about their needs would have to be thought about with caution. Some business systems development methods assume an existing clerical system which can be analysed to yield the logical features of a new, computer-based, system. In these cases a marketing specialist may act as a surrogate user.
- *Specialized techniques* For example, expert system shells and logic-based programming languages have been invented to expedite the development of *knowledge-based systems*. Similarly, a number of specialized techniques and standard components are available to assist in the development of *graphics-based systems*.
- *Hardware environment* The environment in which the system is to operate could put constraints on the way it is to be implemented. The need for a fast response time or restricted computer memory might mean that only low-level programming languages can be used.
- *Safety-critical systems* Where safety and reliability are essential, this might justify the additional expense of a formal specification using a notation such as OCL. Extremely critical systems could justify the cost of having independent teams develop parallel systems with the same functionality. The operational systems can then run concurrently with continuous cross-checking. This is known as *n-version programming*.

OCL stands for Object Constraint Language.

- *Imprecise requirements* Uncertainties or a *novel hardware/software platform* mean that a prototyping approach should be considered. If the environment in which the system is to be implemented is a rapidly changing one, then serious consideration would need to be given to *incremental delivery*. If the users have *uncertain objectives* in connection with the project, then a *soft systems* approach might be desirable.

The implications of prototyping and the incremental approach are explored later in the chapter.

Exercise 4.3

What, in broad outline, would be the most suitable approach for each of the following?

(a) A system which calculates the amount of a drug that should be administered to a patient who has a particular complaint

(b) A system to administer a student loans scheme

(c) A system to control trains in the Channel Tunnel

4.4 Software Processes and Process Models

A software product development process usually starts when a request for the product is received from the customer. For a generic product, the marketing department of the company is usually considered as the customer. This expression of need for the product is called product inception. From the inception stage, a product undergoes a series of transformations through a few identifiable stages until it is fully developed and released to the customer. After release, the product is used by the customer and during this time the product needs to be maintained for fixing bugs and enhancing functionalities. This stage is called the maintenance stage. When the product is no longer useful to the customer, it is retired. This set of identifiable stages through which a product transits from inception to retirement form the life cycle of the product. The software life cycle is also commonly referred to as Software Development Life Cycle (SDLC) and software process.

A life cycle model (also called a process model) of a software product is a graphical or textual representation of its life cycle. Additionally, a process model may describe the details of various types of activities carried out during the different phases and the documents produced.

4.5 Choice of Process Models

The word 'process' emphasizes the idea of a system *in action.* In order to achieve an outcome, the system will have to execute one or more activities: this is its process. This applies to the development of computer-based applications. A number of interrelated activities have to be undertaken to create a final product. These activities can be organized in different ways and we can call these *process models.*

The planner selects methods and specifies how they are to be applied. Not all parts of a methodology such as USDP or SSADM will be compulsory. Many student projects have the rather basic failing that at the planning stage they claim that, say, SSADM is to be used: in the event all that is produced are a few SSADM fragments such as a top-level data flow diagram and a preliminary logical data structure diagram. If this is all the particular project requires, it should be explicitly stated.

4.6 Structure versus Speed of Delivery

The principle behind structured methods is 'get it right first time'.

Although some 'object-oriented' specialists might object(!), we include the OO approach as a structured method – after all, we hope it is not unstructured. Structured methods consist of sets of steps and rules which, when applied, generate system products such as use case diagrams. Each of these products is carefully defined. Such methods are more time consuming and expensive than more intuitive approaches. The pay-off, it is hoped, is a less error prone and more maintainable final system. This balance of costs and benefits is more likely to be justified on a large project involving many developers and users. Because of the additional effort needed and their greater applicability to large and complex projects, these are often called *heavyweight* methods.

It might be thought that users would generally welcome the more professional approach that structured methods imply. However, customers for software are concerned with getting working applications delivered quickly and at less cost and often see structured methods as unnecessarily bureaucratic and slow. One response to this has been *rapid application development* (RAD) which puts the emphasis on quickly producing prototypes of the software for users to evaluate.

The RAD approach does not preclude the use of some elements of structured methods such as the drafting of logical data structure diagrams but also adopts tactics such as *joint application development* (JAD) workshops. In these workshops, developers and users work together intensively for, say, three to five days and identify and agree fully documented system requirements. Often these workshops are conducted away from the normal business and development environments in *clean rooms*, special conference rooms free from outside interruption and suitably furnished with whiteboards and other aids to communication. Advocates of JAD believe that these hot-house conditions can speed up communication and negotiation that might otherwise take several weeks or months.

Joint Application Development by Jane Wood and Denise Silver, Wiley and Sons, 1995, is a useful introduction to JAD.

Use of JAD does not mean that the project is not structured. The definition of the scope of the project, the initial research involving the interviewing of key personnel and the creation of preliminary data and process models would need to planned and executed before the JAD sessions were organized. The results of JAD sessions could be implemented using quite conventional methods.

Another way of speeding up delivery is simply to deliver less. This can be done by breaking a large development into a series of small increments, each of which delivers a small amount of useful functionality quickly.

Two competing pressures can be seen. One is to get the job done as quickly and cheaply as possible, and the other is to make sure that the final product has a robust structure which will be able to meet evolving needs. Later in this chapter and in Chapter 12 we will discuss the increasingly important topic of agile methods which focuses on lightweight processes. There is, however, a contrasting approach which is the attempt to create *model-driven architectures* (MDA). System development using MDA involves creating a platform-independent model (PIM) which specifies system functionality using UML diagrams supplemented by additional information recorded in the Object Constraint Language (OCL). A PIM is the logical structure that should apply regardless of the software and hardware environment in which the system is to be implemented. This can be transformed into a platform-specific model (PSM) that takes account of a particular development and implementation environment. A PSM can then be transformed into executable code to implement a working system. The goal is that once a PIM had been created the creation of PSMs and executable code will be automated. At present, the automation of these transformation processes is still being developed.

4.7 The Waterfall Model

This is the 'classical' model of system development that is also known as the *one-shot* or *once-through* model. As can be seen from the example in Figure 4.2, there is a sequence of activities working from top to bottom. The diagram shows some arrows pointing upwards and backwards. This indicates that a later stage may reveal the need for some extra work at an earlier stage, but this should definitely be the exception rather than the

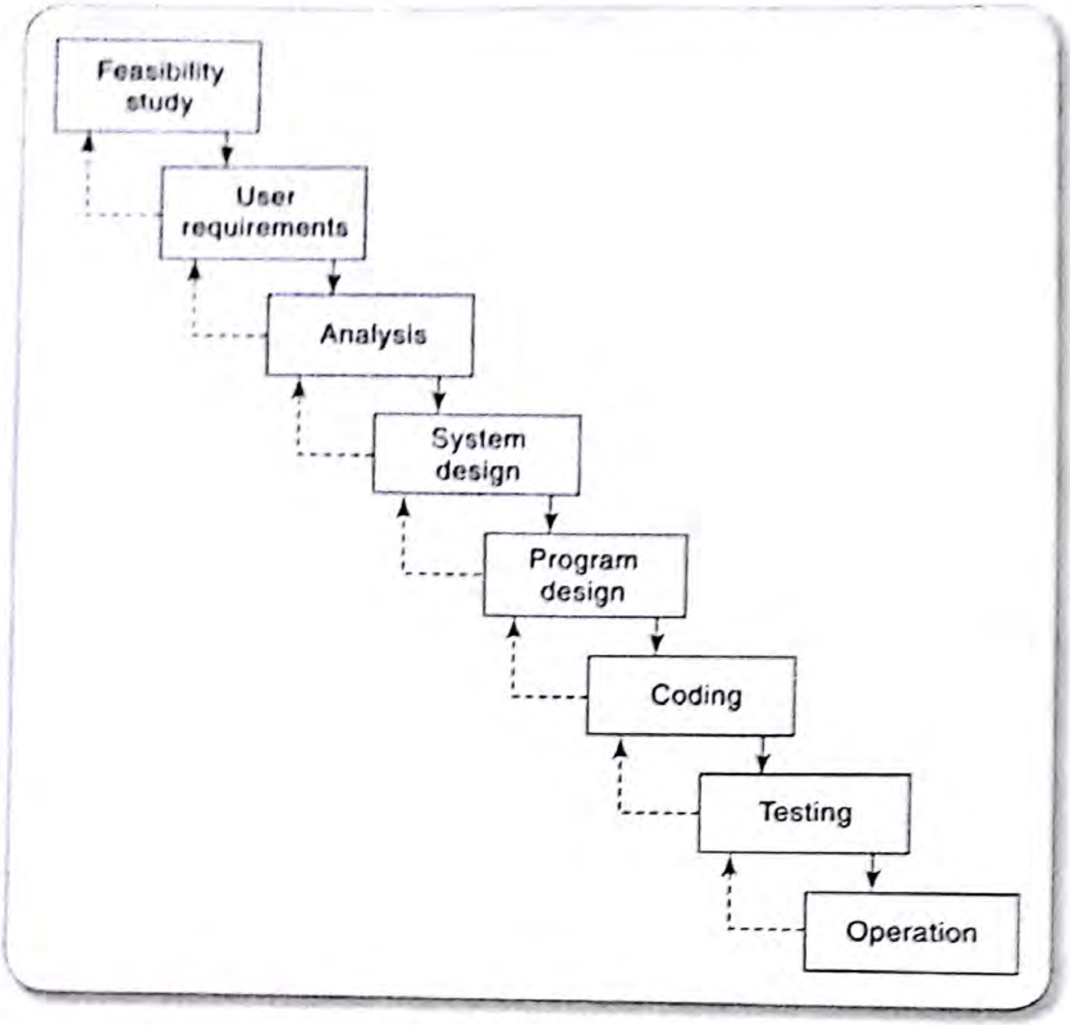


FIGURE 4.2 Waterfall model

rule. After all, the flow of a waterfall should be downwards, with the possibility of just a little splashing back. The limited scope for iteration is in fact one of the strengths of this process model. With a large project you want to avoid reworking tasks previously thought to be completed. Having to reopen completed activities plays havoc with promised completion dates.

The first description of this approach is said to be that of H. D. Bennington in 'Production of Large Computer Programs' in 1956. This was reprinted in 1983 in *Annals of the History of Computing* 5(4).

The waterfall approach may be favoured by some managements because it creates natural milestones at the end of each phase. At these points, managers can review project progress to see whether the business case for the project is still valid. This is sometimes referred to as the stage-gate model. As we will see, stage-gates are compatible with process models other than the waterfall, but higher management may have to accept that activities may have to be grouped in different ways with these alternative approaches.

Even though writers often advocate alternative models, there is nothing intrinsically wrong with the waterfall approach in the right place. It is the ideal for which the project manager strives. Where the requirements are well defined and the development methods are well understood, the waterfall approach allows project completion times to be forecast with some confidence, allowing the effective control of the project. However, where there is uncertainty about how a system is to be implemented, and unfortunately there very often is, a more flexible, iterative, approach is required.

The waterfall model can expanded into the **V-process model** which is further explored in Section 13.11 on testing. This expansion is done by expanding the testing process into different types of testing which check the executable code against the products of each of the activities in the project life cycle leading up to the coding. For example, the code may seem to execute correctly, but may be at variance with the expected design. This is explained further in Chapter 13.

4.8 The Spiral Model

It could be argued that this is another way of looking at the waterfall model. In the waterfall model, it is possible to escape at the end of any activity in the sequence. A feasibility study might decide that the implementation of a proposed system would be beneficial. The management therefore authorize work on the detailed analysis of user requirements. Some analysis, for instance the interviewing of users, might already have taken place at the feasibility stage, but a more thorough investigation is now launched. This could reveal that the costs of implementing the system would be higher than projected benefits and lead to a decision to abandon the project.

The original ideas behind the spiral model can be found in B. W. Boehm's 1988 paper 'A spiral model of software development and enhancement' in *IEEE Computer*, 21(5).

A greater level of detail is considered at each stage of the project and a greater degree of confidence about the probability of success for the project should be justified. This can be portrayed as a loop or a spiral where the system to be implemented is considered in more detail in each sweep. Each sweep terminates with an evaluation before the next iteration is embarked upon. Figure 4.3 illustrates how SSADM can be interpreted in such a way.

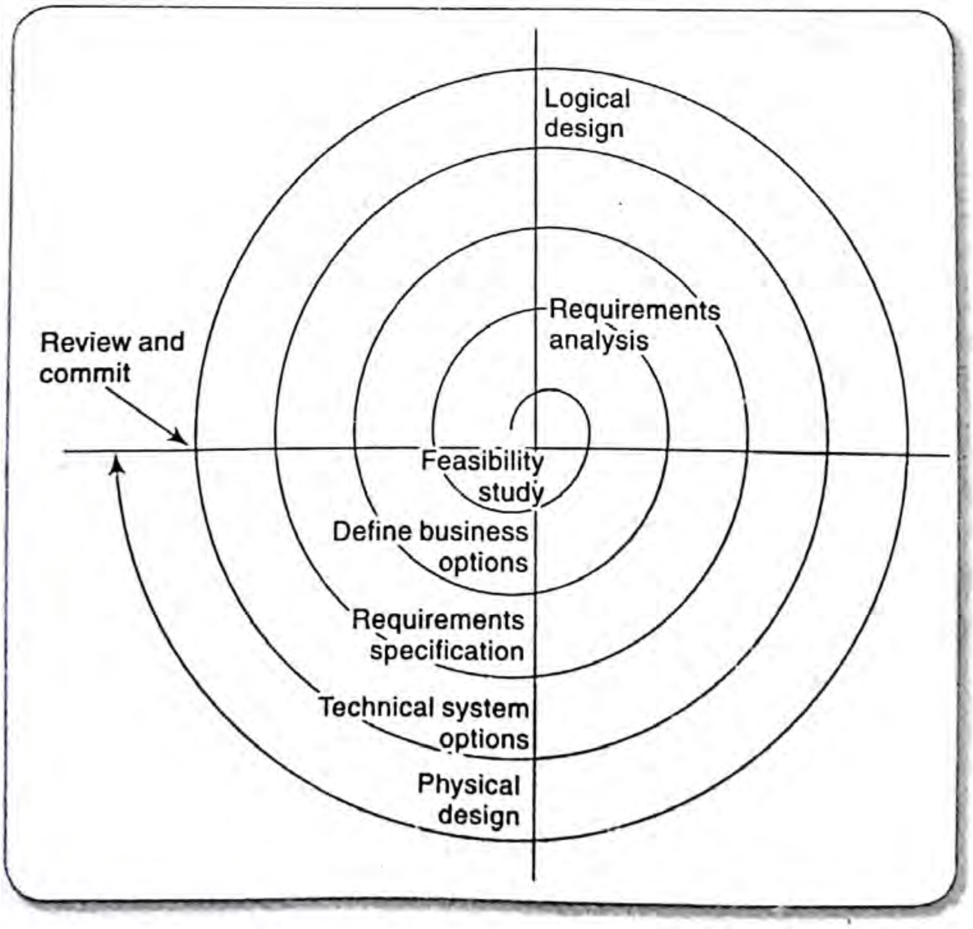


FIGURE 4.3 Application of the spiral model to SSADM version 4

A key point here is that uncertainty about a project is usually because of a lack of knowledge about some aspect. We can spend money on activities at the start of the project that buy knowledge and reduce that uncertainty.

The distinguishing characteristic features of the spiral model are the incremental style of development and the ability to handle various types of risks. Each loop of the spiral is called a phase of this software process. In each phase, one or more features of the product are implemented after resolving any associated risks through prototyping. The exact number of loops of the spiral is not fixed and varies from one project to another. Note that the number of loops shown in Figure 4.4 is just an example illustrating how the spiral model can subsume SSADM. Each loop of the spiral is divided into four quadrants, indicating four stages in each phase. In the first stage of a phase, one or more features of the product are analysed and the risks in implementing those features are identified and resolved through prototyping. In the third stage, the identified features are implemented using the waterfall model. In the fourth and final stage, the developed increment is reviewed by the customer along with the development team and the features to be implemented next are identified. Note that the spiral model provides much more flexibility compared to the other models, in the sense that the exact number of phases through which the product is to be developed can be tailored by the project manager during execution of the project.

4.9 Software Prototyping

This is one way in which we can buy knowledge and reduce uncertainty. A prototype is a working model of one or more aspects of the projected system. It is constructed and tested quickly and inexpensively in order to test out assumptions.

Prototypes can be classified as throw-away or evolutionary.

- *Throw-away prototypes* The prototype tests out some ideas and is then discarded when the true development of the operational system is commenced. The prototype could be developed using a different software or hardware environment. For example, a desktop application builder could be used to evolve an acceptable user interface. A procedural programming language is then used for the final system where machine-efficiency is important.
- *Evolutionary prototypes* The prototype is developed and modified until it is finally in a state where it can become the operational system. In this case the standards that are used to develop the software have to be carefully considered.

Some of the reasons that have been put forward for prototyping follow.

- *Learning by doing* We can usually look back on a task and see where we have made mistakes.
- *Improved communication* Users do not get a feel for how the system is likely to work in practice from a specification.
- *Improved user involvement* The users can be more actively involved in design decisions.
- *Clarification of partially known requirements* Where there is no existing system to mimic, users can often get a better idea of what might be useful to them by trying out prototypes.
- *Demonstration of the consistency and completeness of a specification* Any mechanism that attempts to implement a specification on a computer is likely to uncover ambiguities and omissions. The humble spreadsheet can, for instance, check that calculations have been specified correctly.

The original ideas behind the spiral model can be found in B. W. Boehm's 1988 paper 'A spiral model of software development and enhancement' in *IEEE Computer*, 21(5).

- *Reduced need for documentation* Because a working prototype can be examined there is less need for detailed documentation of requirements.
- *Reduced maintenance costs* If the user is unable to suggest modifications at the prototyping stage they are more likely to ask for changes to the operational system. This reduction of maintenance costs is the core of the financial case for prototypes.

Some may argue, however, that this is a very dangerous suggestion.

- *Feature constraint* If an application-building tool is used, then the prototype will tend to have features that are easily implemented by that tool. A paper-based design might suggest features that are expensive to implement.
- *Production of expected results* The problem with creating test cases is generally not the creation of the test input but the accurate calculation of the expected results. A prototype can help here.

Software prototyping is not without its drawbacks and dangers, however.

- *Users can misunderstand the role of the prototype* For example, they might expect the prototype to have as stringent input validation or as fast a response as the operational system, although this was not intended.
- *Lack of project standards possible* Evolutionary prototyping could just be an excuse for a sloppy 'hack it out and see what happens' approach.
- *Lack of control* It can be difficult to control the prototyping cycle if the driving force is the users' propensity to try out new things.
- *Additional expense* Building and exercising a prototype will incur additional expenses. However, this should not be over-estimated as many analysis and design tasks have to be undertaken whatever the approach.
- *Machine efficiency* A system built through prototyping, while sensitive to the users' needs, might not be as efficient in machine terms as one developed using more conventional methods.
- *Close proximity of developers* Prototyping could mean that code developers have to be sited close to the users. One trend is for organizations in developed countries to transfer software development to developing countries with lower costs such as India. Prototyping might prevent this.

4.10 Other Ways of Categorizing Prototypes

What is being learnt?

The most important reason for prototyping is a need to learn about an area of uncertainty. Thus it is essential to identify at the outset what is to be learnt from the prototype.

Computing students often realize that the software that they are to write as part of their final-year project could not safely be used by real users. They therefore call the software a 'prototype'. However, if it is a real prototype then they must:

- specify what they hope to learn from the prototype;
- plan how the prototype is to be evaluated;
- report on what has actually been learnt.

Prototypes can be used to find out about new development techniques, by using them in a pilot project. Alternatively, the development methods might be well known, but the nature of the application uncertain.

Different projects will have uncertainties at different stages. Prototypes can therefore be used at different stages. A prototype might be used, for instance, at the requirements gathering stage to pin down requirements that seem blurred and shifting. A prototype might, on the other hand, be used at the design stage to test out the users' ability to navigate through a sequence of input screens.

To what extent is the prototyping to be done?

It would be unusual for the whole of the application to be prototyped. The prototyping usually simulates only some aspects of the target application. For example there might be:

- *Mock-ups* As when copies of input screens are shown to the users on a terminal, but the screens cannot actually be used.
- *Simulated interaction* For example, the user can type in a request to access a record and the system will show the details of a record, but the details shown are always the same and no access is made to a database.
- Partial working model:
  - *Vertical* Some, but not all, features are prototyped fully.
  - *Horizontal* All features are prototyped but not in detail – perhaps there is not full validation of input.

What is being prototyped?

- *The human–computer interface* With business applications, business process requirements have usually been established at an early stage. Prototyping tends, therefore, to be confined to the nature of operator interaction. Here the physical vehicle for the prototype should be as similar as possible to the operational system.
- *The functionality of the system* Here the precise way the system should function internally is not known. For example, a computer model of some real-world phenomenon is being developed. The algorithms used might need to be repeatedly adjusted until they satisfactorily imitate real-world behaviour.

Exercise 4.4

At what stage of a system development project (for example, feasibility study, requirements analysis, etc.) would a prototype be useful as a means of reducing the following uncertainties?

(a) There is a proposal that the senior managers of an insurance company have personal access to management information through an executive information system installed on personal computers located on their desks. Such a system would be costly to set up and there is some doubt about whether the managers would actually use the system.

(b) A computer system is to support sales office staff taking phone calls from members of the public enquiring about motor insurance and giving quotations over the phone.

(c) The insurance company is considering implementing the telephone sales system using the system development features supplied by Microsoft Access. They are not sure, at the moment, that it can provide the kind of interface that would be needed and are also concerned about the possible response times of a system developed using Microsoft Access.

Controlling changes during prototyping

A major problem with prototyping is controlling changes to the prototype following suggestions by the users. One approach has been to categorize changes as belonging to one of three types:

- *Cosmetic* (often about 35% of changes)

  These are simple changes to the layout of the screens or reports. They are:

  (a) Implemented

  (b) Recorded

- *Local* (often about 60% of changes)

  These change the way that a screen or report is processed but do not affect other parts of the system. They are:

  (a) Implemented

  (b) Recorded

  (c) Backed-up so that they can be removed at a later stage if necessary

  (d) Inspected retrospectively

- *Global* (about 5% of changes)

  These are changes that affect more than one part of the processing. All changes here have to be the subject of a design review before they can be implemented.

Inspections are discussed in Chapter 13.

4.11 Incremental Delivery

This approach breaks the application down into small components which are then implemented and delivered in sequence. Each component delivered must give some benefit to the user. Figure 4.4 gives a general idea of the approach.

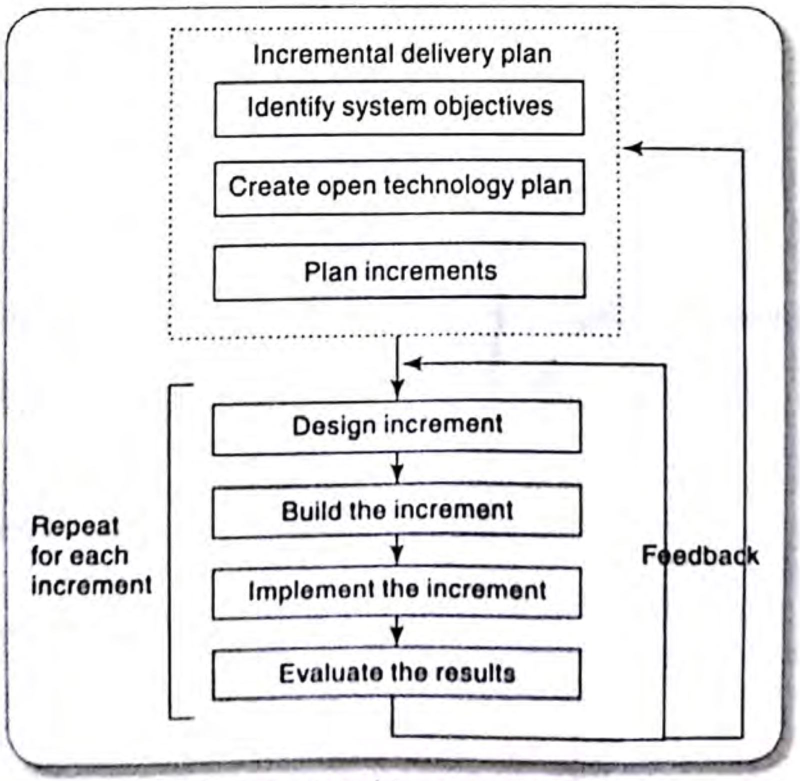

Incremental delivery plan
Identify system objectives
Create open technology plan
Plan increments
Design increment
Build the increment
Implement the increment
Evaluate the results
Repeat for each increment
Feedback

FIGURE 4.4 Intentional incremental delivery

Time-boxing is often associated with an incremental approach. Here the scope of deliverables for an increment is rigidly constrained by an agreed deadline. This deadline has to be met, even at the expense of dropping some of the planned functionality. Omitted features can be transferred to later increments.

Advantages of this approach

Tom Gilb, whose *Principles of Software Engineering Management* was published by Addison-Wesley in 1988, is a prominent advocate of this approach.

These are some of the justifications given for the approach.

- The feedback from early increments improves the later stages.
- The possibility of changes in requirements is reduced because of the shorter time span between the design of a component and its delivery.
- Users get benefits earlier than with a conventional approach.
- Early delivery of some useful components improves cash flow, because you get some return on investment early on.
- Smaller sub-projects are easier to control and manage.
- *Gold-plating*, that is, the requesting of features that are unnecessary and not in fact used, is less as users know that if a feature is not in the current increment then it can be included in the next.
- The project can be temporarily abandoned if more urgent work emerges.
- Job satisfaction is increased for developers who see their labours bearing fruit at regular, short, intervals.

Disadvantages

On the other hand, these disadvantages have been put forward.

- Later increments might require modifications to earlier increments. This is known as *software breakage*.
- Software developers may be more productive working on one large system than on a series of smaller ones.
- Grady Booch, an authority on OO, suggests that with what he calls 'requirements driven' projects (which equate to incremental delivery) '*Conceptual integrity sometimes suffers because there is little motivation to deal with scalability, extensibility, portability or reusability beyond what any vague requirements might imply.*' Booch also suggests there could be a tendency towards a large number of discrete functions with little common infrastructure.

This quotation is from Grady Booch (1996) *Object Solutions: Managing the Object Oriented Project*, Addison-Wesley.

The incremental delivery plan

The process of planning the increments of a project as described by Gilb has similarities with strategic planning described in Chapter 2.

The nature and order of each increment to be delivered to the users have to be planned at the outset.

This process is similar to strategic planning but at a more detailed level. Attention is given to increments of a user application rather than whole applications. The elements of the incremental plan are the *system objectives*, *incremental plan* and the *open technology plan*.

System objectives

Recall that earlier we suggested that project planners ideally want well-defined objectives, but as much freedom as possible about how these are to be met. These overall objectives can be expanded into more specific functional goals and quality goals.

Functional goals will include:

- Objectives it is intended to achieve
- Jobs the system is to do
- Computer/non-computer functions to achieve them

In addition, measurable quality characteristics should be defined, such as reliability, response and security. If this is done properly these overarching quality requirements can go some way to meeting the concerns, expressed by Grady Booch, that these might get lost with the concentration on the requirements at increment level. It also reflects Tom Gilb's concern that system developers always keep sight of the objectives that they are trying to achieve on behalf of their clients. In the changing environment of an application individual requirements could change over the course of the project, but the objectives should not.

Chapter 13 discusses software quality characteristics.

Open technology plan

If the system is to be able to cope with new components being continually added then it needs to be extendible, portable and maintainable.

As a minimum this will require the use of:

- A standard high-level language
- A standard operating system
- Small modules
- Variable parameters, for example items such as the names of an organization and its departments, charge rates, and so on, are held in a parameter file that can be amended without programmer intervention
- A standard database management system

These are all things that might be expected as a matter of course in a modern software development environment.

Although Gilb does not suggest this, following Booch's hints it would be desirable to draw up an initial logical data model or object model for the whole system. It is difficult to see how the next stage of planning the scope and order of each increment could be done without this foundation.

Incremental plan

Having defined the overall objectives and an open technology plan, the next stage is to plan the increments using the following guidelines:

- Steps typically should consist of 1–5% of the total project.
- Non-computer steps should be included.
- An increment should, ideally, not exceed one month and should not, at worst, take more than three months.

A non-computer step could be something like a streamlined clerical procedure.

- Each increment should deliver some benefit to the user.
- Some increments will be physically dependent on others.
- In other cases value-to-cost ratios may be used to decide priorities (see below).

A new system might be replacing an old computer system and the first increments could use parts of the old system. For example, the data for the database of the new system could initially be obtained from the old system's standing files.

Which steps should be first? Some steps will be prerequisites because of physical dependencies but others can be in any order. Value-to-cost ratios (see Table 4.1) can be used to establish the order in which increments are to be developed. The customer is asked to rate the value of each increment with a score in the range 1–10. The developers also rate the cost of developing each of the increments with a score in the range 0–10. This might seem rather crude, but people are often unwilling to be more precise. Dividing the value rating by the cost rating generates a ratio which indicates the relative 'value for money' of each increment.

A zero cost would mean that the change can be implemented without software development – some costs might be incurred by users in changing procedures.

The value to cost ratio = *V/C* where *V* is a score 1–10 representing value to customer and *C* is a score 0–10 representing cost.

TABLE 4.1 Ranking by value-to-cost ratio

Step	Value	Cost	Ratio	Rank
Profit reports	9	1	9	(2nd)
Online database	1	9	0.11	(6th)
Ad hoc enquiry	5	5	1	(4th)
Production sequence plans	2	8	0.25	(5th)
Purchasing profit factors	9	4	2.25	(3rd)
Clerical procedures	0	7	0	(7th)
Profit-based pay for managers	9	0	∞	(1st)

An incremental example

Tom Gilb describes a project where a software supplier negotiated a fixed-price contract with a three-month delivery time with the Swedish government to supply a system to support map-making. It later became apparent that the original estimate of effort upon which the bid was based was probably about half the real effort.

The project was replanned and divided into ten increments, each supplying something of use to the customer. The final increments were not available until three months after the contract's delivery date. The customer was not in fact unhappy about this as the most important parts of the application had actually been delivered early.

4.12 Atern/Dynamic Systems Development Method

In the United Kingdom, SSADM (Structured Systems Analysis and Design Method) has until recently been a predominant methodology. In no small part, this has been because of sponsorship by the United Kingdom government. More recently, however, it has lost some favour, partly because it has been perceived as overly bureaucratic and prescriptive. In contrast, there has been an increased interest in the iterative and incremental approaches we have outlined above. As a consequence, a consortium has developed guidelines for the use of such techniques and packaged the overall approach as the Dynamic Systems Development Method (DSDM). This has been re-badged as Atern. It is possible to attend courses on the method and to become an accredited Atern practitioner.

Eight core Atern principles have been enunciated.

1. *Focus on business need.* Every decision in the development process should be taken with a view to best satisfying business needs. Effectively this is emphasizing the need to avoid means–end inversion that we described in Section 4.1, that is, focusing on the detail of a procedure to the detriment of satisfactory project deliverables.
2. *Deliver on time.* Time-boxing is applied. Every deadline will see the delivery of valuable products, even if some less valuable ones are held over. This is better than delivery dates being pushed back until a delivery of all scheduled products can be made.
3. *Collaborate.* A one-team culture should be promoted, where user representatives are integrated into the delivery team.
4. *Never compromise quality.* Realistic quality targets are set early in the project. A process of continuously testing developing products starting as soon as possible is adopted.
5. *Develop iteratively.* The prototyping approach described in Section 4.8 would be an example of how this might be done.
6. *Build incrementally from firm foundations.* The incremental delivery approach as described in Section 4.11 is embraced.
7. *Communicate continuously.* In the case of users this could, for example, be done via workshops and the demonstration of prototypes.
8. *Demonstrate control.* Atern methodology has a range of plans and reports that can be used to communicate project intentions and outcomes to project sponsors and other management stakeholders.

JAD, Joint Application Development, was discussed in Section 4.6.

Figure 4.5 outlines the general approach. The main life cycle phases are shown:

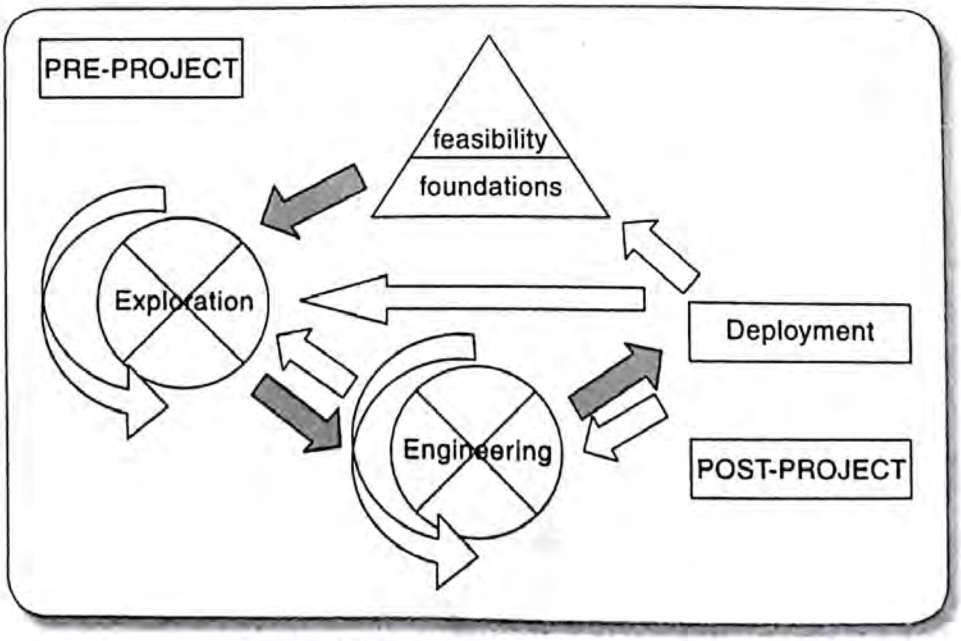


FIGURE 4.5 Atern process model

- *Feasibility/foundation*. Among the activities undertaken here is derivation of a business case of the sort discussed in Chapter 2 and general outlines of the proposed architecture of the system to be developed.
- *Exploration cycle*. This investigates the business requirements. These requirements are translated into a viable design for the application. This could be an iterative process that could involve the creation of exploratory prototypes. A large project could be decomposed into smaller increments to assist the design process.
- *Engineering cycle*. This takes the design generated in the exploration cycle and converts it into usable components of the final system that will be used operationally. Once again this could be done using incremental and evolutionary techniques.
- *Deployment*. This gets the application created in the engineering cycle into actual operational use.

Not only can there be iterations within the exploration and engineering cycles, but an increment could involve requirements investigation followed by the building of the functionality.

Time-boxes were discussed in Section 4.11 on incremental delivery.

Atern encourages the use of time-boxes. It is suggested that these should typically be between two and six weeks in order to make participants focus on real needs. It will be recalled that in order to meet the deadline imposed by a time-box, the implementation of less important features may be held over to later increments (or even dropped altogether). The relative importance of requirements can be categorized using the 'MoSCoW' classification:

- *Must have*: that is, essential features.
- *Should have*: these would probably be mandatory if you were using a conventional development approach – but the system can operate without them.
- *Could have*: these requirements can be delayed with some inconvenience.
- *Won't have*: these features are wanted, but their delay to a later increment is readily accepted.

The possibility of requirements being reallocated to different increments means that project plans will need to be constantly updated if the project is to be successfully controlled.

4.13 Rapid Application Development

Rapid Application Development (RAD) model is also sometimes referred to as the rapid prototyping model. This model has the features of both the prototyping and the incremental delivery models.

The major aims of the RAD model are as follows:

- to decrease the time taken and the cost incurred to develop software systems; and
- to limit the costs of accommodating change requests by incorporating them as early as possible before large investments have been made on development and testing.

One of the major problems that has been identified with the waterfall model is the following. Clients often do not know what they exactly want until they see a working system. However, they do not see the working system until the development is complete in all respects and delivered to them. As a result, the exact requirements are brought out only through the process of customers commenting on the installed application. The required changes are incorporated through subsequent maintenance efforts. This makes the cost of accommodating any change extremely high. As a result, it takes a long time and enormous cost to have a good solution in place. Clearly, this model of developing software would displease even the best customer. The RAD model tries to overcome this problem by inviting and incorporating customer feedback on successively developed prototypes. In the RAD model, absence of long-term and detailed planning gives the flexibility to accommodate requirements change requests solicited from the customer during project execution.

In the RAD model, development takes place in a series of short cycles called iterations. Plans are made for one iteration at a time only. The time planned for each iteration is called a time box. Each iteration enhances the implemented functionality of the application a little. During each iteration, a quick and dirty prototype for some functionality is developed. The customer evaluates the prototype and gives feedback, based on which the prototype is refined. Thus, over successive iterations, the full set of functionalities of the software takes shape. However, it needs to be noted that in the RAD model, the prototype is used as an instrument for gathering customer feedback only and is not released to the customer for regular use.

The development team is also required to include a customer representative to clarify the requirements. Thus, conscious attempts are made to bridge the communication gap between the customer and the development team and to tune the system to the exact customer requirements. But, how does RAD model lead to faster product development? RAD emphasizes code reuse as an important means to get the work done fast. In fact, the RAD adopters were the earliest to embrace object-oriented languages and practices. RAD also advocates the use of specialized tools for faster creation of working prototypes.

4.14 Agile Methods

In the following, we first discuss the need for agile methods. Subsequently, we discuss the important characteristics of agile methods.

Need for agile methods Traditional heavyweight software development methodologies worked fine till about two decades back. However, as the complexity of the software to be developed continued to increase, it soon became difficult to use it in modern software development projects. One of the major difficulties that were faced is that the traditional heavyweight methodologies required the customers to come up with all the requirements upfront. Also, the traditional heavyweight processes were too rigid and it became difficult to use these in projects involving significant reuse and modifications to the existing code. We elaborate these difficulties experienced with the traditional development processes in the following.

Difficult to accommodate change requests The heavyweight processes are based on making a long-term project management plan and comprehensive design for the project based on the requirements specified upfront. Therefore, any change to the requirements afterwards requires making changes to the various plans and designs. However, in modern software development projects, change requests from customers have become common during execution of the project. Often, as much as 50 percent requirements are either new or modified after the project has started. Needless to say that frequent requirement changes lead to lot of rework and render traditional heavyweight processes inefficient.

Documentation-driven A disadvantage of the traditional heavyweight methodologies is that these mandate production of voluminous documents, even though these may be rarely referred to by any one later. Usually a lot of effort is invested in preparing the documentations in the heavyweight development methodologies. According to some estimates, as much as 50 percent of the development efforts are invested in preparing the documentations.

Too rigid The traditional heavy weight processes worked fine when software was being developed from scratch. However, as we have noted in Chapter 1, the project characteristics have changed drastically over the last couple of decades. Now significant code reuse is made during software development and the proportion of the new code written is often as low as 10 percent of the total code of the software being developed. An example of such projects is the customization project. Due to the rigidity of the traditional processes, it becomes difficult to tailor these for efficient development of modern projects requiring significant amount of code reuse.

Overview of agile methods Agile methods are designed to overcome the important disadvantages of the heavyweight development methodologies. The most glaring change advocated by the agile techniques is iterative development. This approach involves development of one feature at a time by making only short-term plans. After each incremental feature is developed, the software is released to the customers for their use and feedback. Also, interaction with the customers is enhanced by including a few customer representatives in the development team. Note that *agile method* is an umbrella term that refers to a group of development processes, and not any single process for software development. There are various agile methods, including the following:

- Crystal technologies
- Atern (formerly DSDM)
- Feature-driven development
- Scrum
- Extreme programming (XP)
- Lean

Basic principles The following principles are central to the agile methods.

- *Incremental delivery after each time box* In agile methods, the required features are decomposed into many small parts that can be incrementally developed. The agile model adopts an iterative approach, in the sense that each incremental part is developed over an iteration. At a time, only one increment is planned, developed and then deployed at the customer site. No long-term plans are made. The time to complete an iteration is called a *time box*. The implication of the term 'time box' is that the end date for an iteration does not change. The development team can, however, decide to reduce the delivered functionality during a time box if necessary, but the delivery date is considered sacrosanct. During an iteration, one or more features are analysed, designed, coded and tested. Each iteration is intended to be small and easily manageable and lasts for a couple of weeks only. For large projects, multiple iterations may be progressing simultaneously that may be focusing on parallel development of different sets of features.
- *Face-to-face communication* Agile model emphasizes face-to-face communication over written documents. In order to facilitate face-to-face communication, the team size is deliberately kept small (5–9 people) and the team members share the same office space. This makes the agile model well-suited to be used in small projects. However, large projects can also be executed using the agile model through suitable adaptations of the model. In a large project, it is likely that the collaborating teams might work at different locations. In this case, the different teams are needed to maintain daily contact through various communication channels such as video conferencing, telephone and e-mail.
- *Customer interactions* In order to foster close interaction with the customer, an agile project usually includes a few customer representatives in the team. Customer participation in the project is further enhanced by inviting the customer representatives along with the stakeholders at the end of each iteration to review the progress made, re-evaluate the requirements, and give necessary feedbacks to the development team.

- *Minimal documentation* Agile documents are created on a *need to know basis*. That is, a piece of information is documented only if it is expected to be referred to by some stakeholders or is needed for communicating with some external group. Also, agile documents describe information that is unlikely to change. Consequently, the documentation is light, and it not only saves significant amount of documentation preparation effort, but it also becomes easy to keep these up-to-date and consistent.
- *Pair programming* Agile development projects usually deploy pair programming. In this approach, two programmers work together at one work station. One of the programmer types in the code, while the other reviews the code as it is typed in. The two programmers switch their roles every hour or so. Several studies indicate that programmers working in pairs produce compact well-written code and commit fewer errors as compared to programmers working individually.

Adoption detractors A team intending to adopt and agile development process, needs to be aware of a few difficulties that the teams face while adapting these models. The agile methods actively encourage change requests from the customers. Consequently, it becomes harder for the manager to manage feature creep and customer expectations. Also, since the development gets underway with only an overall understanding of the requirements, it becomes difficult to accurately quantify the cost and time at the start of the project. This makes bidding for a project more complicated. Further, short iterations inhibit long-term planning and high-level design. Therefore, unless proper care is taken, the code and design qualities can degrade.

Exercise 4.5

As can be seen, there is much in common between the RAD model and the agile model. Identify the important differences between the agile model and the RAD model.

4.15 Extreme Programming (XP)

The primary source of information on XP is Kent Beck's *Extreme programming explained: embrace change*, first published in 1999 and updated in 2004. The description here is based on the first edition, with some comments where the ideas have been developed further in the second.

See Kent Beck (with Cynthia Andreas), *Extreme Programming Explained: Embrace Change*, Addison-Wesley, 1st edition 1999, 2nd edition 2004. 'Extreme programming' is sometimes shown with a capital 'X' i.e. 'eXtreme Programming'.

The ideas were largely developed on the C3 payroll development project at Chrysler. The approach is called 'extreme programming' because, according to Beck, '*XP takes commonsense principles to extreme levels*'. Four core values are presented as the foundations of XP.

1. **Communication and feedback.** It is argued that the best method of communication is face-to-face communication. Also, the best way of communicating to the users the nature of the software under production is to provide them with frequent working increments. Formal documentation is avoided.
2. **Simplicity.** The simplest design that implements the users' requirements should always be adopted. Effort should not be spent trying to cater for future possible needs – which in any case might never actually materialize.
3. **Responsibility.** The developers are the ones who are ultimately responsible for the quality of the software – not, for example, some system testing or quality control group.

4. **Courage.** This is the courage to throw away work in which you have already invested a lot of effort, and to start with a fresh design if that is what is called for. It is also the courage to try out new ideas – after all, if they do not work out, they can always be scrapped. Beck argues that this attitude is more likely to lead to better solutions.

Among the *core practices* of XP are the following.

The planning exercise

In the second edition of his book, Beck favours iterations of one week on the grounds that people tend to work naturally in weekly cycles.

Previously, when we talked about 'increments' we meant components of the system that users could actually use. XP refers to these as *releases*. Within these releases code is developed in *iterations*, periods of one to four weeks' duration during which specific features of the software are created. Note that these are not usually 'iterations' in the sense that they are new, improved, versions of the same feature – although this is a possibility. The planning game is the process whereby the features to be incorporated in the next release are negotiated. Each of the features is documented in a short textual description called a *story* that is written on a card. A process similar to value-to-cost ratio analysis discussed earlier in Section 4.11 or Atern's MoSCoW rating is carried out in order to give priorities to the features. At the time of the next code release, any features that have not been completed will be held over – that is, time-boxing is employed.

Small releases

The time between releases of functionality to users should be as short as possible. Beck suggests that releases should ideally take a month or two. This is compatible with Tom Gilb's recommendation of a month as the ideal time for an increment, with a maximum of three months.

Metaphor

The system to be built will be software code that reflects things that exist and happen in the real world. A payroll application will calculate and record payments to employees. The terms used to describe the corresponding software elements should, as far as possible, reflect real-world terminology – at a very basic level this would mean using meaningful names for variables and procedures such as 'hourly_rate' and 'calculate_gross_pay'. Beck suggests that what he calls the use of metaphor can do the job that 'system architecture' does on conventional projects. In this context 'architecture' refers to the use of system models such as class and collaboration diagrams to describe the system. The astute reader might point out that the use of the term 'architecture' is itself a metaphor.

Simple design

This is the practical implementation of the value of simplicity that was described above.

Testing

Testing is done at the same time as coding. The test inputs and expected results should be scripted so that the testing can be done using automated testing tools. These test cases can then be accumulated so that they can be used for regression testing to ensure that later developments do not insert errors into existing working code. This idea can be extended so that the tests and expected results are actually created before the code is created. Working out what tests are needed to check that a function is correct can itself help to clarify requirements. Two types of testing are needed: unit testing which focuses on the code a developer has just written, and function testing which is user-oriented and checks the correctness of a particular feature and which may involve several code units.

Refactoring

A threat to the target of striving to have always the simplest design is that over time, as modifications are made to code, the structure tends to become more spaghetti-like. The answer to this is to have the courage to resist the temptation to make changes that affect as little of the code as possible and be prepared to rewrite whole sections of code if this will keep the code structured. The repository of past test cases – see the section immediately above – can be executed to ensure that the refactoring has not introduced bugs into the application.

Pair programming

All software code is written by pairs of developers, one actually doing the typing and the other observing, discussing and making comments and suggestions about what the other is doing. At intervals, the developers can swap roles. The ideal is that you are constantly changing partners so that you get to know about a wide range of features that are under development. It follows from this that office environments need to be designed carefully to allow this type of working, and that developers will generally need to keep the same office hours.

Helen Sharp of the Open University has studied XP in practice. One of her observations is that the social nature of the development process encourages a rhythm of group meetings, pair working and daily 'builds' when new code is integrated that helps to give the project momentum. Interestingly, this rhythm of activity and review acting as a heart-beat of the project has also been noted in a successful dispersed project.

Collective ownership

This is really the corollary of pair programming. The team as a whole takes collective responsibility for the code in the system. A unit of code does not 'belong' to just one programmer who is the only one who can modify it.

Continuous integration

This is another aspect of testing practice. As changes are made to software units, integrated tests are run regularly – at least once a day – to ensure that all the components work together correctly.

Forty-hour weeks

Chapter 11 discusses, among other issues, the question of stress. It points out that working excessive hours (in some cases 60 hours or more a week) can lead to ill-health and be generally counterproductive. The principle is that normally developers should not work more than 40 hours a week. It is realistic to accept that sometimes there is a need for overtime work to deal with a particular problem – but in this case overtime should not be worked for two weeks in a row. Interestingly, in some case studies of the application of XP, the 40-hour rule was the only one not adhered to.

On-site customers

Fast and effective communication with the users is achieved by having a user domain expert on-site with the developers.

Coding standards

If code is genuinely to be shared, then there must be common, accepted, coding standards to support the understanding and ease of modification of the code.

Limitations of XP

The successful use of XP is based on certain conditions. If these do not exist, then its practice could be difficult. These conditions include the following.

- There must be easy access to users, or at least a customer representative who is a domain expert. This may be difficult where developers and users belong to different organizations.
- Development staff need to be physically located in the same office.
- As users find out about how the system will work only by being presented with working versions of the code, there may be communication problems if the application does not have a visual interface.
- For work to be sequenced into small iterations of work, it must be possible to break the system functionality into relatively small and self-contained components.
- Large, complex systems may initially need significant architectural effort. This might preclude the use of XP.

XP does also have some intrinsic potential problems – particularly with regard to its reliance on tacit expertise and knowledge as opposed to externalized knowledge in the shape of documentation.

- There is a reliance on high-quality developers which makes software development vulnerable if staff turnover is significant.

  understood [illegible] being [illegible]
- Even where staff retention is good, once an application has been developed and implemented, the tacit. personal, knowledge of the system may decay. This might make it difficult, for example, for maintenance staff without documentation to identify which bits of the code to modify to implement a change in requirements.
- Having a repository of comprehensive and accurate test data and expected results may not be as helpful as might be expected if the rationale for particular test cases is not documented. For example, where a change is made to the code, how do you know which test cases need to be changed?
- Some software development environments have focused on encouraging code reuse as a means of improving software development productivity. Such a policy would seem to be incompatible with XP.

4.16 Scrum

Scrum is one of the agile development models. In the Scrum model, a project is divided into small work parts that can incrementally be developed and delivered over time boxes that are called sprints. Each sprint is typically 2 to 4 weeks long. During a sprint an incremental functionality of the software is completed. At the end of each sprint, the stakeholders and the team members meet to assess the developed software increment. The stakeholders may suggest any changes and improvements to the developed software that they might feel necessary. The software therefore gets developed over a series sprints. In each sprint, manageable increments to the software (or chunks) are deployed at the client site and the client feedback is obtained after each sprint.

Key roles and responsibilities In the Scrum model, the team members assume three basic roles: product owner, scrum master and team member. The responsibilities associated with these three basic roles are discussed below.

- *Product owner* The product owner represents the customer's perspective and guides the team towards building the right software. In other words, in various meetings the product owner takes the responsibility of communicating the customer's views to the development team. To this end, in every sprint the product owner in consultation with the team members defines the features of the software to be developed in the next sprint, decides on the release dates, and also reprioritizes the software features if needed.
- *Scrum master* The scrum master acts as the project manager for the project. The responsibilities of the scrum master include removing any impediments that the project may face, ensuring that the team is fully productive by fostering close cooperation among all team members. Also, the scrum master acts as a liaison between the customers, top management and the team and facilitates the development work. The scrum team is, therefore, shielded by the scrum master from external interferences.
- *Team member* A scrum team usually consists of cross-functional team members with expertise in areas such as quality assurance, programming, user interface design and testing. The team is self-organizing in the sense that the team members distribute the responsibilities among themselves, in contrast to a conventional team where a team leader decides who will do what.

Artefacts Three main artefacts form an important part of the scrum methodology. These are as follows: product backlog, sprint backlog and sprint burndown chart. We briefly describe the purpose and contents of these three documents in the following.

- *Product backlog* This document lists all the features that remain to be developed. In this document, the features of the software are usually written in the form of user stories. During the course of development, new features may get added to the product backlog and some features may even get deleted. This document is, therefore, a dynamic document that is periodically updated and reprioritized. The product backlog forms the pool of features from which some of the features are chosen for development during the next sprint.
- *Sprint backlog* During a sprint planning meeting, the team identifies one or more features (user stories) from the product backlog and decides on the tasks that would be needed to be undertaken for the development of the identified features and this forms the sprint backlog. In other words, we can say that the sprint backlog lists the tasks that are identified and committed by the team to develop and complete during the sprint.
- *Sprint burndown chart* During a sprint, the sprint burndown chart is used as a tool to visualize the progress made and the work remaining on a daily basis. At the end of a daily stand-up meeting, the scrum master determines the work completed in the previous day and the list of work that remains to be completed and represents these in the sprint burndown chart. The horizontal axis of the sprint burndown chart represents the days in the sprint, and the vertical axis shows the amount of work remaining (in hours of effort) at the end of each day. An example of a sprint burndown chart has been shown in Figure 4.6. As can be seen, the chart visually represents the progress made on a day-to-day basis and the work that is remaining to be completed. This chart, therefore, helps to quickly determine whether the sprint is on schedule and whether all the planned work would finish by the desired date.

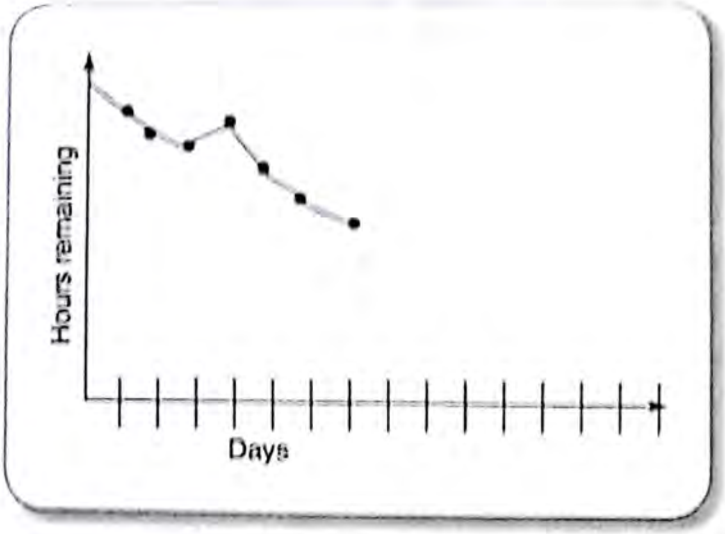


Figure 4.6 An example of a sprint burndown chart

Scrum ceremonies The term *scrum ceremonies* is used to denote the meetings that are mandatorily held during the duration of a project. The scrum ceremonies include three different types of meetings: sprint planning, daily scrum and sprint review meetings.

- *Sprint planning* During the sprint planning meeting, the team members commit to develop and deliver certain features in the ensuing sprint, out of those listed in the product backlog. In this meeting, the product owner works with the team to negotiate which product backlog items the team should work on in the next sprint in order to meet the release goals. It is the responsibility of the scrum master to ensure that the team agrees to realistic goals for a sprint.
- *Daily scrum* The daily scrum is a short stand-up meeting conducted every day morning to review the status of the progress achieved and the major issues being faced on a day-to-day basis. The daily scrum meeting is not a problem-solving meeting, rather each member updates the teammates about what he has achieved in the previous day. Each team member focuses on answering three questions: What did he do yesterday? What will he do today? What obstacles are in his way? The daily scrum meeting helps the scrum master to track the progress made so far and helps to address any problems needing immediate attention. Also, the team members get an appraisal of the project status and any specific problems that are being faced. To keep the meeting short (usually 15 or 20 minutes) and focused, this meeting is conducted with the team members standing up.
- *Sprint review meeting* At the end of each sprint, a sprint review meeting is conducted. In this meeting, the team demonstrates the new functionality developed during the sprint that was just completed to the product owner and to the stakeholders. Feedback is collected from the participants of the meeting and these are either taken into account in the next sprint or are added to the product backlog.

4.17 Lean Software Development

The origin of the Lean software development process can be traced to the Lean process that was developed in a car manufacturing industry (Toyota production system). It was soon found to be an effective product development process and holds significant benefits. It soon became widely accepted and used in various types of product-manufacturing industries. The central theme of Lean is to achieve overall process efficiency through eliminating various aspects that cause waste of work and introduce delays. Kanban methodology was developed as a part of the Lean approach to visualize the work flow. Using Kanban it becomes easy to identify and eliminate potential delays and bottlenecks. Due to its obvious advantages, the Kanban methodology has now become widely accepted and has emerged as a popular methodology on its own standing and is being used in conjunction with other agile methodologies such as XP.

Lean methodology in software development About a decade back, Lean methodology was adopted for use in the software development projects and has since gained significant popularity. In software development projects, it has been found effective in reducing delays and bottlenecks by minimizing waste. Please note that in the Lean methodology, any work that does not add value to the customer is considered to be waste. A few examples of waste are rework required for defect correction, gold plating and scope creep, delay in staffing, and excessive documentation.

Kanban Kanban is a Japanese word meaning a signboard. The main objective of Kanban is to provide visibility to the workflow. This in turn is expected to help debottleneck congestions in the process and minimize delays. Though developed in the context of general product manufacturing industries, Kanban has been observed to be highly appropriate in software development projects. A possible reason behind this could be that in manufacturing, the process is visible as the work product progresses along the production line. But, in software development, the visibility of the product, the product line and the work performed are low. In this context, the Kanban method helps a project team to visualise the workflow, limit the work in progress (WIP), and also measure the cycle time.

Kanban board and Kanban card A principal artefact of the Kanban approach is the Kanban board. A Kanban board is typically a white board on which sticky notes called Kanban cards are attached to represent the work items that are waiting for completion at different development stages. A card is moved on the board as the corresponding work is completed at a stage. This provides visualization of the work flow and the work queued up at different stages. The process steps are called stages or work stations, and are drawn as columns on the Kanban board. On a Kanban board, the work process causing delay is easy to spot, and remedial actions can be initiated.

One of the main premises of the Kanban approach is that during development when some work stage becomes overloaded with work, it introduces delays and slows down the entire development process. This eventually shows up as schedule slips. In the Kanban board, the different stages of development such as coding, code review and testing are represented by different columns in the board. The work itself is broken down into small work items and the work item name is written on a card. The card is stuck to the appropriate column of the Kanban board to represent the stage at which the work item is waiting for completion. As the work item progresses through different stages, the card is moved accordingly on the Kanban board. In Kanban, it is a requirement that the number of work items (represented as cards) that can be in progress at any one time are to be limited. We can therefore say that Kanban enforces work in progress limits (WIP). The general idea behind it is to reduce the workload at a processing station, so that the developers can concentrate only on a few tasks and complete those before taking up anything new. The goal of limiting WIP is to reduce stress and to raise productivity as well as product quality.

Visibility provided by Kanban board The Kanban board provides visibility to the way software development work proceeds. That is, it shows work assigned to each developer at any time and the work flow. It therefore becomes possible to define and communicate the priorities and the bottlenecks get highlighted. The average time it takes to complete a work item (sometimes called the *cycle time*) is tracked and optimized so that the process becomes efficient and predictable. The Kanban system, therefore, helps to limit the amount of work in process so that the work flowing through the system matches its full capacity.

4.18 Managing Iterative Processes

This discussion of agile methods might be confusing as it seems to turn many of our previous planning concepts on their head.

Approaches like XP correctly emphasize the importance of communication and of removing artificial barriers to development productivity. XP to many might seem to be simply a 'licence to hack'. However, a more detailed examination of the techniques of XP shows that many (such as pair programming and installation standards) are conscious techniques to counter the excesses of hacking and to ensure that good maintainable code is written.

Booch suggests that there are two levels of development: the macro process and the micro process. The macro process is closely related to the waterfall process model. At this level, a range of activities carried out by a variety of specialist groups has to be coordinated. We need to have some dates when we know that major activities will be finished so that we know when we will need to bring in staff to work on subsequent activities. Within this macro process there will be micro process activities which might involve iterative working. Systems testing has always been one. Figure 4.7 illustrates how a sequential macro process can be imposed on a number of iterative sub-processes. With iterative micro processes, the use of time-boxes is needed to control at the macro level.

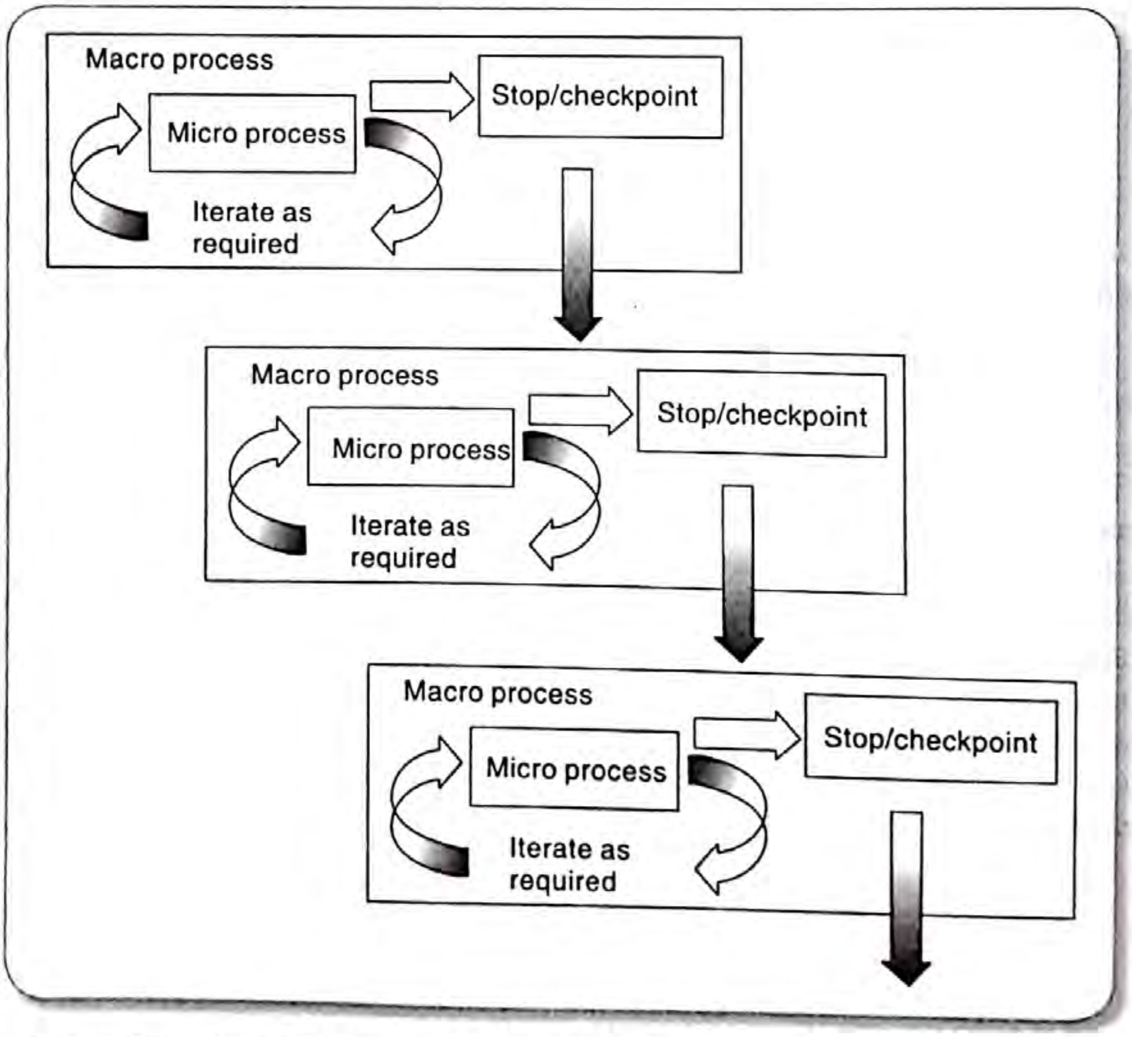


FIGURE 4.7 A macro process containing three iterative micro processes

There are cases where the macro process itself can be iterative. It might be that a prototype for a complex technical system is produced in two or three successive versions, each taking several months to create and evaluate. In these circumstances, each iteration should be treated as a project in its own right.

The packaging of micro processes within larger macro processes means that it is possible for agile projects using XP practices to exist within a more traditional stage-gate project environment (see Section 4.7) which has formal milestones where the business case for the project is reviewed. Agile projects might even contribute helpfully to this process as their progress is more visible.

D. Karlström and P. Runeson (2005), 'Combining agile methods with stage-gate project management' IEEE Software, May/June.

4.19 Selecting the Most Appropriate Process Model

Construction of an application can be distinguished from its *installation*. It is possible to use different approaches for these two stages. For example, an application could be constructed using a waterfall or one-shot strategy but then be released to its users in increments. The only combination of construction and installation strategies that are not feasible are the evolutionary installation with any construction approach other than evolutionary.

Whenever uncertainty is high, an evolutionary approach needs to be favoured. An example of this situation would be where the users' requirements are not clearly defined. Where the requirements are relatively certain but there are many complexities, as with a large embedded system needing a large amount of code, then an incremental approach is favoured. Where deadlines are tight, then either an evolutionary or an incremental approach is favoured over a one-shot strategy, as both tactics should allow at least something to be delivered at the deadline, even if it is not all that was originally promised. Students about to plan final-year projects would do well to note this.

Selection of an appropriate process model for a project can depend on several issues such as the characteristics of the software to be developed, the characteristics of the development team, and those of the customer. For development of simple and well-understood applications, the waterfall model should be sufficient. In fact, the waterfall model should be preferred in this case as it is an efficient model for well-understood projects undertaken by experienced programmers. Furthermore, the waterfall model results in production of good documents.

If the development team is entirely novice, then even the development of a simple application may require an incremental or prototyping model to be adopted. An incremental delivery model is usually suitable for object-oriented development projects. The spiral model would be appropriate, if the project is large and it is not possible to anticipate the project risks at the start of the project. The user interface part is usually developed using the prototyping model. If the customer is unsure about some features of the software to be developed, then an evolutionary or an agile model would possibly be the best choice. Where deadlines are tight, an evolutionary, incremental, or agile approach should be favoured over a one-shot strategy, as at least something would get delivered by the deadline. Students about to plan their final-year projects should make a note of this.

Exercise 4.6

A travel agency needs software for automating its book-keeping activities. The set of activities to be automated are rather simple and are at present being carried out manually. The travel agency has indicated that it is unsure about the type of user interface which would be suitable for its employees and its customers. Would it be proper for a development team to use the spiral model for developing this software?

Conclusion

This chapter has stressed the need to examine each project carefully to see if it has characteristics which suggest a particular approach or process model. These characteristics might suggest the addition of specific activities to the project plan.

The classic waterfall process model, which attempts to minimize iteration, should lead to projects that are easy to control. Unfortunately, many projects do not lend themselves to this structure. Prototyping may be able to reduce project uncertainties by allowing knowledge to be bought through experimentation. The incremental approach encourages the execution of a series of small, manageable, 'mini-projects' but does have some costs.

Further Exercises

1. A building society has a long history of implementing computer-based information systems to support the work of its branches. It uses a proprietary structured systems analysis and design method. It has been decided to create a computer model of the property market. This would attempt, for example, to calculate the effect of changes of interest rates on house values. There is some concern that the usual methodology used for IS development would not be appropriate for the new project.
   (a) Why might there be this concern and what alternative approaches should be considered?
   (b) Outline a plan for the development of the system which illustrates the application of your preferred methodology for this project.
2. A software package is to be designed and built to assist in software cost estimation. It will input certain parameters and produce initial cost estimates to be used at bidding time.
   (a) It has been suggested that a software prototype would be of value in these circumstances. Explain why this might be.
   (b) Discuss how such prototyping could be controlled to ensure that it is conducted in an orderly and effective way and within a specified time span.
3. An invoicing system is to have the following transactions: amend invoice, produce invoice, produce monthly statements, record cash payment, clear paid invoices from database, create customer records, delete customer.
   (a) What physical dependencies govern the order in which these transactions are implemented?
   (b) How could the system be broken down into increments which would be of some value to the users (**Hint** – think about the problems of taking existing details onto a database when a system is first implemented)?
4. In Section 4.10, the need was stressed of defining what is to be learnt from a prototype and the way that it will be evaluated to obtain the new knowledge. Outline the learning outcomes and evaluation for the following.

(a) A final-year degree student is to build an application that will act as a 'suggestions box' in a factory. The application will allow employees to make suggestions about process improvements, and will track the subsequent progress of the suggestion as it is evaluated. The student wants to use a web-based front-end with a conventional database. The student has not previously developed any applications using this mix of technologies.

(b) An engineering company has to maintain a large number of different types of document relating to current and previous projects. It has decided to evaluate the use of a computer-based document retrieval system and wishes to try it out on a trial basis.

(c) A business which specializes in 'e-solutions', that is, the development of business applications that exploit the World Wide Web, has been approached by the computing school of a local university. The school is investigating setting up a special website for its former students. The website's core will be information about job and training opportunities and it is hoped that this will generate income through advertising. It is agreed that some kind of pilot to evaluate the scheme is needed.

5. In a college environment, an intranet for students that holds information about courses, such as lecture programmes, reading lists and assignment briefs, is often set up. As a 'real' exercise, plan, organize and carry out a JAD session to design (or improve the design of) an intranet facility.

   This will require: ·

   - Preliminary interviews with representative key stakeholders (for example, staff who might be supplying information for the intranet)
   - Creation of documents for use in the JAD proceedings
   - Recording of the JAD proceedings
   - Creating a report which will present the findings of the JAD session

6. What are the major shortcomings of the waterfall model? How have those shortcomings been overcome by the agile model?

7. Identify the pros and cons of using pair programming over programmers working alone. Based on your analysis, point out if there are any situations where the pair programming technique may not be suitable.

8. Explain how the agile development methods help project teams to overcome some of the important disadvantages associated with the traditional heavyweight development processes.

9. Briefly explain the main principles of the agile development methodologies.

10. What do you understand by the term 'ceremonies' in a Scrum project? Explain the different types of ceremonies that are observed in a Scrum project and their significance.

11. What are the different roles that the members of a Scrum team assume? Explain the responsibilities that go with each role.

12. What do you mean by Kanban? What can be achieved using Kanban? Briefly explain the Kanban methodology.

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

    (i) Which one of the following activities spans all the stages of a software development life cycle (SDLC)?

    (a) Coding (b) Testing

    (c) Project management (d) Design

(ii) The operation phase in the waterfall model is a synonym for which one of the following phases?

(a) Coding and unit testing phase (b) Integration and system testing phase

(c) Maintenance phase (d) Design phase

(iii) The implementation phase in the waterfall model is a synonym for which one of the following phases?

(a) Coding and unit testing phase (b) Integration and system testing phase

(c) Maintenance phase (d) Design phase

(iv) Which one of the following phases accounts for the maximum effort during the development of a typical software?

(a) Coding (b) Testing

(c) Designing (d) Specification

(v) Which one of the following feedback paths is not present in an iterative waterfall model?

(a) Design phase to feasibility study phase

(b) Implementation phase to design phase

(c) Implementation phase to requirements specification phase

(d) Design phase to requirements specification phase

(vi) Defects get introduced into a work product due to mistakes committed by the members of the development team. A mistake in an activity pertaining to which one of the following phases introduces the most expensive defect?

(a) System testing (b) Design

(c) Coding and unit testing (d) Requirements analysis and specification

(vii) Which one of the following is a suitable SDLC model for developing a moderate-sized software for which the customer is not clear about his exact requirements?

(a) RAD model (b) V model

(c) Iterative waterfall model (d) Classical waterfall model

(viii) Change requests from customers later in the development cycle are the easiest to handle in which one of the following life cycle models?

(a) Iterative waterfall model (b) Prototyping model

(c) V model (d) Evolutionary model

(ix) Which one of the following disadvantages may be experienced when a systematic development process model is adopted by a project team in preference to a build-and-fix style of development?

(a) Increased documentation overhead (b) Increased development cost

(c) Decreased maintainability (d) Increased development time

(x) Which one among the following SDLC models can be considered to be the most effective for determination of the exact customer requirements?

(a) Iterative waterfall model (b) V model

(c) Prototyping model (d) Classical waterfall model

(xi) In the waterfall SDLC model, unit testing is carried out during which one of the following phases?

(a) Coding (b) Testing

(c) Design (d) Maintenance

(xii) In which one of the following SDLC models, testing activities are spread over the entire development life cycle?

(a) Iterative waterfall model (b) V model

(c) Prototyping model (d) Classical waterfall model

(xiii) Which one of the following SDLC models would be suitable for use in a project involving customization of a medium-sized computer communication package? Assume that the project would be manned by experienced personnel and that the schedule for the project has been very aggressively set.

(a) V model (b) Iterative waterfall model

(c) Prototyping model (d) Agile model

(xiv) Which one of the following is not a characteristic of the agile model of software development?

(a) Well-demarcated phases (b) Evolutionary development

(c) Iterative development (d) Periodic delivery of working software

(xv) Which one of the following can be considered to be the primary focus of pair-wise programming?

(a) Incremental development (b) Test-driven development

(c) Continuous review (d) Iterative development

(xvi) Which one of the following life cycle models lacks the characteristics of iterative software development?

(a) Spiral model (b) Agile model

(c) Classical waterfall model (d) Evolutionary model

(xvii) Which one of the following life cycle models does not involve constructing a prototype any time during software development?

(a) Spiral model (b) Prototyping model

(c) RAD (d) Evolutionary model

(xviii) Which one of the following is the most appropriate reason behind Scrum teams to be called self-organizing?

(a) The team members independently decide when to join and leave the project.

(b) The team members decide among themselves their respective roles and responsibilities.

(c) The team members decide among themselves their respective roles in the project, but the scrum master assigns them specific responsibilities.

(d) The team members decide who would report to whom among themselves.

(xix) Which one of the following is not a Sprint ceremony?

(a) Sprint planning meeting (b) Daily stand-up meeting

(c) Sprint retrospective meeting (d) Project start up meeting

(xx) When prototyping is to be incorporated into an iterative waterfall process model, it should be included in which phase of development?

(a) Feasibility study (b) Requirements analysis and specification

(c) Design (d) Coding and unit testing

(xxi) Which one of the following is true for prototypes?

(a) Construction of prototypes incurs significant costs and should be avoided as far as possible.

(b) A prototype is a useful tool for eliciting early feedback from the users on the requirements.

(c) Prototypes are usually constructed towards the end of the design phase.

(d) Prototypes increase the risk of misunderstanding of the requirements by the users.

(xxii) In the prototyping model of software development, which one of the following is the principal reason for developing a prototype?

(a) A prototype is iteratively enhanced into the working software and is finally deployed at the client site.

(b) A prototype is deployed at the client site as an operational software till the full version is developed.

(c) A working prototype helps the customer to provide meaningful feedback about requirements.

(d) A prototype helps in project scheduling.

(xxiii) Which one of the following is not an expected outcome of using Kanban method?

(a) Reduced delay (b) Reduced fatigue of team members

(c) Reduced manpower (d) More balanced work load

5 Software Effort Estimation

Learning Objectives

- Avoid the dangers of unrealistic estimates
- Understand the range of estimating methods that can be used
- Estimate projects using a bottom-up approach
- Estimate the effort needed to implement software using a procedural programming language
- Count the function points for a system
- Understand the COCOMO II approach and use it to estimate project effort

5.1 Introduction

A successful project is one delivered '*on time, within budget and with the required quality*'. This implies that targets are set which the project manager then tries to meet. This assumes that the targets are reasonable – no account is taken of the possibility of project managers achieving record levels of productivity from their teams, but still not meeting a deadline because of incorrect initial estimates. Realistic estimates are therefore crucial.

A project manager like Amanda has to produce estimates of *effort*, which affect costs, and of activity *durations*, which affect the delivery time. These could be different, as in the case where two testers work on the same task for the same five days.

Some of the difficulties of estimating arise from the complexity and invisibility of software. Also, the intensely human activities which make up system development cannot be treated in a purely mechanistic way. Other difficulties include:

- *Subjective nature of estimating* For example, some research shows that people tend to underestimate the difficulty of small tasks and over-estimate that of large ones.

In Chapter 1, the special characteristics of software identified by Brooks, i.e. complexity, conformity, changeability and invisibility, were discussed.

- *Political implications* Different groups within an organization have different objectives. The IOE information systems development managers may, for example, want to generate work and will press estimators to reduce cost estimates to encourage higher management to approve projects. As Amanda is responsible for the development of the annual maintenance contracts subsystem, she will want to ensure that the project is within budget and timescale, otherwise this will reflect badly on herself. She might therefore try to increase the estimates to create a 'comfort zone'. To avoid these 'political' influences, one suggestion is that estimates be produced by a specialist estimating group, independent of the users and the project team. Not all agree with this, as developers will be more committed to targets they themselves have set.

The possibility of the different groups with stakes in a project having different and possibly conflicting objectives was discussed in Chapter 1.

- *Changing technology* Where technologies change rapidly, it is difficult to use the experience of previous projects on new ones.
- *Lack of homogeneity of project experience* Even where technologies have not changed, knowledge about typical task durations may not be easily transferred from one project to another because of other differences between projects.

It would be very difficult on the basis of this information to advise a project manager about what sort of productivity to expect, or about the probable distribution of effort between the phases of design, coding and testing that could be expected from a new project.

Using existing project data for estimating is also difficult because of uncertainties in the way that various terms can be interpreted. For example, what exactly is meant by the term 'testing'? Does it cover the activities of the software developer when debugging code?

The ISO 12207 standard, touched upon in Chapter 1, is an attempt to address this problem by standardizing on some of the terms used.

Exercise 5.1

Calculate the productivity (i.e. SLOC per work month) of each of the projects in Table 5.1 and also for the organization as a whole. If the project leaders for projects a and d had correctly estimated the source number of lines of code (SLOC) and then used the average productivity of the organization to calculate the effort needed to complete the projects, how far out would their estimates have been from the actual effort?

TABLE 5.1 Some project data – effort in work months (as percentage of total effort in brackets)

Project	Design		Coding		Testing		Total	
	wm	(%)	wm	(%)	wm	(%)	wm	SLOC
a	3.9	(23)	5.3	(32)	7.4	(44)	16.7	6050
b	2.7	(12)	13.4	(59)	6.5	(26)	22.6	8363
c	3.5	(11)	26.8	(83)	1.9	(6)	32.2	13334
d	0.8	(21)	2.4	(62)	0.7	(18)	3.9	5942

The figures are taken from B. A. Kitchenham and N. R. Taylor (1985) 'Software project development cost estimation' *Journal of Systems and Software (5)*. The abbreviation SLOC stands for 'source lines of code'. SLOC is one way of indicating the size of a system.

(Contd)

e	1.8	(10)	7.7	(44)	7.8	(45)	17.3	3315
f	19.0	(28)	29.7	(44)	19.0	(28)	67.7	38988
g	2.1	(21)	7.4	(74)	0.5	(5)	10.1	38614
h	1.3	(7)	12.7	(66)	5.3	(27)	19.3	12762
i	8.5	(14)	22.7	(38)	28.2	(47)	59.5	26500

Exercise 5.2

In the data presented in Table 5.1, observe that programmer productivity varies from 7 SLOC/day to 150 SLOC/day. In fact, in the industry the average productivity figure for programmers is only about 10 SLOC/day. Would you consider programmer productivity of 10 SLOC/day to be too low?

5.2 Where are the Estimates Done?

Estimates are carried out at various stages of a software project for a variety of reasons.

- *Strategic planning* Project portfolio management involves estimating the costs and benefits of new applications in order to allocate priorities. Such estimates may also influence the scale of development staff recruitment.
- *Feasibility study* This confirms that the benefits of the potential system will justify the costs.

Chapter 2 discussed project portfolio management in some detail.

- *System specification* Most system development methodologies usefully distinguish between the definition of the users' requirements and the design which shows how those requirements are to be fulfilled. The effort needed to implement different design proposals will need to be estimated. Estimates at the design stage will also confirm that the feasibility study is still valid.
- *Evaluation of suppliers' proposals* In the case of the IOE annual maintenance contracts subsystem, for example, IOE might consider putting development out to tender. Potential contractors would scrutinize the system specification and produce estimates as the basis of their bids. Amanda might still produce her own estimates so that IOE could question a proposal which seems too low in order to ensure that the proposer has properly understood the requirements. The cost of bids could also be compared to in-house development.

The estimate at this stage cannot be based only on the user requirement: some kind of technical plan is also needed – see Chapter 4.

- *Project planning* As the planning and implementation of the project becomes more detailed, more estimates of smaller work components will be made. These will confirm earlier broad-brush estimates, and will support more detailed planning, especially staff allocations.

As the project proceeds, so the accuracy of the estimates should improve as knowledge about the project increases. At the beginning of the project the user requirement is of paramount importance and premature consideration of the possible physical implementation is discouraged. However, in order to produce an estimate, there will need to be speculation about the eventual shape of the application.

To set estimating into the context of the Step Wise framework (Figure 5.1) presented in Chapter 3, re-estimating could take place at almost any step, but specific provision is made for the production of a relatively high-level estimate at Step 3, 'Analyse project characteristics', and for each individual activity in Step 5. As Steps 5–8 are repeated at progressively lower levels, so estimates will be done at a finer degree of detail. As we will see later in this chapter, different methods of estimating are needed at these different planning steps.

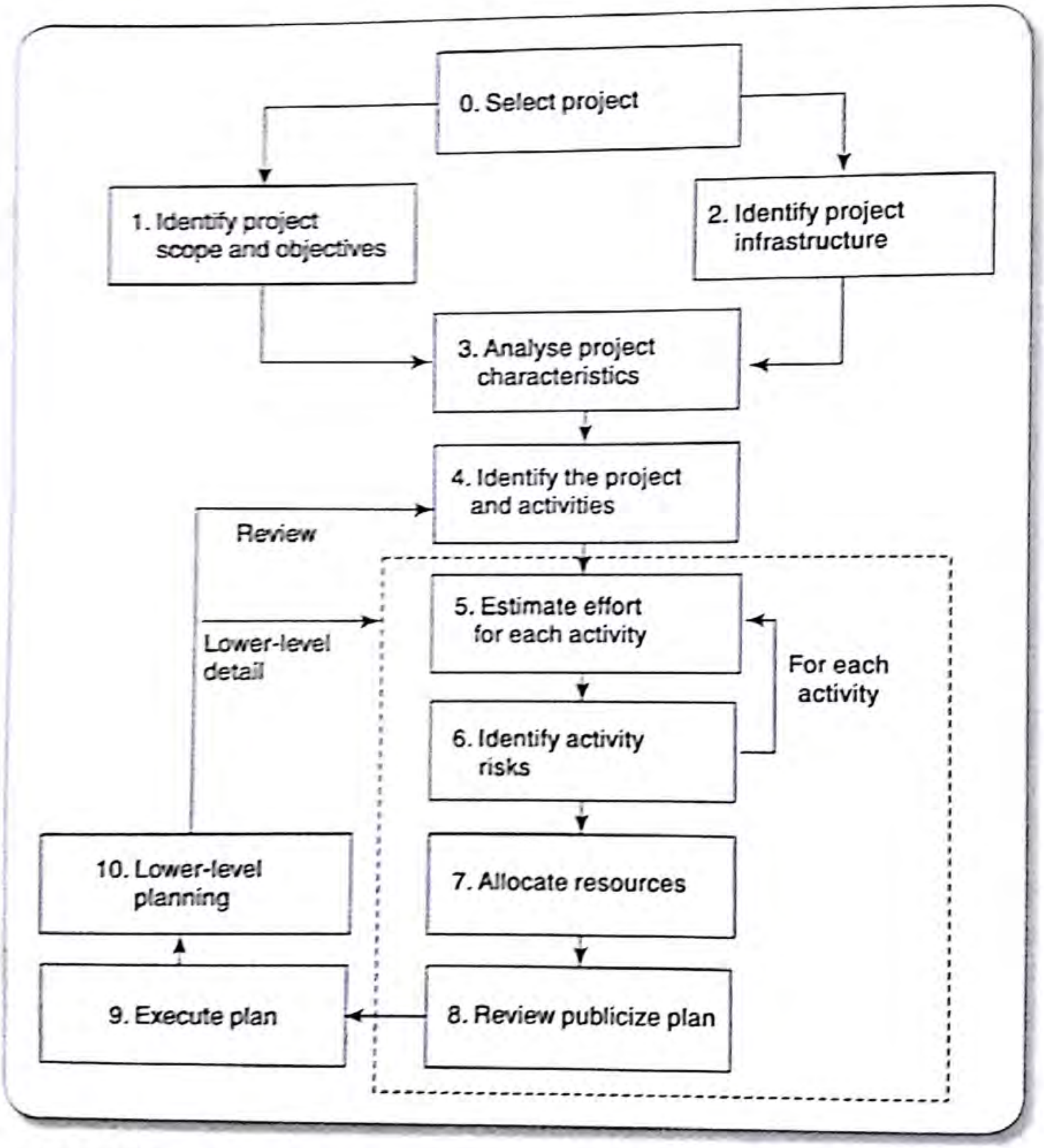

0. Select project
1. Identify project scope and objectives
2. Identify project infrastructure
3. Analyse project characteristics
4. Identify the project and activities
Review
5. Estimate effort for each activity
Lower-level detail
For each activity
6. Identify activity risks
7. Allocate resources
10. Lower-level planning
9. Execute plan
8. Review publicize plan

FIGURE 5.1 Software estimation takes place in Steps 3 and 5 in particular

5.3 Problems with Over- and Under-Estimates

A project leader such as Amanda will need to be aware that an over-estimate may cause the project to take longer than it would otherwise. This can be explained by the application of two 'laws'.

- *Parkinson's Law 'Work expands to fill the time available'*, that is, given an easy target staff will work less hard.

- ***Brooks' Law*** The effort of implementing a project will go up disproportionately with the number of staff assigned to the project. As the project team grows in size, so will the effort that has to go into management, coordination and communication. This has given rise, in extreme cases, to the notion of Brooks' Law: '*putting more people on a late job makes it later*'. If there is an over-estimate of the effort required, this could lead to more staff being allocated than needed and managerial overheads being increased.

Parkinson's law was originally expounded in C. Northcote Parkinson's tongue-in-cheek book *Parkinson's Law*, John Murray, 1957. Brooks' law comes from *The Mythical Man-month* which has been referred to already.

Some have suggested that while the under-estimated project might not be completed on time or to cost, it might still be implemented in a shorter time than a project with a more generous estimate.

The danger with the under-estimate is the effect on quality. Staff, particularly those with less experience, could respond to pressing deadlines by producing work that is substandard. This may be seen as a manifestation of Weinberg's zeroth law of reliability: '*if a system does not have to be reliable, it can meet any other objective*'. Substandard work might only become visible at the later, testing, phases of a project which are particularly difficult to control and where extensive rework can easily delay project completion.

See, for example, T. K. Hamid and S. E. Madnick (1986) 'Impact of schedule estimation on software project behaviour' *IEEE Software* July 3(4) 70–5.

Exercise 5.3

How do agile methods such as XP – see Chapter 4 – attempt to address the problems with estimates described above?

Research has found that motivation and morale are enhanced where targets are achievable. If, over time, staff become aware that the targets set are unattainable and that projects routinely miss targets, motivation is reduced. People like to think of themselves as winners and there is a general tendency to put success down to our own efforts and blame failure on the organization.

An estimate is not really a prediction, it is a *management goal*. Barry Boehm has suggested that if a software development cost is within 20% of the estimated cost for the job then a good manager can turn it into a self-fulfilling prophecy. A project leader like Amanda will work hard to make the actual performance conform to the estimate.

Barry Boehm devised the COCOMO estimating models which are described later in this chapter.

5.4 The Basis for Software Estimating

The need for historical data

Most estimating methods need information about past projects. However, care is needed when applying past performance to new projects because of possible differences in factors such as programming languages and the experience of staff. If past project data is lacking, externally maintained datasets of project performance data can be accessed. One well-known international database is that maintained by the International Software Benchmarking Standards Group (ISBSG), which currently contains data from 4800 projects.

Details of the work of the International Software Benchmarking Standards Group can be found at http://isbsg.org

Parameters to be estimated

The project manager needs to estimate two project parameters for carrying out project planning. These two parameters are effort and duration. Duration is usually measured in months. Work-month (wm) is a popular unit for effort measurement. We have already used this unit of effort measurement in Table 5.1. The term person-month (pm) is also frequently used to mean the same as work-month. One person-month is the effort an individual can typically put in a month. The person-month estimate implicitly takes into account the productivity losses that normally occur due to time lost in holidays, weekly offs, coffee breaks, etc. Person-month (pm) is considered to be an appropriate unit for measuring effort compared to person-days or person-years because developers are typically assigned to a project for a certain number of months.

Measure of work

Measure of work involved in completing a project is also called the size of the project. Work itself can be characterized by cost in accomplishing the project and the time over which it is to be completed. Direct calculation of cost or time is difficult at the early stages of planning. The time taken to write the software may vary according to the competence or experience of the software developers might not even have been identified. Implementation time may also vary depending on the extent to which CASE (Computer Aided Software Engineering) tools are used during development. It is therefore a standard practice to first estimate the project size; and by using it, the effort and time taken to develop the software can be computed. Thus, we can consider project size as an independent variable and the effort or time required to develop the software as dependent variables.

Let us examine the meaning of the term 'project size'. The size of a project is obviously not the number of bytes that the source code occupies, neither is it the size of the executable code. The project size is a measure of the problem complexity in terms of the effort and time required to develop the product. Two metrics are at present popularly being used to measure size. These are Source Lines of Code (SLOC) and Function Point (FP). The SLOC measure suffers from various types of disadvantages, which are to a great extent corrected in the FP measure. However, the SLOC measure is intuitively simpler, so it is still being widely used. It is important, however, to be aware of the major shortcomings of the SLOC measure.

- *No precise definition.* SLOC is a very imprecise measure. Unfortunately, researchers have not been consistent on points like does it include comment lines or are data declarations to be included? The writers' view is that comment lines are excluded in determining the SLOC measure. This can be debated, but the main point is that consistency is essential.
- *Difficult to estimate at start of a project.* From the project manager's perspective, the biggest shortcoming of the SLOC metric is that it is very difficult to estimate it during project planning stage, and can be accurately computed only after the development of the software is complete. The SLOC count can only be guessed at the beginning of a project, often leading to grossly inaccurate estimations.
- *Only a code measure.* SLOC is a measure of coding activity alone. This point has been illustrated in Exercise 5.2. A good problem size measure should consider the effort required for carrying out all the life cycle activities and not just coding.
- *Programmer-dependent.* SLOC gives a numerical value to the problem size that can vary widely with the coding style of individual programmers. This aspect alone renders any LOC-based size and effort estimations inaccurate.

R. E. Park has devised a standard for counting source statements that has been widely adopted – see *Software Size Measurement: A Framework for Counting Source Statements*, Software Engineering Institute, 1992.

- *Does not consider code complexity.* Two software components with the same KLOC will not necessarily take the same time to write, even if done by the same programmer in the same environment. One component might be more complex. Because of this, the effort estimate based on SLOC might have to be modified to take its complexity into account. Attempts have been made to find objective measures of complexity, but it depends to a large extent on the subjective judgment of the estimator.

Measure of effort

Man-month (MM) [also referred to as Person-month (PM)] is a popular unit for effort measurement. It quantifies the effort that can be put in by one person over 1 month. Person-month (PM) is considered to be an appropriate unit for measuring effort as compared to person-day or person-year, because developers are typically assigned to a project for a certain number of months. It should be noted that an effort estimation of 100 PM does not imply that 100 persons should work for 1 month. Neither does it imply that one person should be employed for 100 months to complete the project.

Even though the effort that has been put in by a team can be measured in units of man-month based on the number of persons deployed and the number of months that they have worked, it may be fallacious to relate this to the progress achieved in the project. This aspect has been highlighted by Fred Brooks in his book 'The Mythical Man-Month'. This is a classic book on the human elements of software project management and provides several insights as to why projects fail. In the following, we discuss why inferring the project progress by measuring effort expended in units of person-month may be fallacious.

The unit of man-month as a measure of work completed in a project may suggest that the number of people working on a project and the duration for which they have worked to be tradable. That is, the progress achieved by deploying 100 persons for one day would be the same as one person working for 100 days. This aspect is expressed by Brooks as follows: 'Cost varies as product of men and months, progress does not.' Brooks concludes that man-month as a unit for measuring the progress achieved in a project is a deceptive myth.

Let us investigate why progress cannot be measured as the product of men and months. Men and months are tradable only when the project tasks can be partitioned equally among all the workers, there are no dependencies among the tasks, and the communication requirement among the workers is negligible. In such projects, the progress can be computed by the number of persons deployed and the number of months for which they have worked. However, this is far from the truth in software development projects. The progress that can be achieved by increasing the number of workers for such a project is shown in Figure 5.2(a). As can be seen in Figure 5.2(a), the completion time steadily decreases as the number of workers increases. However, in practical projects the situation is very different.

In practical projects, there is a substantial communication requirement among the team members, there exist intricate dependencies among various tasks and also for almost any task very fine-grained partitioning is not feasible. For example, consider the task of requirements analysis and requirements specification. It can be meaningfully carried out by four or six analysts. However, if hundreds or thousands of analysts are deployed, then it would not be possible to assign work to many. Also as the tasks are divided into finer subtasks, the communication and management overheads increase drastically. Further, dependencies exist among tasks. For example, design cannot be carried out for a feature for which requirements analysis and specification is not complete. This aspect is shown in Figure 5.2(b), where the completion time initially decreases with increase in the number of workers. However, after some time it actually increases indicating the drastically increased communication and management overheads.

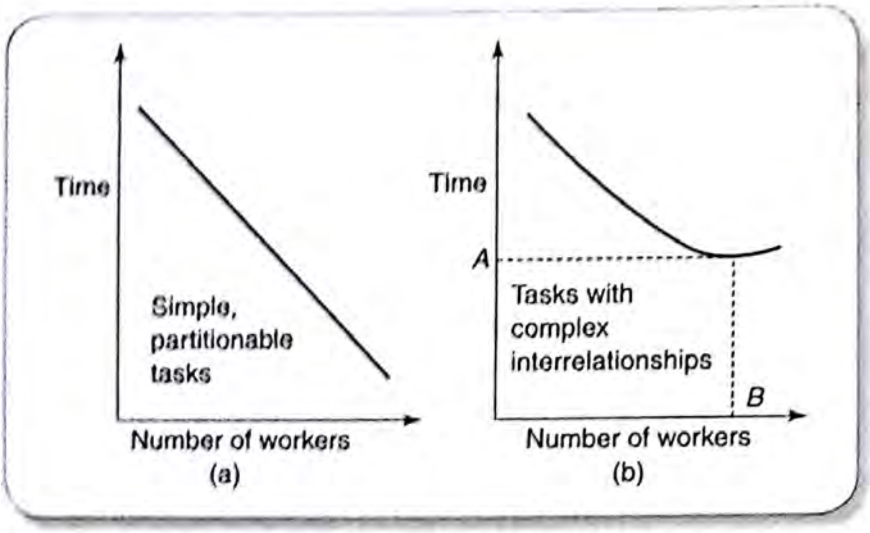


FIGURE 5.2 Impact of addition of workers on the completion time for various types of projects

Software development is an intellectual work, and requires significant amount of communication among the team members. In fact, often the effort in communication dominates the actual work. Communication is made up of two parts as follows: training and intercommunications. Training (technology, goals, overall strategy and work plan) cannot be partitioned and more effort does no good. The intercommunication overhead rises as the number of members in the team increases. Assuming that members talk pairwise, the communication overhead increases as the square of the number of persons in the team. For a team with n number of team members, the number of pairwise communications (meetings involving two persons) is $n(n-1)/2$. Interactions involving more than two people can make the required number of communications even worse. Therefore, in a typical project increasing manpower can become counter-productive after some number of workers. In Figure 5.2(b) observe, that A is the minimum time by which the project can be completed by deploying B number of persons. Increasing the number of deployed persons further, may actually result in increase in project completion time. The above discussions can be extended to explain why adding man power to a late project may make it later.

5.5 Software Effort Estimation Techniques

See B. W. Boehm (1981) *Software Engineering Economics*, Prentice-Hall

Barry Boehm, in his classic work on software effort models, identified the main ways of deriving estimates of software development effort as:

- *Algorithmic models*, which use 'effort drivers' representing characteristics of the target system and the implementation environment to predict effort
- *Expert judgement*, based on the advice of knowledgeable staff
- *Analogy*, where a similar, completed, project is identified and its actual effort is used as the basis of the estimate
- *Parkinson*, where the staff effort available to do a project becomes the 'estimate'
- *Price to win*, where the 'estimate' is a figure that seems sufficiently low to win a contract
- *Top-down*, where an overall estimate for the whole project is broken down into the effort required for component tasks
- *Bottom-up*, where component tasks are identified and sized and these individual estimates are aggregated

Clearly, the 'Parkinson' method is not really an effort prediction method, but a method of setting the scope of a project. Similarly, 'price to win' is a way of identifying a price and not a prediction. Although Boehm rejects them as prediction techniques, they have value as management techniques. There is, for example, a perfectly acceptable engineering practice of '*design to cost*'.

This is also the principle behind the concept of time-boxing discussed in Chapter 4 in the context of incremental delivery.

We will now look at some of these techniques more closely. First we will examine the difference between top-down and bottom-up estimating.

5.6 Bottom-up Estimating

With the bottom-up approach the estimator breaks the project into its component tasks. With a large project, the process of breaking it down into tasks is iterative: each task is decomposed into its component subtasks and these in turn could be further analysed. It is suggested that this is repeated until you get tasks an individual could do in a week or two. Why is this not a 'top-down approach'? After all, you start from the top and work down. Although this top-down analysis is an essential precursor to bottom-up estimating, it is really a separate process – that of producing a work breakdown schedule (WBS). The bottom-up part comes in adding up the calculated effort for each activity to get an overall estimate.

The bottom-up approach is best at the later, more detailed, stages of project planning. If this method is used earlier, assumptions about the characteristics of the final system and project work methods will have to be made.

Where a project is completely novel or there is no historical data available, the estimator would be forced to use the bottom-up approach.

Exercise 5.4

Brigette at Brightmouth College has been told that there is a requirement, once the payroll system has been successfully installed, to create a subsystem that analyses the staffing costs for each course. Details of the pay that each member of staff receives may be obtained from the payroll standing data. The number of hours that each member of staff spends teaching on each course may be obtained from standing files in a computer-based timetabling system.

What tasks would have to be undertaken to implement this requirement? Try to identify tasks that would take one person about 1 or 2 weeks.

Which tasks are the ones whose durations are most difficult to estimate?

A procedural code-oriented approach

The bottom-up approach described above works at the level of activities. In software development a major activity is writing code. Here we describe how a bottom-up approach can be used at the level of software components.

(a) **Envisage the number and type of software modules in the final system**
Most information systems, for example, are built from a small set of system operations, e.g. Insert, Amend, Update, Display, Delete, Print. The same principle should equally apply to embedded systems, albeit with a different set of primitive functions.

'Software module' here implies a component that can be separately compiled and executed.

(b) **Estimate the SLOC of each identified module**

One way to judge the number of instructions likely to be in a program is to draw up a program structure diagram and to visualize how many instructions would be needed to implement each identified procedure. The estimator may look at existing programs which have a similar functional description to assist in this process.

(c) **Estimate the work content, taking into account complexity and technical difficulty**

The practice is to multiply the SLOC estimate by a factor for complexity and technical difficulty. This factor will depend largely on the subjective judgement of the estimator. For example, the requirement to meet particular highly constrained performance targets can greatly increase programming effort.

(d) **Calculate the work-days effort**

Historical data can be used to provide ratios to convert weighted SLOC to effort.

Note that the above steps can be used to derive an estimate of lines of code that can be used as an input to one of the COCOMO models which are described later.

Exercise 5.5

The IOE annual maintenance contracts subsystem for which Amanda is responsible will have a transaction which sets up details of new annual maintenance contract customers.

The operator will input:

- Customer account number
- Customer name
- Address
- Postcode
- Customer type
- Renewal date

All this information will be set up in a CUSTOMER record on the system's database. If a CUSTOMER account already exists for the account number that has been input, an error message will be displayed to the operator.

Draw up an outline program structure diagram for a program to do the processing described above. For each box on your diagram, estimate the number of lines of code needed to implement the routine in a programming language that you are familiar with, such as Java.

5.7 The Top-down Approach and Parametric Models

The top-down approach is normally associated with *parametric* (or *algorithmic*) *models*. These may be explained using the analogy of estimating the cost of rebuilding a house. This is of practical concern to house-owners who need insurance cover to rebuild their property if destroyed. Unless the house-owner is in the building trade he or she is unlikely to be able to calculate the numbers of bricklayer-hours, carpenter-hours, electrician-hours, and so on, required. Insurance companies, however, produce convenient tables where the house-owner can find estimates of rebuilding costs based on such *parameters* as the number of storeys and the floor space of a house. This is a simple parametric model.

Project effort relates mainly to variables associated with characteristics of the final system. A parametric model will normally have one or more formulae in the form:

$$\textit{effort} = (\textit{system size}) \times (\textit{productivity rate})$$

For example, system size might be in the form 'thousands of lines of code' (KLOC) and have the specific value of 3 KLOC while the productivity rate was 40 days per KLOC. These values will often be matters of judgement.

A model to forecast software development effort therefore has two key components. The first is a method of assessing the amount of the work needed. The second assesses the rate of work at which the task can be done. For example, Amanda at IOE may estimate that the first software module to be constructed is 2 KLOC. She may then judge that if Kate undertook the development of the code, with her expertise she could work at a rate of 40 days per KLOC per day and complete the work in 2 × 40 days, i.e. 80 days, while Ken, who is less experienced, would need 55 days per KLOC and take 2 × 55, i.e. 110 days to complete the task. In this case KLOC is a *size driver* indicating the amount of work to be done, while developer experience is a productivity driver influencing the productivity or work rate.

If you have figures for the effort expended on past projects (in work-days for instance) and also the system sizes in KLOC, you should be able to work out a productivity rate as

$$\textit{productivity} = \textit{effort/size}$$

A more sophisticated way of doing this would be by using the statistical technique *least squares regression* to derive an equation in the form:

$$\textit{effort} = \textit{constant}_1 + (\textit{size} \times \textit{constant}_2)$$

Some parametric models, such as that implied by function points, are focused on system or task size, while others, such are COCOMO, are more concerned with productivity factors. Those particular models are described in more detail later in this chapter.

Exercise 5.6

Students on a course are required to produce a written report on an ICT-related topic each semester. If you wanted to create a model to estimate how long it should take a student to complete such an assignment, what measure of work content would you use? Some reports might be more difficult to produce than others: what factors might affect the degree of difficulty?

Having calculated the overall effort required, the problem is then to allocate proportions of that effort to the various activities within that project.

At the earlier stages of a project, the top-down approach would tend to be used, while at later stages the bottom-up approach might be preferred.

The top-down and bottom-up approaches are not mutually exclusive. Project managers will probably try to get a number of different estimates from different people using different methods. Some parts of an overall estimate could be derived using a top-down approach while other parts could be calculated using a bottom-up method.

5.8 Expert Judgement

See R. T. Hughes (1996) 'Expert judgement as an estimating method' Information and *Software Technology* 38(3) 67–75.

This is asking for an estimate of task effort from someone who is knowledgeable about either the application or the development environment. This method is often used when estimating the effort needed to change an existing piece of software. The estimator would have to examine the existing code in order to judge the proportion of code affected and from that derive an estimate. Someone already familiar with the software would be in the best position to do this.

Some have suggested that expert judgement is simply a matter of guessing, but our own research has shown that experts tend to use a combination of an informal analogy approach where similar projects from the past are identified (see below), supplemented by bottom-up estimating.

There may be cases where the opinions of more than one expert may need to be combined. The Delphi technique described in Section 12.3 tackles group decision-making.

5.9 Estimating by Analogy

See M. Shepperd and C. Schofield (1997) 'Estimating software project effort using analogies' *IEEE Transactions in Software Engineering* SE-23(11) 736–43.

This is also called *case-based reasoning*. The estimator identifies completed projects (*source cases*) with similar characteristics to the new project (the *target case*). The effort recorded for the matching source case is then used as a base estimate for the target. The estimator then identifies differences between the target and the source and adjusts the base estimate to produce an estimate for the new project.

This can be a good approach where you have information about some previous projects but not enough to draw generalized conclusions about what might be useful drivers or typical productivity rates.

A problem is identifying the similarities and differences between applications where you have a large number of past projects to analyse. One attempt to automate this selection process is the ANGEL software tool. This identifies the source case that is nearest the target by measuring the Euclidean distance between cases. The Euclidean distance is calculated as:

$$\textit{distance} = \textit{square-root of}\ ((\textit{target\_parameter}_1 - \textit{source\_parameter}_1)^2 + \ldots$$
$$(\textit{target\_parameter}_n - \textit{source\_parameter}_n)^2)$$

Example 5.1

Say that the cases are being matched on the basis of two parameters, the number of inputs to and the number of outputs from the application to be built. The new project is known to require 7 inputs and 15 outputs. One of the past cases, project A, has 8 inputs and 17 outputs. The Euclidean distance between the source and the target is therefore the square-root of $((7 - 8)^2 + (17 - 15)^2)$, that is 2.24.

Exercise 5.7

Project B has 5 inputs and 10 outputs. What would be the Euclidean distance between this project and the target new project being considered above? Is project B a better analogy with the target than project A?

The above explanation is simply to give an idea of how Euclidean distance may be calculated. The ANGEL package uses rather more sophisticated algorithms based on this principle.

5.10 Albrecht Function Point Analysis

This is a top-down method that was devised by Allan Albrecht when he worked for IBM. Albrecht was investigating programming productivity and needed to quantify the functional size of programs independently of their programming languages. He developed the idea of function points (FPs).

See A. J. Albrecht and J. E. Gaffney Jr., 'Software function, source lines of code, and development effort prediction: a software science validation', in M. Shepperd (ed.) (1993) *Software Engineering Metrics* (Vol. 1), McGraw-Hill.

The basis of function point analysis is that information systems comprise five major components, or '*external user types*' in Albrecht's terminology, that are of benefit to the users.

- *External input types* are input transactions which update internal computer files.
- *External output types* are transactions where data is output to the user. Typically these would be printed reports, as screen displays would tend to come under external inquiry types (see below).
- *External inquiry types* – note the US spelling of inquiry – are transactions initiated by the user which provide information but do not update the internal files. The user inputs some information that directs the system to the details required.
- *Logical internal file types* are the standing files used by the system. The term 'file' does not sit easily with modern information systems. It refers to a group of data items that is usually accessed together. It may be made up of one or more *record types*. For example, a purchase order file may be made up of a record type PURCHASE-ORDER plus a second which is repeated for each item ordered on the purchase order – PURCHASE-ORDER-ITEM. In structured systems analysis, a logical internal file would equate to a datastore, while record types would equate to relational tables or entity types.
- *External interface file types* allow for output and input that may pass to and from other computer applications. Examples of this would be the transmission of accounting data from an order processing system to the main ledger system or the production of a file of direct debit details on a magnetic or electronic medium to be passed to the Bankers Automated Clearing System (BACS). Files shared between applications would also be counted here.

Albrecht also dictates that outgoing external interface files should be double counted as logical internal file types as well.

The analyst identifies each instance of each external user type in the application. Each component is then classified as having either high, average or low complexity. The counts of each external user type in each complexity band are multiplied by specified weights (see Table 5.2) to get FP scores which are summed to obtain an overall FP count which indicates the information processing size.

Table 5.2 Albrecht complexity multipliers

External user type	Multiplier		
	Low	Average	High
External input type	3	4	6
External output type	4	5	7
External inquiry type	3	4	6
Logical internal file type	7	10	15
External interface file type	5	7	10

Exercise 5.8

The task for which Brigette has been made responsible in Exercise 5.4 needs a program which will extract yearly salaries from the payroll file, and hours taught on each course by each member of staff and the details of courses from two files maintained by the timetabling system. The program will produce a report showing for each course the hours taught by each member of staff and the cost of those hours.

Using the method described above, calculate the Albrecht function points for this subsystem assuming that the report is of high complexity, but that all the other elements are of average complexity.

The International FP User Group (IFPUG) have developed and published extensive rules governing FP counting. Hence Albrecht FPs are now often referred to as IFPUG FPs.

With FPs as originally defined by Albrecht, the question of whether the external user type was of high, low or average complexity was intuitive. The International FP User Group (IFPUG) has now promulgated rules on how this is assessed. For example, in the case of logical internal files and external interface files, the boundaries shown in Table 5.3 are used to decide the complexity level. Similar tables exist for external inputs and outputs.

Table 5.3 IFPUG file type complexity

Number of record types	Number of data types		
	< 20	20–50	> 50
1	Low	Low	Average
2 to 5	Low	Average	High
>5	Average	High	High

5.2 Example

A logical internal file might contain data about purchase orders. These purchase orders might be organized into two separate record types: the main PURCHASE-ORDER details, namely purchase order number, supplier reference and purchase order date, and then details for each PURCHASE-ORDER-ITEM specified in the order, namely the product code, the unit price and number ordered. The number of record types for that file would therefore be 2 and the number of data types would be 6. According to Table 5.3, this file type would be rated as 'low'. This would mean that according to Table 5.2, the FP count would be 7 for this file.

Function point analysis recognizes that the effort required to implement a computer-based information system relates not just to the number and complexity of the features provided but also to the operational environment of the system.

Fourteen factors have been identified which can influence the degree of difficulty associated with implementing a system. The list that Albrecht produced related particularly to the concerns of information system developers in the late 1970s and early 1980s. Some technology which was then new and relatively threatening is now well established.

Further details on TCA can be found in the Albrecht and Gaffney paper.

The technical complexity adjustment (TCA) calculation has had many problems. Some have even found that it produces less accurate estimates than using the unadjusted function point count. Because of these difficulties, we omit further discussion of the TCA.

Tables have been calculated to convert the FPs to lines of code for various languages. For example, it is suggested that 53 lines of Java are needed on average to implement an FP, while for Visual C++ the figure is 34. You can then use historical productivity data to convert the lines of code into an effort estimate, as previously described in Section 5.7.

The COCOMO II Model Definition Manual A contains a table of suggested conversion rates and can be downloaded from http://sunset.usc.edu/csse

Exercise 5.9

In the case of the subsystem described in Exercise 5.8 for which Brigette is responsible at Brightmouth HE College, how many lines of Java code should be needed to implement this subsystem, according to the standard conversion? Assuming a productivity rate of 50 lines of code a day, what would be the estimate of effort?

5.11 Function Points Mark II

The Mark II method was originally sponsored by what was then the CCTA (Central Computer and Telecommunications Agency, now the Office of Government Commerce or OGC), which lays down standards for UK government projects. The 'Mark II' label implies an improvement and replacement of the Albrecht method. The Albrecht (now IFPUG) method, however, has had many refinements made to it and FPA Mark II remains a minority method used mainly in the United Kingdom.

This method has came into the public domain with the publication of the book by Charles R. Symons (1991) *Software Sizing and Estimating – Mark II FPA*, John Wiley and Sons.

As with Albrecht, the information processing size is initially measured in unadjusted function points (UFPs) to which a technical complexity adjustment can then be applied (TCA). The assumption is that an information system comprises transactions which have the basic structure shown in Figure 5.3.

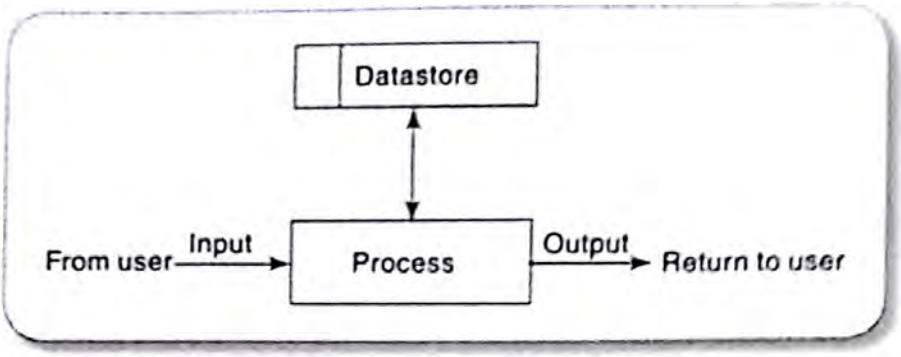


FIGURE 5.3 Model of a transaction

For each transaction the UFPs are calculated:

$W_i \times$ (*number of input data element types*) +

$W_e \times$ (*number of entity types referenced*) +

$W_o \times$ (*number of output data element types*)

W_i, W_e and W_o are weightings derived by asking developers the proportions of effort spent in previous projects developing the code dealing respectively with inputs, accessing and modifying stored data and processing outputs.

The proportions of effort are then normalized into ratios, or weightings, which add up to 2.5. This process for calculating weightings is time consuming and most FP counters use industry averages which are currently 0.58 for W_i, 1 .66 for W_e and 0.26 for W_o.

The only reason why 2.5 was adopted here was to produce FP counts similar to the Albrecht equivalents.

Example 5.3

A cash receipt transaction in the IOE maintenance accounts subsystem accesses two entity types – INVOICE and CASH-RECEIPT.

The data inputs are:

- Invoice number
- Date received
- Cash received

If an INVOICE record is not found for the invoice number then an error message is issued. If the invoice number is found then a CASH-RECEIPT record is created. The error message is the only output of the transaction. The unadjusted function points, using the industry average weightings, for this transaction would therefore be:

$(0.58 \times 3) + (1.66 \times 2) + (0.26 \times 1) = 5.32$

Exercise 5.10

Calculate the number of unadjusted Mark II function points for the transaction described previously for Exercise 5.5, using the industry average weightings.

Mark II FPs follow the Albrecht method in recognizing that one system delivering the same functionality as another may be more difficult to implement (but also more valuable to the users) because of additional technical requirements. For example, the incorporation of additional security measures would increase the amount of effort to deliver the system. The identification of further factors to suit local circumstances is encouraged.

Symons is very much against the idea of using function points to estimate SLOC rather than effort. One finding by Symons is that productivity, that is, the effort per function point to implement a system, is influenced by the size of the project. In general, larger projects, up to a certain point, are more productive because of economies of scale. However, beyond a certain size they tend to become less productive because of additional management overheads.

Some of the rules and weightings used in FP counting, especially in the case of the Albrecht flavour, are rather arbitrary and have been criticized by academic writers on this account. FPs, however, have been found useful as a way of calculating the price for extensions to existing systems, as will be seen in Chapter 10 on managing contracts.

5.12 COSMIC Full Function Points

While approaches like that of IFPUG are suitable for information systems, they are not helpful when it comes to sizing real-time or embedded applications. This has resulted in the development of another version of function points – the COSMIC FFP method.

COSMIC-FFP stands for Common Software Measurement Consortium – Full Function Points.

The full function point (FFP) method has its origins in the work of two interlinked research groups in Québec, Canada. At the start, the developers were at pains to stress that this method should be seen as simply an extension to the IFPUG method for real-time systems. The original work of FFPs has been taken forward by the formation of the Common Software Measurement Consortium (COSMIC) which has involved not just the original developers in Canada, but others from many parts of the world, including Charles Symons, the originator of Mark II function points. Interestingly, there has been little participation by anyone from the United States.

The argument is that existing function point methods are effective in assessing the work content of information systems where the size of the internal procedures mirrors the number of external features. With a real-time, or embedded, system, its features will be hidden because the software's user will probably not be a human but a hardware device or another software component.

COSMIC deals with this by decomposing the system architecture into a hierarchy of software *layers*. The software component to be sized can receive requests for services from layers above and can request services from those below it. At the same time there could be separate software components at the same level that engage in *peer-to-peer communication*. This identifies the boundary of the software component to be assessed and thus the points at which it receives inputs and transmits outputs. Inputs and outputs are aggregated into *data groups*, where each group brings together data items that relate to the same object of interest.

Data groups can be moved about in four ways:

- *entries* (E), which are effected by subprocesses that move the data group into the software component in question from a 'user' outside its boundary – this could be from another layer or another separate software component in the same layer via peer-to-peer communication;
- *exits* (X), which are effected by subprocesses that move the data group from the software component to a 'user' outside its boundary;
- *reads* (R), which are data movements that move data groups from persistent storage (such as a database) into the software component;
- *writes* (W), which are data movements that transfer data groups from the software component into persistent storage.

Exercise 5.11

A small computer system controls the entry of vehicles to a car park. Each time a vehicle pulls up before an entry barrier, a sensor notifies the computer system of the vehicle's presence. The system examines a count that it maintains of the number of vehicles that are currently in the car park. This count is kept on backing storage so that it will still be available if the system is temporarily shut down, for example because of a power cut. If the count does not exceed the maximum allowed then the barrier is lifted and the count is incremented. When a vehicle leaves the car park, a sensor detects the exit and reduces the count of vehicles.

There is a system administration system that can set the maximum number of cars allowed, and which can be used to adjust or replace the count of cars when the system is restarted.

Identify the entries, exits, reads and writes in this application.

The overall FFP count is derived by simply adding up the counts for each of the four types of data movement. The resulting units are *Cfsu* (COSMIC functional size units). The method does not take account of any processing of the data groups once they have been moved into the software component. The framers of the method do not recommend its use for systems involving complex mathematical algorithms, for example, but there is provision for the definition of local versions for specialized environments which could incorporate counts of other software features.

The NESMA FP method has been developed by the Netherlands Software Measurement Association.

COSMIC FFPs have been incorporated into an ISO standard – ISO/IEC 19761:2003. Prior to this there were attempts to produce a single ISO standard for 'functional size measurement' and there is an ISO document – ISO/IEC 14143–1:1998 – which lays down some general principles. ISO has decided, diplomatically, that it is unable to judge the relative merits of the four main methods in the field: IFPUG, Mark II, NESMA and COSMIC-FFP, and all four have been allowed to submit their methods as candidates to become ISO standards and then to '*let the market decide*'.

5.13 COCOMO II: A Parametric Productivity Model

Boehm's COCOMO (COnstructive COst MOdel) is often referred to in the literature on software project management, particularly in connection with software estimating. The term COCOMO really refers to a group of models.

Because there is now a newer COCOMO II, the older version is now referred to as COCOMO81.

Boehm originally based his models in the late 1970s on a study of 63 projects. Of these only seven were business systems and so the models could be used with applications other than information systems. The basic model was built around the equation

Table 5.4 COCOMO81 constants

System type	c	k
Organic	2.4	1.05
Semi-detached	3.0	1.12
Embedded	3.6	1.20

$$(effort) = c(size)^k$$

where *effort* was measured in *pm* or the number of 'person-months' consisting of units of 152 working hours, *size* was measured in *kdsi*, thousands of delivered source code instructions, and *c* and *k* were constants.

The first step was to derive an estimate of the system size in terms of *kdsi*. The constants, *c* and *k* (see Table 5.4), depended on whether the system could be classified, in Boehm's terms, as 'organic', 'semi-detached' or 'embedded'. These related to the technical nature of the system and the development environment.

- *Organic mode* This would typically be the case when relatively small teams developed software in a highly familiar in-house environment and when the system being developed was small and the interface requirements were flexible.
- *Embedded mode* This meant that the product being developed had to operate within very tight constraints and changes to the system were very costly.
- *Semi-detached mode* This combined elements of the organic and the embedded modes or had characteristics that came between the two.

Generally, information systems were regarded as organic while real-time systems were embedded.

The exponent value *k*, when it is greater than 1, means that larger projects are seen as requiring disproportionately more effort than smaller ones. This reflected Boehm's finding that larger projects tended to be less productive than smaller ones because they needed more effort for management and coordination.

Over the years, Barry Boehm and his co-workers have refined a family of cost estimation models of which the key one is COCOMO II. This approach uses various multipliers and exponents the values of which have been set initially by experts. However, a database containing the performance details of executed projects has been built up and periodically analysed so that the expert judgements can be progressively replaced by values derived from actual projects. The new models take into account that there is now a wider range of process models in common use than previously. As we noted earlier, estimates are required at different stages in the system life cycle and COCOMO II has been designed to accommodate this by having models for three different stages.

The detailed COCOMO II Model Definition Manual has been published by the Center for Software Engineering, University of Southern California.

- *Application composition* Here the external features of the system that the users will experience are designed. Prototyping will typically be employed to do this. With small applications that can be built using high-productivity application-building tools, development can stop at this point.
- *Early design* Here the fundamental software structures are designed. With larger, more demanding systems, where, for example, there will be large volumes of transactions and performance is important, careful attention will need to be paid to the architecture to be adopted.
- *Post architecture* Here the software structures undergo final construction, modification and tuning to create a system that will perform as required.

In COCOMO81, estimation was done at the start of the project even before the requirement specification document is fully written. In COCOMO81, the estimates on the average have 50–100 percent error in estimation. In COCOMO II, the estimations can be done with increasing accuracy as the project progresses (see Figure 5.4) through different life cycle phases as the project work advances with time and as more information about the project becomes available. The estimations with increasing accuracy can help the project manager refine the plans and make more accurate plans as the project progresses.

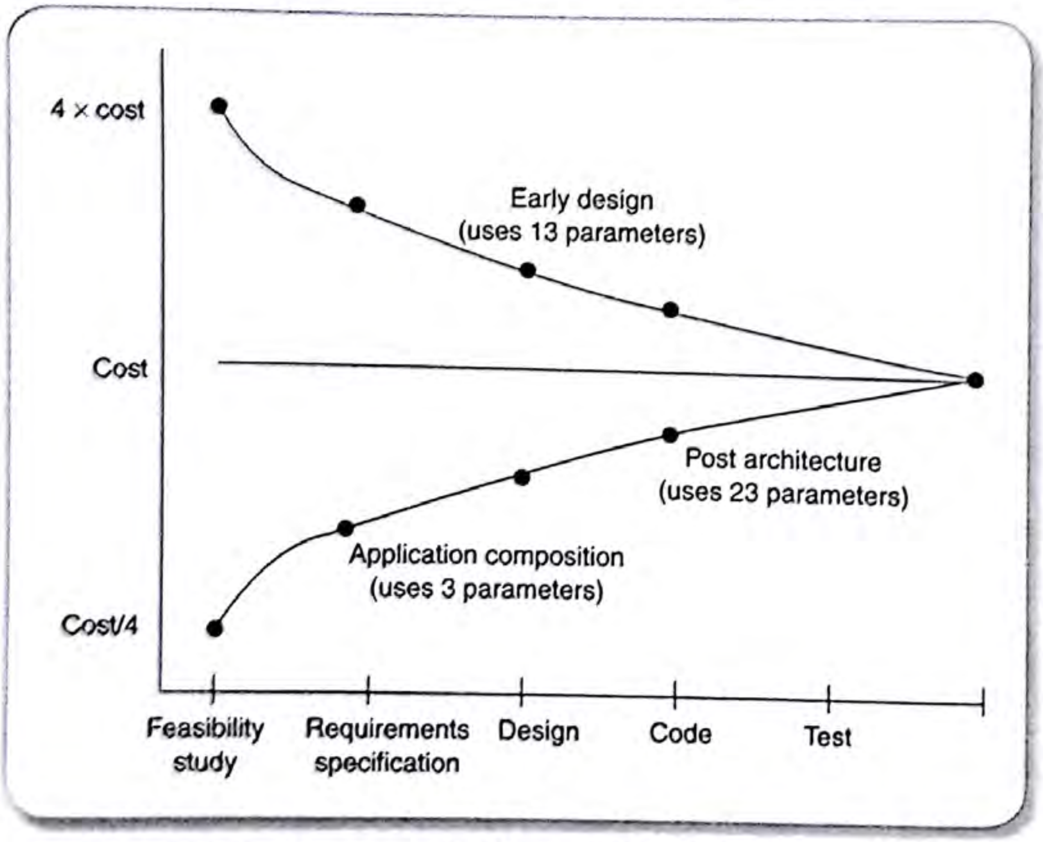


FIGURE 5.4 Accuracy of different COCOMO II estimations

As shown in Figure 5.4, at the feasibility study stage, the project manager makes rough estimates and the estimates can vary significantly often by 400 percent. The actual estimate would lie between the upper bound and lower bounds, which is plotted in Figure 5.4. COCOMO II application composition model can be used during requirements elicitation and prototype construction and gives much more accurate estimation than the rough estimation arrived by the project manager during the feasibility study stage. As shown, in the application composition model, estimates are made based on three parameters that are determined by the project manager. The early design model can be used after the requirements specification and during the early design stage. This model requires the project manager to determine 13 independent parameters based on which the estimates are made. One of the main parameters to be estimated is the size of the software in function points, which is determined from the requirements document. This model typically produces much more accurate estimations than the early design model. The postarchitecture model is used after the high-level design is complete and requires the project manager to estimate 23 independent parameters based on which the effort and duration estimates are made. This model produces much more accurate estimation than the early design estimates.

To estimate the effort for *application composition*, the counting of *object points* is recommended by the developers of COCOMO II. This follows the function point approach of counting externally apparent features of the software. It differs by focusing on the physical features of the application, such as screens and reports, rather than 'logical' ones such as entity types. This is seen as being more useful where the requirements are being elicited via prototypes.

See R. D. Banker, R. Kauffman and R. Kumar (1992) 'An empirical test of object-based output measurement metrics' *Journal of MIS*, 8(3).

At the *early design* stage, FPs are recommended as the way of gauging a basic system size. An FP count may be converted to an LOC equivalent by multiplying the FPs by a factor for the programming language that is to be used – see Section 5.10.

The following model can then be used to calculate an estimate of person-months.

$$pm = A(size)^{(sf)} \times (em_1) \times (em_2) \times \ldots \times (em_n)$$

where *pm* is the effort in 'person-months', *A* is a constant (which was set in 2000 at 2.94), *size* is measured in *kdsi* (which may have been derived from an FP count as explained above), and *sf* is exponent scale factor.

The scale factor is derived thus:

$$sf = B + 0.01 \times \Sigma\ (exponent\ driver\ ratings)$$

where *B* is a constant currently set at 0.91. The effect of the exponent ('. . . to the power of. . .') scale factor is to increase the effort predicted for larger projects, that is, to take account of diseconomies of scale which make larger projects less productive.

The qualities that govern the exponent drivers used to calculate the scale factor are listed below. Note that the less each quality is applicable, the bigger the value given to the exponent driver. The fact that these factors are used to calculate an exponent implies that the lack of these qualities increases the effort required disproportionately more on larger projects.

- *Precedentedness (PREC)* This quality is the degree to which there are precedents or similar past cases for the current project. The greater the novelty of the new system, the more uncertainty there is and the higher the value given to the exponent driver.
- *Development flexibility (FLEX)* This reflects the number of different ways there are of meeting the requirements. The less flexibility there is, the higher the value of the exponent driver.
- *Architecture/risk resolution (RESL)* This reflects the degree of uncertainty about the requirements. If they are liable to change then a high value would be given to this exponent driver.
- *Team cohesion (TEAM)* This reflects the degree to which there is a large dispersed team (perhaps in several countries) as opposed to there being a small tightly knit team.

- *Process maturity (PMAT)* Chapter 13 on software quality explains the process maturity model. The more structured and organized the way the software is produced, the lower the uncertainty and the lower the rating will be for this exponent driver.

Each of the scale factors for a project is rated according to a range of judgements: very low, low, nominal, high, very high, extra high. There is a number related to each rating of the individual scale factors – see Table 5.5. These are summed, then multiplied by 0.01 and added to the constant 0.91 to get the overall exponent scale factor.

TABLE 5.5 COCOMO II scale factor values

Driver	Very low	Low	Nominal	High	Very high	Extra high
PREC	6.20	4.96	3.72	2.48	1.24	0.00
FLEX	5.07	4.05	3.04	2.03	1.01	0.00
RESL	7.07	5.65	4.24	2.83	1.41	0.00
TEAM	5.48	4.38	3.29	2.19	1.10	0.00
PMAT	7.80	6.24	4.68	3.12	1.56	0.00

Exercise 5.12

A new project has 'average' novelty for the software supplier that is going to execute it and is thus given a nominal rating on this account for precedentedness. Development flexibility is high, but requirements may change radically and so the risk resolution exponent is rated very low. The development team are all located in the same office and this leads to team cohesion being rated as very high, but the software house as a whole tends to be very informal in its standards and procedures and the process maturity driver has therefore been given a rating of 'low'.

(i) What would be the scale factor (*sf*) in this case?

(ii) What would be the estimate of effort, if the size of the application was estimated as in the region of 2000 lines of code?

In the COCOMO II model the *effort multipliers* (*em*) adjust the estimate to take account of productivity factors, but do not involve economies or diseconomies of scale. The multipliers relevant to early design are in Table 5.6 and those used at the post architecture stage in Table 5.7. Each of these multipliers may, for a particular application, be given a rating of very low, low, nominal, high or very high. Each rating for each effort multiplier has an associated value. A value greater than 1 increases development effort, while a value less than 1 decreases it. The nominal rating means that the multiplier has no effect. The intention is that the values that these and other ratings use in COCOMO II will be refined over time as actual project details are added to the database.

TABLE 5.6 COCOMO II early design effort multipliers

Code	Effort modifier	Extra low	Very low	Low	Nominal	High	Very high	Extra high
RCPX	Product reliability and complexity	0.49	0.60	0.83	1.00	1.33	1.91	2.72
RUSE	Required reusability			0.95	1.00	1.07	1.15	1.24
PDIF	Platform difficulty			0.87	1.00	1.29	1.81	2.61
PERS	Personnel capability	2.12	1.62	1.26	1.00	0.83	0.63	0.50
PREX	Personnel experience	1.59	1.33	1.12	1.00	0.87	0.74	0.62
FCIL	Facilities available	1.43	1.30	1.10	1.00	0.87	0.73	0.62
SCED	Schedule pressure		1.43	1.14	1.00	1.00	1.00	

TABLE 5.7 COCOMO II post architecture effort multipliers

Modifier type	Code	Effort modifier
Product attributes	RELY	Required software reliability
	DATA	Database size
	DOCU	Documentation match to life-cycle needs
	CPLX	Product complexity
	REUSE	Required reusability
Platform attributes	TIME	Execution time constraint
	STOR	Main storage constraint
	PVOL	Platform volatility
Personnel attributes	ACAP	Analyst capabilities
	AEXP	Application experience
	PCAP	Programmer capabilities
	PEXP	Platform experience
	LEXP	Programming language experience
	PCON	Personnel continuity
Project attributes	TOOL	Use of software tools
	SITE	Multisite development
	SCED	Schedule pressure

Example 5.4

Consider a company is developing a software package for an educational institute that would automate various bookkeeping activities associated with the institute's academic activities such as course registration and grading. The institute has already installed other software applications that automate its various activity areas such as stores and purchase, accounting, and faculty pay roll, which are already operational. The size of code that is expected to be written for the academic package is 10,000 SLOC. The package to be developed by a vendor is very similar to a software developed by the same vendor for a different client. The software to be developed needs to seamlessly work with other applications running at the institute and has to use the existing DBMS and other hardware components. The requirements for the academic package are clear and are unlikely to change. The development team put together by the vendor is collocated and cohesive. Other aspects of the project such as required reliability and product complexity, required reusability, platform difficulty, personnel capability, facilities available and schedule pressure are nominal. Determine the effort required by the vendor assuming that it uses ad hoc development practices. Compare the effort to what would be incurred if the vendor had high process maturity.

Solution

From the description of the project, the following values can be assigned to the COCOMO II project parameters: PREC = Very high, FLEX = Low, RESL = High, Team = Very high, and PMAT would be very low for the organization using ad hoc development practices and very high for the organization having high-process maturity.

For the organization with ad hoc process, $sf = 0.91 + 0.01(1.24 + 4.05 + 2.83 + 1.1 + 7.8) = 0.91 + 0.17 = 1.08$

For the organization with mature process, $sf = 0.91 + 0.01(1.24 + 4.05 + 2.83 + 1.1 + 1.56) = 0.91 + 0.1 = 1.01$

From the project characteristics, the effort multipliers are nominal.

The effort required by the ad hoc organization = $2.94 \times (10)1.08 \times 1 = 2.94 \times 12.022 = 35.34$ man months

The effort required by the highly mature organization = $2.94 \times (10)1.01 \times 1 = 2.94 \times 10.23 = 30.08$ man months

Observe according to COCOMO II, the organization using ad hoc practices would require about 18 percent more effort for the project as compared to a mature organization.

Exercise 5.13

A software supplier has to produce an application that controls a piece of equipment in a factory. A high degree of reliability is needed as a malfunction could injure the operators. The algorithms to control the equipment are also complex. The product reliability and complexity are therefore rated as very high. The company would like to take the opportunity to exploit fully the investment that they made in the project by reusing the control system, with suitable modifications, on future contracts. The reusability requirement is therefore rated as very high. Developers are familiar with the platform and the possibility of potential problems in that respect is regarded as low. The current staff are generally very capable and are rated in this respect as very high, but the project is in a somewhat novel application domain for them so experience is rated as nominal. The toolsets available to the developers are judged to be typical for the size of company and are rated as nominal, as is the degree of schedule pressure to meet a deadline.

Given the data in Table 5.6,

(i) What would be the value for each of the effort multipliers?

(ii) What would be the impact of all the effort multipliers on a project estimated as taking 200 staff-months?

At a later stage of the project, detailed design of the application will have been completed. There will be a clearer idea of application size in terms of lines of code, and the factors influencing productivity will be better known. A revised estimate of effort can be produced based on the broader range of effort modifiers seen in Table 5.7. The method of calculation is the same as for early design. Readers who wish to apply the model using the post architecture effort multipliers are directed to the COCOMO II Model Definition Manual which is available from the University of Southern California website http://sunset.usc.edu/csse/research/COCOMOII/COCOMO_main.html.

5.14 Cost Estimation

Project cost can be obtained by multiplying the estimated effort (in man-month, from the effort estimate) with the manpower cost per month. Implicit in this project cost computation is the assumption that the entire project cost is incurred on account of the manpower cost alone. However, in addition to manpower cost, a project would incur several other types of costs which we shall refer to as the overhead costs. The overhead costs would include the costs of hardware and software required for the project and the company overheads for administration, office space, etc. Depending on the expected values of the overhead costs, the project manager has to suitably scale up the cost estimated by using the COCOMO formula.

Exercise 5.14

Assume that the size of an organic type software product is estimated to be 32,000 lines of source code. Assume that the average salary of a software developer is £2,000 per month. Determine the effort required to develop the software product, the nominal development time, and the staff cost to develop the product.

5.15 Staffing Pattern

After the effort required to complete a software project has been estimated, the staffing requirement for the project can be determined. Putnam was the first to study the problem of what should be a proper staffing pattern for software projects. He extended the classical work of Norden who had earlier investigated the staffing pattern of general research and development (R&D) type of projects. In order to appreciate the staffing pattern desirable for software projects, we must understand both Norden's and Putnam's results.

Norden's work

Norden studied the staffing patterns of several R&D projects. He found the staffing patterns of R&D projects to be very different from that of manufacturing or sales type of work. In a sales outlet, the number of sales staff does not usually vary with time. For example, in a supermarket the number of sales personnel would depend on the number of sales counters alone and the number of sales personnel therefore remains fixed for years together. However, the staffing pattern of R&D type of projects changes dynamically over time for efficient manpower utilization. At the start of an R&D project, the activities of the project are planned and initial investigations are made. During this time, the manpower requirements are low. As the project progresses, the manpower requirement increases until it reaches a peak. Thereafter the manpower requirement gradually diminishes. Norden concluded that the staffing pattern for any R&D project can be approximated by the Rayleigh distribution curve shown in Figure 5.5.

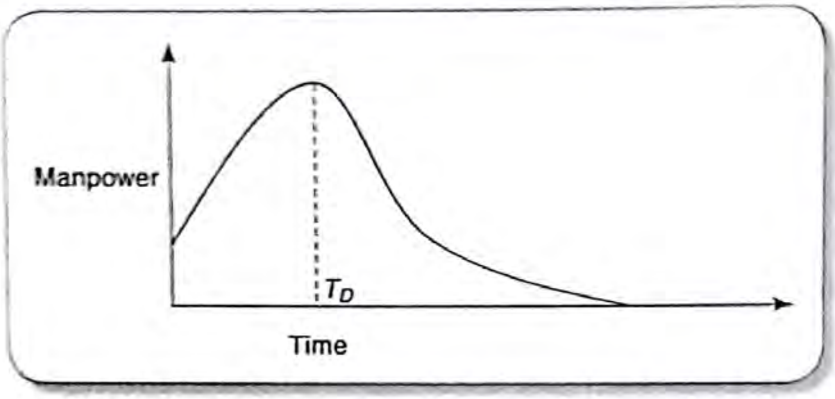


FIGURE 5.5 Rayleigh–Norden Curve

Putnam's work

Norden's work was carried out in the context of general R&D projects. Putnam studied the problem of staffing of software projects and found that the staffing pattern for software development projects has characteristics very similar to R&D projects. Putnam adapted the Rayleigh–Norden curve to relate the number of delivered lines of code to the effort and the time required to develop the product. Only a small number of developers are needed at the beginning of a project to carry out the planning and specification tasks. As the project progresses and more detailed work is performed, the number of developers increases and reaches a peak during product delivery which has been shown to occur at time T_D in Figure 5.5. After product delivery, the number of project staff falls consistently during product maintenance.

Putnam suggested that starting from a small number of developers, there should be a staff build-up and after a peak size has been achieved, staff reduction is required. However, the staff build-up should not be carried out in large installments. Experience shows that a very rapid build-up of project staff any time during the project development correlates with schedule slippage.

Exercise 5.15

Suppose you are the project manager of a large development project. The top management informs that you would have to manage the project with a fixed team size throughout the duration of your project. What would be the likely impact of this decision on your project?

5.16 Effect of Schedule Compression

It is quite common for a project manager to encounter client requests to deliver products faster, that is, to compress the delivery schedule. It is therefore important to understand the impact of schedule compression on project cost. Putnam studied the effect of schedule compression on the development effort and expressed it in the form of the following equation:

$$pm_{new} = pm_{org} \times \left(\frac{td_{org}}{td_{new}}\right)^4$$

where pm_{new} is the new effort, pm_{org} is the originally estimated effort and td_{org} is the originally estimated time for project completion and td_{new} is the compressed schedule.

From this expression, it can easily be observed that when the schedule of a project is compressed, the required effort increases in proportion to the fourth power of the degree of compression. It means that a relatively small compression in a delivery schedule can result in substantial penalty on human effort. For example, if the estimated development time using COCOMO formula is one year, then in order to develop the product in six months, the total effort required (and hence the project cost) increases 16 times.

Boehm arrived at the result that there is a limit beyond which a software project cannot reduce its schedule by buying any more personnel or equipment. This limit occurs roughly at 75% of the nominal time estimate for small and medium sized projects. Thus, if a project manager accepts a customer demand to compress the development schedule of a typical project (medium or small project) by more than 25%, he is very unlikely to succeed. The main reason being, that every project has only a limited amount of activities which can be carried out in parallel, and the sequential activities cannot be speeded up by hiring any number of additional developers.

Exercise 5.16

The nominal effort and duration of a project is estimated to be 1000 pm and 15 months. The project cost is negotiated to be £200,000. This needs the product to be developed and delivered in 12 months time. What is the new cost that needs to be negotiated?

Exercise 5.17

Why does the effort requirement then increase drastically upon schedule compression (as per Putnam's results 16 times for schedule is compressed by 50%)? After all, isn't it the same product that is being developed?

5.17 Capers Jones Estimating Rules of Thumb

Capers Jones published a set of empirical rules in 1996 in the IEEE Computer journal. He formulated these rules based on his experience in estimating various parameters of a large number of software projects. Jones wanted that his rules should be as easy to use as possible, and yet should give the project manager a fairly good idea of various aspects of a project. Because of their simplicity, these rules are handy to use for making off-hand estimates. However, these rules should not be expected to yield very accurate estimations and are certainly not considered appropriate for working out formal cost contracts. Still, while working out formal contracts, these rules are used to carry out sanity checks for estimations arrived using other more rigorous techniques. An interesting aspect of Jones' rules is that these rules give an insight into many aspects of a project (such as the rate of requirements creep) for which no formal methodologies exist as yet. In the following section, we discuss a few of Jones' rules of thumb that are often useful.

***Rule 1:** SLOC Function Point Equivalence* One function point = 125 SLOC for C programs.

We have already pointed out in Section 5.4 that the SLOC measure is intuitive and helps in developing a good understanding of the size of a project. SLOC is also used in several popular techniques for estimating several project parameters. However, often the size estimations for a software project are done using the function point analysis due to the inherent advantages of the function point metric. In this situation, it often becomes necessary for the project manager to come up with the SLOC measure for the project from its function point measurements. Jones determined the equivalence between SLOC and function point for several programming languages based on experimental data.

To gain an insight into why SLOC function point equivalence varies across different programming languages let us examine the following. According to Jones, it would take about 320 lines of assembly code to implement one function point. Why does assembly coding take as much as three times the number of instructions required in C language to code one function point? It can be argued that to express one SLOC of C would require several instructions in assembly language.

***Rule 2:** Project Duration Estimation* Function points raised to the power 0.4 predicts the approximate development time in calendar months.

To illustrate the applicability of this rule, consider that the size of a project is estimated to be 150 function points (that is, approximately 18,750 SLOC by Rule 1). The development time (time necessary to complete the project) would be about eight months by Rule 2.

***Rule 3:** Rate of Requirements Creep* User requirements creep in at an average rate of 2% per month from the design through coding phases.

In almost every project, the features required by the customer keep on increasing due to a variety of reasons. Of course, requirement creeps are normally not expected during project testing and installation stages. Observe that the rule has been carefully worded to take into account the fact that while predicting the total requirements creep, it is necessary to remember that the requirement creeps occur from the end of the requirements phase till the testing phase. Therefore, only an appropriate fraction of the project completion period needs to be considered to exclude the durations of the requirements and testing phases.

Assume that the size of a project is estimated to be 150 function points. Then, the duration for this project can be estimated to be eight months by Jones' Rule 2. Since we need to exclude the duration of requirements specification and testing phase, it is reasonable to assume that the requirements creep would occur for five months only. By Rule 3, the original requirements will grow by a rate of three function points per month. So, the total requirements creep would roughly be 15 function points. Thus, the total size of the project for which the project manager needs to plan would be 165 function points rather than 150 function points.

Rule 4: *Defect Removal Efficiency* Each software review, inspection, or test step will find and remove 30% of the bugs that are present.

This rule succinctly captures the reason why software development organizations use a series of defect removal steps, viz., requirements review, design review, code inspection, and code walk-through, followed by unit, integration, and system testing. In fact, a series of about ten consecutive defect removal operations must be utilized to achieve good product reliability.

Exercise 5.18

For a certain project, consider that in the design document 1000 defects are present at the end of the design stage. Compute how many of these defects would survive after the processes of code review, unit, integration, and system testing have been completed. Assume that the defect removal effectiveness of each error removal stage is 30%.

Rule 5: *Project Manpower Estimation* The size of the software (in function points) divided by 150 predicts the approximate number of the personnel required for developing the application.

To understand the use of this rule, consider a project whose size is estimated to be 500 function points. By Rule 5, the number of development personnel required would be four. Observe that Rule 5 predicts the manpower requirement without considering several other relevant aspects of a project that can significantly affect the required effort. These aspects include the project complexity, the level of usage of CASE tools, and the programming language being used. It is therefore natural to expect that the actual manpower requirement would defer from that predicted by Rule 5. This inaccuracy, however, is in keeping with Jones' objective of having rules that are as simple as possible, so that these can be used off-hand to get a gross understanding of the important project parameters.

Rule 6: *Software Development Effort Estimation* The approximate number of staff months of effort required to develop a software is given by the software development time multiplied with the number of personnel required.

It can be observed that this rule is actually a corollary of the Rules 2 and 5. As an example for application of this rule, consider a project whose size is estimated to be 150 function points. Using Rules 2 and 5, the estimated development effort would be 8 months × 1 person = 8 person-months.

Rule 7: *Function points divided by 500 predicts the approximate number of personnel required for regular maintenance activities.*

According to Rule 1, 500 function points is equivalent to about 62,500 SLOC for C programs. Thus, we can say that approximately for every 60,000 SLOC, one maintenance personnel would be required to carry out minor bug fixes and functionality adaptations during the operation phase of the software.

Conclusion

To summarize some key points:

- Estimates are really management targets.
- Collect as much information about previous projects as possible.
- Use more than one method of estimating.
- Top-down approaches will be used at the earlier stages of project planning while bottom-up approaches will be more prominent later on.
- Be careful about using other people's historical productivity data as a basis for your estimates, especially if it comes from a different environment (this includes COCOMO).
- Seek a range of opinions.
- Document your method of doing estimates and record all your assumptions.

Further Exercises

1. The size (that is, the effort needed to complete it) of any task will depend on its characteristics. The units into which the work is divided will also differ. Identify the factors affecting the size of the task and work units for the following activities:
   - installing computer workstations in a new office;
   - transporting assembled personal computers from the factory where they were assembled to warehouses distributed in different parts of the country;
   - typing in and checking the correctness of data that is populating a new database;
   - system testing a newly written software application.
2. If you were asked as an expert to provide an estimate of the effort needed to make certain changes to an existing piece of software, what information would you like to have to hand to assist you in making that estimate?
3. A small application maintains a telephone directory. The database for the application contains the following data types:
   - Staff reference
   - Surname
   - Forenames
   - Title
   - Department code
   - Room number
   - Telephone extension
   - E-mail address
   - Fax number

Transactions are needed which:

(i) set up new entries;

(ii) mend existing entries;

(iii) delete entries;

(iv) allow enquirers to list online the details for a particular member of staff;

(v) produce a complete listing of the telephone directory entries in alphabetical order.

(a) Use this scenario to produce an estimated Mark II FP count. List all the assumptions you will need to make.

(b) Another requirement could be to produce the listing in (v) in departmental order. In your view, should this increase FP count and if so by how much?

4. The following details are held about previously developed software modules.

Module	Inputs	Entity types accessed	Outputs	Days
a	1	2	10	2.60
b	10	2	1	3.90
c	5	1	1	1.83
d	2	3	11	3.50
e	1	3	20	4.30

A new module has 7 inputs, 1 entity type access and 7 outputs. Which of the modules a to e is the closest analogy in terms of Euclidean distance?

5. Using the data in further exercise 4 above, calculate the Symons Mark II FPs for each module. Using the results, calculate the effort needed for the new module described in further exercise 4. How does this estimate compare to the one based on analogy?

6. Given the project data below:

Project	Inputs	Outputs	Entity accesses	System users	Programming language	Developer days
1	210	420	40	10	x	30
2	469	1406	125	20	x	85
3	513	1283	76	18	y	108
4	660	2310	88	200	y	161

5	183	367	35	10	z	22
6	244	975	65	25	z	42
7	1600	3200	237	25	y	308
8	582	874	111	5	z	62
X	180	350	40	20	y	
Y	484	1190	69	35	y	

(a) What items are size drivers?

(b) What items are productivity drivers?

(c) What are the productivity rates for programming languages x, y and z?

(d) What would be the estimated effort for projects X and Y using a Mark II function point count?

(e) What would be the estimated effort for X and Y using an approximate analogy approach?

(f) What would have been the best estimating method if the actual effort for X turns out to be 30 days and for Y turns out to be 120 days? Can you suggest why the results are as they are and how they might be improved?

7. A report in a college timetabling system produces a report showing the students who should be attending each timetabled teaching activity. Four files are accessed: the STAFF file, the STUDENT file, the STUDENT-OPTION file and the TEACHING-ACTIVITY file. The report contains the following information:

- Teaching activity reference
- Topic name
- Staff forenames
- Staff surname
- Title
- Semester (1 or 2)
- Day of week
- Time
- Duration
- Location
- For each student:
  - student forename
  - student surnames

Calculate the Mark II FPs that this transaction would generate. What further information would you need to create an estimate of effort?

8. Suppose you are the manager of a software project. Explain why it would not be proper to calculate the number of developers required for the project as a simple division of the effort estimate (in person-months) by the nominal duration estimate (in months).

9. Suppose that off-the-shelf price of a certain management information system (MIS) software product is £50,000 and its size is 100 kdsi. Assuming that in-house developers cost £2000 per programmer-month (including overheads); would it be more cost-effective to buy the product or build it? Which elements of the cost are not included in COCOMO estimation model? What additional factors should be considered while making the decision to buy or build the product?

10. Suppose you are the manager of a project to develop a software product for business application. You have estimated the effort required for completion of the project to be 50 person-months. Can you complete the project by employing 50 developers for a period of 1 month? Justify your answer.

11. Suppose you are the project manager of a certain project. If by using COCOMO-II you have estimated a project to cost ₹10 million and take 5 months to develop. The customer is seriously requesting you to develop the software in 4 months, and is even prepared to pay extra. What would be the revised project cost?

12. Identify two possible impacts of a highly aggressive (underestimated) schedule set for a project by a project manager. Also identify the impact of a highly conservative (overestimated) schedule.

13. Identify three important advantages of FP (floating point) measure of size over LOC (Lines of Code) measure of size.

14. For a certain organization, the following table summarizes the weightings to be used for computation of function point measure of a software development project.

    The organization has undertaken the development of a software having the following characteristics:

Number of user inputs	10 (simple)
Number of user outputs	7 (simple)
Number of user inquiries	3 (average)
Number of files	6 (average)
Number of external interfaces	1 (complex)

    What would be the unadjusted function point (UFP) measure of the size of the software system?

15. Consider that expert judgment was used to determine the following optimistic, likely, and pessimistic lines of code for three major components of a software being developed. From this data, what can be inferred about the approximate estimated lines of code for the software?

Software component	Optimistic	Most likely	Pessimistic
Graphical user interface	2500	2300	3100
Middle-tier	4700	6100	8200
DBMS-related	4300	6800	9500

(Contd.)

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

(i) Which one of the following statements concerning the way Albrecht's function point measure for a project is computed is most accurate?

(a) It is computed from the software requirements specification document.

(b) It is computed from the design document.

(c) It is computed from the code implementing the requirements.

(d) It is computed from the configuration control document.

(ii) Effort is measured using which one of the following units?

(a) persons

(b) person-months

(c) months

(d) £ (unit of currency)

(iii) Using COCOMO estimation model, which one of the following can be estimated?

(a) LOC

(b) Effort

(c) Function points

(d) Project milestones

(iv) Which one of the following correctly characterizes the accuracy of project estimations carried out at different stages of the project life cycle?

(a) Accuracy decreases as a project progresses through its life cycle.

(b) Accuracy increases as a project progresses through its life cycle.

(c) Accuracy stays constant throughout the project life cycle.

(d) Accuracy is independent of the specific point in project life cycle at which estimation is made.

(v) Which one of the following project parameters is usually the first to be estimated by a project manager?

(a) Cost

(b) Effort

(c) Size

(d) Duration

(vi) Which one of the following is not a reason for late project becoming later due to addition of manpower?

(a) Increased communication among team members

(b) Learning by the added members

(c) Increased project scope

(d) Limited scope for parallelizing various project activities

(vii) Which one of the following is not a factor for 'Lines of code' being considered a poor software size metric?

(a) It is programming language dependent.

(b) It penalizes efficient and compact coding.

(c) It is programmer dependent.

(d) It is dependent on the complexity of the requirements.

(viii) The use of resources such as personnel in a software development project varies with time. Which one of the following statistical distributions models the personnel requirements for a project over time most closely?

(a) Poisson

(b) Beta

(c) Rayleigh

(d) Log-Normal

(ix) For a certain software development project, an effort estimation of 100 person-months was arrived by using COCOMO model. Which one of the following can be inferred from this?

(a) The project needs to be completed by employing 100 persons for 1 month.

(b) The project needs to be completed by employing one person for 100 months.

(c) The project needs to be completed by employing 10 persons for 10 months

(d) The number of persons employed over different project phases would correspond to Raleigh distribution.

(x) Suppose a project manager realizes that his project is already delayed. Which one of the following can be said, if the project manager decides to deploy additional manpower to complete the project at the earliest?

(a) It would be always counter-productive

(b) It can help to a very limited extent

(c) It is the most effective way to tackle the situation

(d) It should lead to project completion in the shortest time

(xi) Which one of the following is the correct order in which a software project manager estimates various project parameters while using COCOMO?

(a) cost, effort, duration and size

(b) cost, duration, effort and size

(c) size, effort, duration and cost

(d) size, cost, effort and duration

(xii) Which one of the following is not a factor for 'Lines of code' being considered a poor software size metric?

(a) It is programming language-dependent

(b) It penalizes efficient and compact coding

(c) It is programmer-dependent

(d) It is dependent on the complexity of the requirements

(xiii) Which one of the following is not true about estimating by analogy?

(a) Estimation carried out is based on past projects

(b) It is based on qualitative judgment and does not yield accurate estimations

(c) It essentially uses a bottom-up approach

(d) It is a form of an expert judgment

(xiv) Parametric estimation models are typically based on which one of the following?

(a) Expert judgment of independent variables and coefficients

(b) Refinement on expected value estimation

(c) Regression analysis of historical project data

(d) Trial and error estimation of variables and their coefficients

(xv) Which one of the following statements is true of the COCOMO model?

(a) Cost is considered to be the most fundamental attribute of a software product, based on which the project size and duration are measured.

(b) Size is considered to be the most fundamental attribute of a software product, based on which the project cost and duration are measured.

(c) Effort is considered to be the most fundamental attribute of a software product, based on which the project size and cost are measured.

(d) Duration is considered to be the most fundamental attribute of a software product, based on which the project size and effort are measured.

(xvi) Suppose a certain software of size S takes M months to develop. Then according to the COCOMO estimation model which one of the following can be said about the duration (in months) that would be required to develop a similar software of size $2 \times S$?

(a) Greater than $2 \times M$ months

(b) Greater than $3 \times M$ months

(c) Less than $2 \times M$ months

(d) Greater than $4 \times M$ months

(xvii) Suppose you are a project manager and your team has eight members including yourself. How many communication channels exist in your team?

(a) 7

(b) 8

(c) 28

(d) 32

(xviii) Which one of the following may be a reason as to why COCOMO project duration computation would be more accurate than the duration computation by using the expression duration = size/productivity?

(a) Productivity of personnel for a project cannot be determined

(b) Duration is dependent on the number of personnel deployed

(c) Productivity can vary widely among team members

(d) Duration can only be derived from effort

(xix) Suppose you are the project manager of a software project. Based on your experience with three similar past projects, you estimate the project duration to be 5 months. Which one of the following types of estimation techniques has you made use of?

(a) Three point estimating

(b) Bottom-up estimating

(c) COCOMO

(d) Expert judgement

(xx) Which one of the following is not true about estimating by analogy?

(a) Estimation is based on data about past projects

(b) It is essentially a heuristic estimation technique

(c) It is usually a bottom-up approach

(d) It is a form of an expert judgment

(xxi) The least accurate estimates are likely to be obtained during which one of the following project stages?

(a) Requirements specification

(b) Handover

(c) Implementation

(d) Feasibility study

(xxii) Assume that you have estimated the size of a project to be 200 function points. What would be the number of C source lines of code in the implementation of the project according to the Capers Jones estimating rules of thumb?

(a) 100,000

(b) 200,000

(c) 250,000

(d) 300,000

(xxiii) Suppose you are the project manager for a project and you notice that your delivery date is only a month away and you are already running late by 1 month. Which one of the following strategies would you adopt?

(a) Borrow manpower from a project that is comfortably placed

(b) Require all project personnel to work 1 hour extra every day and also come in the week-ends

(c) Negotiate with the customer regarding the delivery date

(d) Cancel tea and coffee breaks for the team members

(xxiv) Parametric estimation models are typically based on which one of the following approaches?

(a) Expert judgment of independent variables and coefficients

(b) Refinement on expected value estimation

(c) Regression analysis of historical project data

(d) Trial and error estimation of variables and their coefficients

(xxv) Which one of the following COCOMO II estimation levels would provide most accurate estimations?

(a) Application composition

(b) Early design

(c) Post architecture

(d) All COCOMO II estimation levels provide equally accurate results.

(xxvi) Suppose as the IT manager of an educational institute, you have the responsibility of either procuring or developing an application software to automate the bookkeeping activities associated with the academic, finance and employee management aspects. When considering off-the-shelf purchase versus in-house development, which one of the following facts would be a major point in favour of in house development?

(a) In-house development may be a bit cheaper.

(b) Off-the-shelf software is unlikely to meet all the company's present and future needs.

(c) In-house solution can take much longer to implement because of the software's complexity.

(d) The user documentation of off-the-shelf software may be inadequate.

6 Activity Planning

Learning Objectives

- Produce an activity plan for a project
- Estimate the overall duration of a project
- Create a critical path and a precedence network for a project

6.1 Introduction

In earlier chapters we looked at methods for forecasting the effort required for a project – both for the project as a whole and for individual activities. A detailed plan for the project, however, must also include a schedule indicating the start and completion times for each activity. This will enable us to:

- ensure that the appropriate resources will be available precisely when required;
- avoid different activities competing for the same resources at the same time;
- produce a detailed schedule showing which staff carry out each activity;
- produce a detailed plan against which actual achievement may be measured;
- produce a timed cash flow forecast;
- replan the project during its life to correct drift from the target.

To be effective, a plan must be stated as a set of targets, the achievement or non-achievement of which can be unambiguously measured. The activity plan does this by providing a target start and completion date for each activity (or a window within which each activity may be carried out). The starts and completions of activities must be clearly visible and this is one of the reasons why it is advisable to ensure that each and every project activity produces some tangible product or 'deliverable'. Monitoring the project's progress is then, at least in part, a case of ensuring that the products of each activity are delivered on time.

Project monitoring is discussed in more detail in Chapter 9.

As a project progresses it is unlikely that everything will go according to plan. Much of the job of project management concerns recognizing when something has gone wrong, identifying its causes and revising the plan to mitigate its effects. The activity plan should provide a means of evaluating the consequences of not meeting any of the activity target dates and guidance as to how the plan might most effectively be modified to bring the project back to target. We shall see that the activity plan may well also offer guidance as to which components of a project should be most closely monitored.

6.2 Objectives of Activity Planning

In addition to providing project and resource schedules, activity planning aims to achieve a number of other objectives which may be summarized as follows.

- *Feasibility assessment* Is the project possible within required timescales and resource constraints? In Chapter 5 we looked at ways of estimating the effort for various project tasks. However, it is not until we have constructed a detailed plan that we can forecast a completion date with any reasonable knowledge of its achievability. The fact that a project may have been estimated as requiring two work-years' effort might not mean that it would be feasible to complete it within, say, three months were eight people to work on it – that will depend upon the availability of staff and the degree to which activities may be undertaken in parallel.
- *Resource allocation* What are the most effective ways of allocating resources to the project. When should the resources be available? The project plan allows us to investigate the relationship between timescales and resource availability (in general, allocating additional resources to a project shortens its duration) and the efficacy of additional spending on resource procurement.
- *Detailed costing* How much will the project cost and when is that expenditure likely to take place? After producing an activity plan and allocating specific resources, we can obtain more detailed estimates of costs and their timing.
- *Motivation* Providing targets and being seen to monitor achievement against targets is an effective way of motivating staff, particularly where they have been involved in setting those targets in the first place.
- *Coordination* When do the staff in different departments need to be available to work on a particular project and when do staff need to be transferred between projects? The project plan, particularly with large projects involving more than a single project team, provides an effective vehicle for communication and coordination among teams. In situations where staff may need to be transferred between project teams (or work concurrently on more than one project), a set of integrated project schedules should ensure that such staff are available when required and do not suffer periods of enforced idleness.

Chapter 11 discusses motivation in more detail.

This coordination will normally form part of Programme Management.

Activity planning and scheduling techniques place an emphasis on completing the project in a minimum time at an acceptable cost or, alternatively, meeting a set target date at minimum cost. These are not, in themselves, concerned with meeting quality targets, which generally impose constraints on the scheduling process.

One effective way of shortening project durations is to carry out activities in parallel. Clearly we cannot undertake all the activities at the same time – some require the completion of others before they can start and there are likely to be resource constraints limiting how much may be done simultaneously. Activity scheduling will, however, give us an indication of the cost of these constraints in terms of lengthening timescales and provide us with an indication of how timescales may be shortened by relaxing those constraints. If we try relaxing precedence constraints by, for example, allowing a program coding task to commence before the design has been completed, it is up to us to ensure that we are clear about the potential effects on product quality.

6.3 When to Plan

Planning is an ongoing process of refinement, each iteration becoming more detailed and more accurate than the last. Over successive iterations, the emphasis and purpose of planning will shift.

During the feasibility study and project start-up, the main purpose of planning will be to estimate timescales and the risks of not achieving target completion dates or keeping within budget. As the project proceeds beyond the feasibility study, the emphasis will be placed upon the production of activity plans for ensuring resource availability and cash flow control.

Throughout the project, until the final deliverable has reached the customer, monitoring and replanning must continue to correct any drift that might prevent meeting time or cost targets.

6.4 Project Schedules

Before work commences on a project or, possibly, a stage of a larger project, the project plan must be developed to the level of showing dates when each activity should start and finish and when and how much of each resource will be required. Once the plan has been refined to this level of detail we call it a project schedule. Creating a project schedule comprises four main stages.

On a large project, detailed plans for the later stages will be delayed until information about the work required has emerged from the earlier stages.

The first step in producing the plan is to decide what activities need to be carried out and in what order they are to be done. From this we can construct an *ideal activity plan* – that is, a plan of when each activity would ideally be undertaken were resources not a constraint. It is the creation of the ideal activity plan that we shall discuss in this chapter. This activity plan is generated by Steps 4 and 5 of Step Wise (Figure 6.1).

The ideal activity plan will then be the subject of an activity risk analysis, aimed at identifying potential problems. This might suggest alterations to the ideal activity plan and will almost certainly have implications for resource allocation. Activity risk analysis is the subject of Chapter 7.

The third step is *resource allocation*. The expected availability of resources might place constraints on when certain activities can be carried out, and our ideal plan might need to be adapted to take account of this. Resource allocation is covered in Chapter 8.

The final step is *schedule production*. Once resources have been allocated to each activity, we will be in a position to draw up and publish a project schedule, which indicates planned start and completion dates and a resource requirements statement for each activity. Chapter 9 discusses how this is done and the role of the schedule in managing a project.

6.5 Projects and Activities

Defining activities

Before we try to identify the activities that make up a project it is worth reviewing what we mean by a project and its activities and adding some assumptions that will be relevant when we start to produce an activity plan.

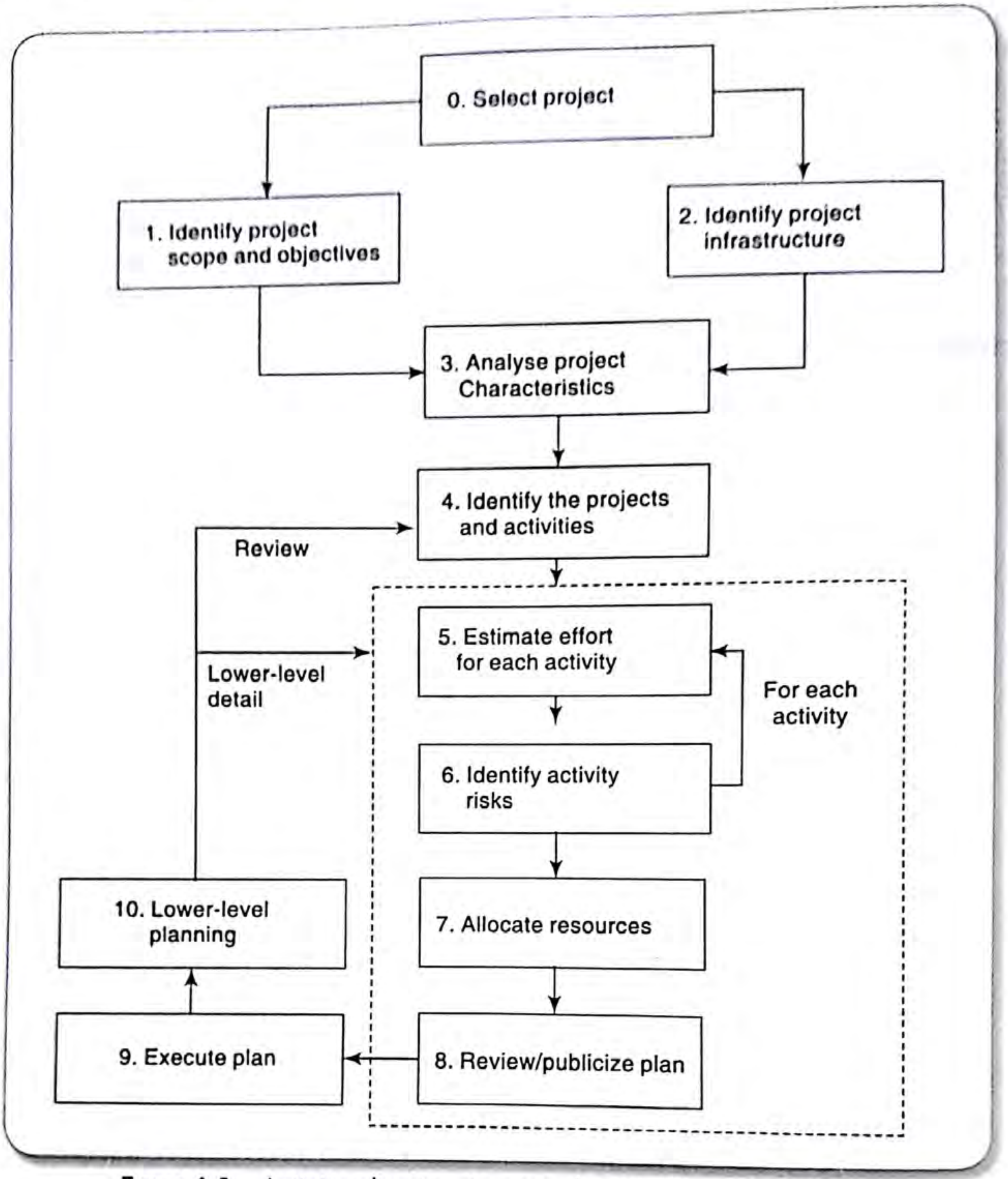

0. Select project
1. Identify project scope and objectives
2. Identify project infrastructure
3. Analyse project Characteristics
4. Identify the projects and activities
Review
Lower-level detail
5. Estimate effort for each activity
For each activity
6. Identify activity risks
7. Allocate resources
8. Review/publicize plan
9. Execute plan
10. Lower-level planning

FIGURE 6.1 Activity planning is carried out in Steps 4 and 5

- A project is composed of a number of interrelated activities.

Activities must be defined so that they meet these criteria. Any activity that does not meet these criteria must be redefined.

- A project may start when at least one of its activities is ready to start.
- A project will be completed when all of the activities it encompasses have been completed.
- An activity must have a clearly defined start and a clearly defined end-point, normally marked by the production of a tangible deliverable.
- If an activity requires a resource (as most do) then that resource requirement must be forecastable and is assumed to be required at a constant level throughout the duration of the activity.

- The duration of an activity must be forecastable – assuming normal circumstances, and the reasonable availability of resources.
- Some activities might require that others are completed before they can begin (these are known as *precedence requirements*).

Identifying activities

Essentially there are three approaches to identifying the activities or tasks that make up a project – we shall call them the *activity-based approach, the product-based approach* and the *hybrid approach.*

The activity-based approach

The activity-based approach consists of creating a list of all the activities that the project is thought to involve. This might require a brainstorming session involving the whole project team or it might stem from an analysis of similar past projects. When listing activities, particularly for a large project, it might be helpful to subdivide the project into the main life-cycle stages and consider each of these separately.

Rather than doing this in an ad hoc manner, with the obvious risks of omitting or double-counting tasks, a much favoured way of generating a task list is to create a *Work Breakdown Structure* (WBS). This involves identifying the main (or high-level) tasks required to complete a project and then breaking each of these down into a set of lower-level tasks. Figure 6.2 shows a fragment of a WBS where the design task has been broken down into three tasks and one of these has been further decomposed into two tasks.

WBSs are advocated by BS 6079, the British Standards Institution's *Guide to Project Management*.

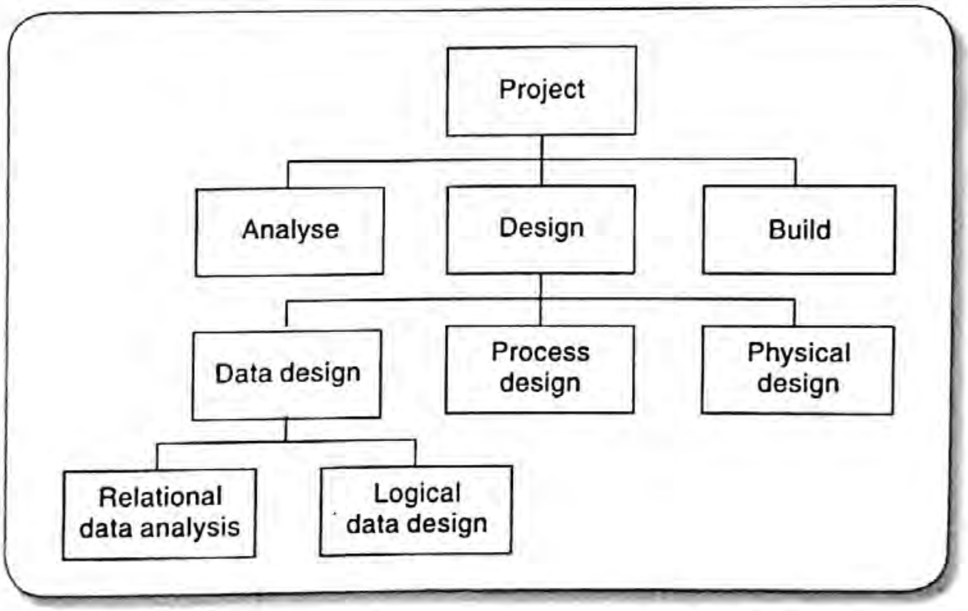


FIGURE 6.2 A fragment of an activity-based Work Breakdown Structure

Activities are added to a branch in the structure if they contribute directly to the task immediately above – if they do not contribute to the parent task, then they should not be added to that branch. The tasks at each level in any branch should include everything that is required to complete the task at the higher level.

When preparing a WBS, consideration must be given to the final level of detail or depth of the structure. Too great a depth will result in a large number of small tasks that will be difficult to manage, whereas a too shallow structure will provide insufficient detail for project control. Each branch should, however, be broken down at least to a level where each leaf may be assigned to an individual or responsible section within the organization.

A complete task catalogue will normally include task definitions along with task input and output products and other task-related information.

Advantages claimed for the WBS approach include the belief that it is much more likely to result in a task catalogue that is complete and is composed of non-overlapping activities. Note that it is only the leaves of the structure that comprise the list of activities in the project – higher-level nodes merely represent collections of activities.

The WBS also represents a structure that may be refined as the project proceeds. In the early part of a project we might use a relatively high-level or shallow WBS, which can be developed as information becomes available, typically during the project's analysis and specification phases.

Once the project's activities have been identified (whether or not by using a WBS), they need to be sequenced in the sense of deciding which activities need to be completed before others can start.

Product-based approach

The product-based approach, used in PRINCE2 and Step Wise, has already been described in Chapter 3. It consists of producing a Product Breakdown Structure and a Product Flow Diagram. The PFD indicates, for each product, which other products are required as inputs. The PFD can therefore be easily transformed into an ordered list of activities by identifying the transformations that turn some products into others. Proponents of this approach claim that it is less likely that a product will be left out of a PBS than that an activity might be omitted from an unstructured activity list.

This approach is particularly appropriate if using a methodology such as SSADM or USDP (Unified Software Development Process), which clearly specifies, for each step or task, each of the products required and the activities required to produce it. For example, the SSADM Reference Manual provides a set of generic PBSs for each stage in SSADM, which can be used as a basis for generating a project specific PBS.

See I. Jacobson, G. Booch and J. Rumbaugh (1999) *The Unified Software Development Process*, Addison-Wesley.

In the USDP, products are referred to as *artifacts* – see Figure 6.3 – and the sequence of activities needed to create them is called a *workflow*– see Figure 6.4 for an example. Some caution is needed in drawing up an activity network from these workflows. USDP emphasizes that processes are iterative. This means that it may not be possible to map a USDP process directly onto a single activity in a network. In Section 4.18 we saw how one or more iterated processes could be hidden in the single execution of a larger activity. All projects, whether they contain iterations or not, will need to have some fixed milestones or time-boxes if progress towards a planned delivery date is to be maintained. These larger activities with the fixed completion dates would be the basis of the activity network.

Hybrid approach

BS 6079 states that WBSs may be product-based, cost-centre-based, task-based or function-based but that product-based WBSs are preferred.

The WBS illustrated in Figure 6.2 is based entirely on a structuring of activities. Alternatively, and perhaps more commonly, a WBS may be based upon the project's products as illustrated in Figure 6.5, which is in turn based on a simple list of final deliverables and, for each deliverable, a set of activities required to produce that product. Figure 6.5 illustrates a flat WBS and it is likely that, in a project of any size, it would be beneficial to introduce additional levels – structuring both products and

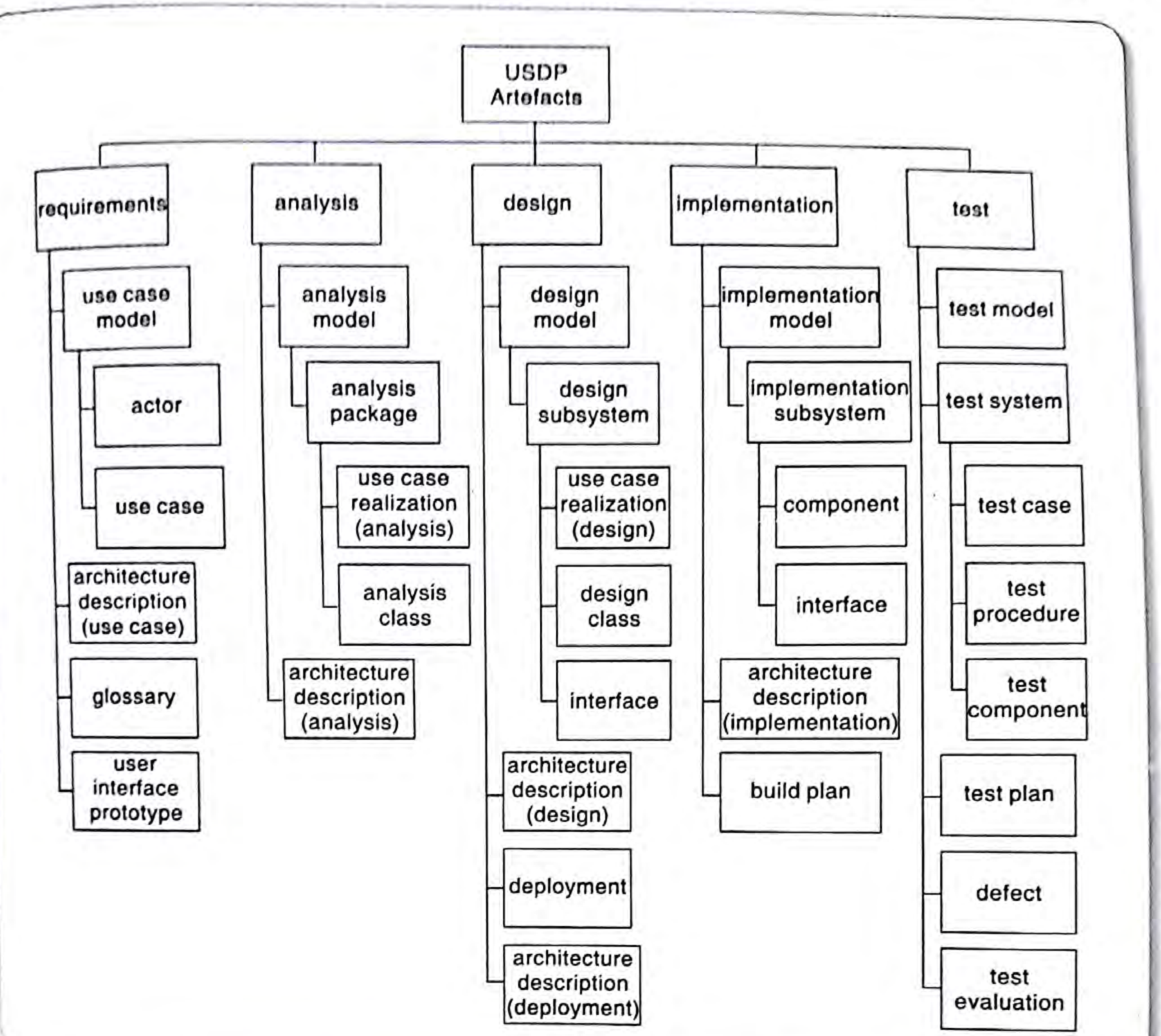


Figure 6.3 USDP product breakdown structure based on artefacts identified in Jacobson, Booch and Rumbaugh (1999)

activities. The degree to which the structuring is product-based or activity-based might be influenced by the nature of the project and the particular development method adopted. As with a purely activity-based WBS, having identified the activities we are then left with the task of sequencing them.

A framework dictating the number of levels and the nature of each level in the structure may be imposed on a WBS. For example, in their MITP methodology, IBM recommend that the following five levels should be used in a WBS:

Not all of the products in this activity structuring will be final products. Some will be further refined in subsequent steps.

- *Level 1: Project*
- *Level 2: Deliverables* such as software, manuals and training courses

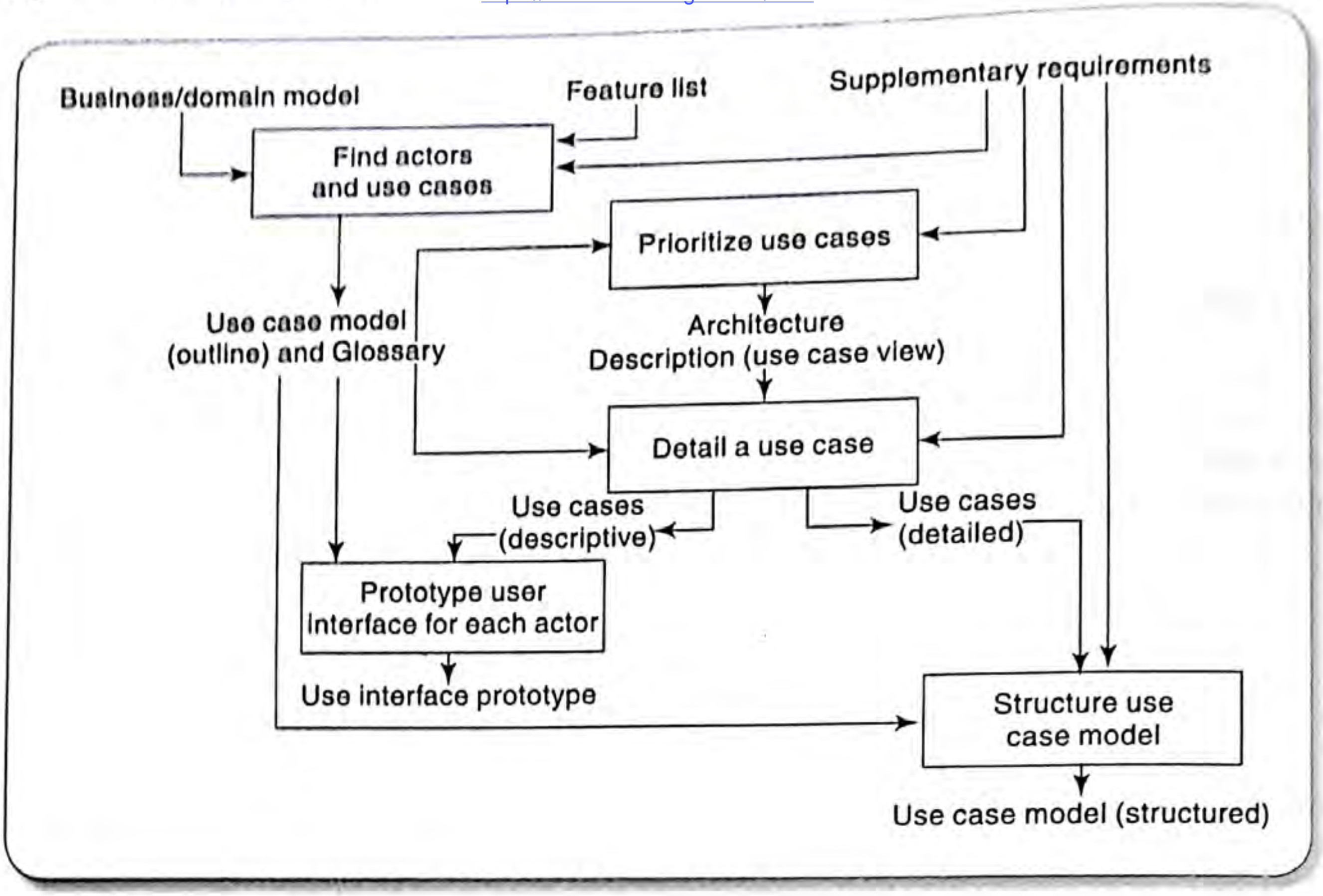

Business/domain model
Feature list
Supplementary requirements
Find actors and use cases
Prioritize use cases
Use case model (outline) and Glossary
Architecture Description (use case view)
Detail a use case
Use cases (descriptive)
Use cases (detailed)
Prototype user interface for each actor
Use interface prototype
Structure use case model
Use case model (structured)

FIGURE 6.4 A structuring of activities for the USDP requirements capture workflow based on Jacobson, Booch and Rumbaugh (1999)

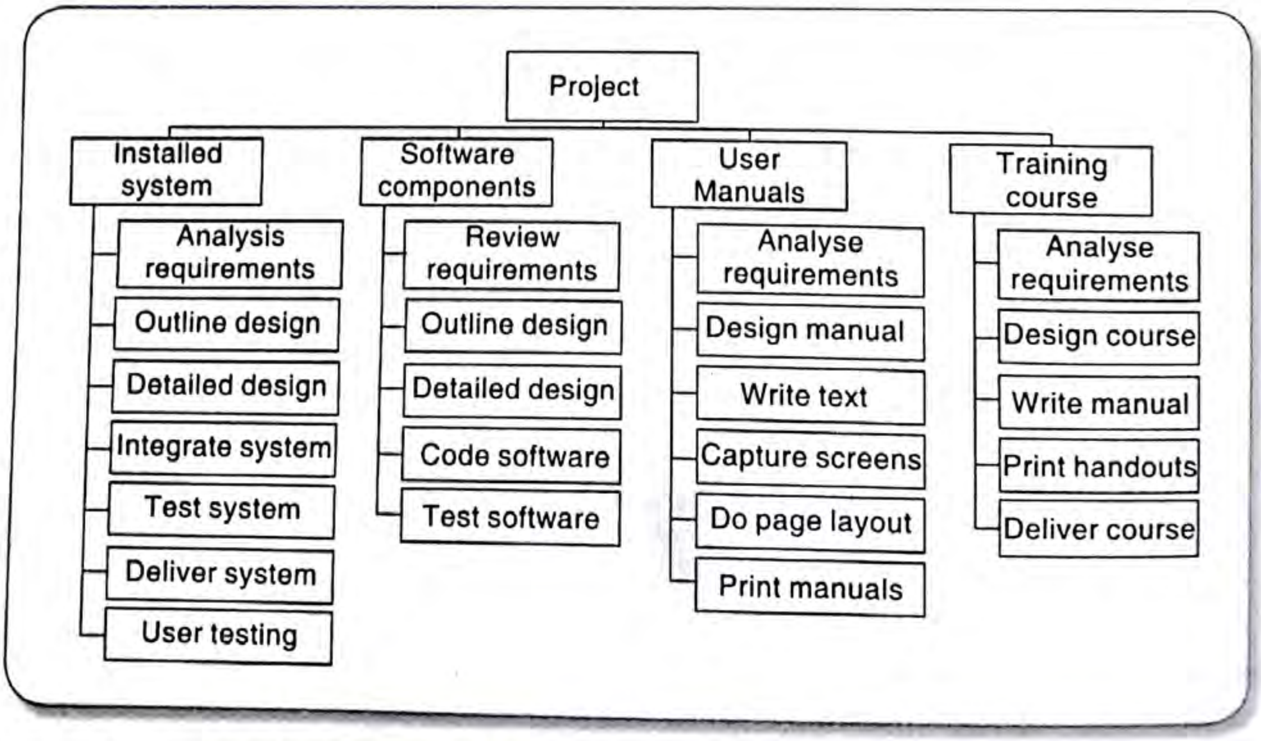
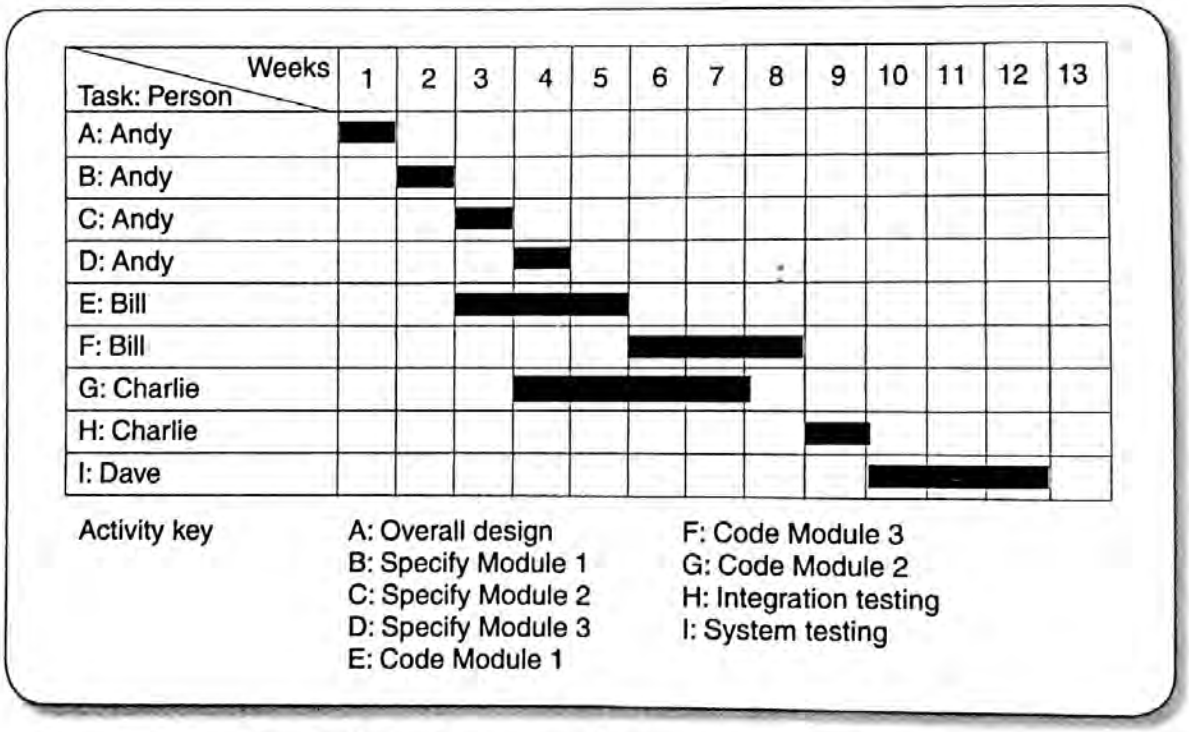


FIGURE 6.5 A hybrid Work Breakdown Structure based on deliverables and activities

- *Level 3: Components*, which are the key work items needed to produce deliverables, such as the modules and tests required to produce the system software
- *Level 4: Work-packages*, which are major work items, or collections of related tasks, required to produce a component
- *Level 5: Tasks*, which are tasks that will normally be the responsibility of a single person

6.6 Sequencing and Scheduling Activities

Throughout a project, we will require a schedule that clearly indicates when each of the project's activities is planned to occur and what resources it will need. We shall be considering scheduling in more detail in Chapter 8, but let us consider in outline how we might present a schedule for a small project. One way of presenting such a plan is to use a bar chart as shown in Figure 6.6.



Weeks / Task: Person	1	2	3	4	5	6	7	8	9	10	11	12	13
A: Andy	■												
B: Andy		■											
C: Andy			■										
D: Andy				■									
E: Bill			■	■	■								
F: Bill						■	■	■					
G: Charlie				■	■	■	■						
H: Charlie									■				
I: Dave										■	■	■	

Activity key

A: Overall design
B: Specify Module 1
C: Specify Module 2
D: Specify Module 3
E: Code Module 1
F: Code Module 3
G: Code Module 2
H: Integration testing
I: System testing

Figure 6.6 A project plan as a bar chart

The chart shown has been drawn up taking account of the nature of the development process (that is, certain tasks must be completed before others may start) and the resources that are available (for example, activity C follows activity B because Andy cannot work on both tasks at the same time). In drawing up the chart, we have therefore done two things – we have sequenced the tasks (that is, identified the dependencies among activities dictated by the development process) and scheduled them (that is, specified when they should take place). The scheduling has had to take account of the availability of staff and the ways in which the activities have been allocated to them. The schedule might look quite different were there a different number of staff or were we to allocate the activities differently.

The bar chart does not show why certain decisions have been made. It is not clear, for example, why activity H is not scheduled to start until week 9. It could be that it cannot start until activity F has been completed or it might be because Charlie is going to be on holiday during week 8.

In the case of small projects, this combined sequencing–scheduling approach might be quite suitable, particularly where we wish to allocate individuals to particular tasks at an early planning stage. However, on larger projects it is better to separate out these two activities: to sequence the tasks according to their logical relationships and then to schedule them taking into account resources and other factors.

Separating the logical sequencing from the scheduling may be likened to the principle in systems analysis of separating the logical system from its physical implementation.

Approaches to scheduling that achieve this separation between the logical and the physical use networks to model the project and it is these approaches that we will consider in subsequent sections of this chapter.

6.7 Network Planning Models

CPM was developed by the DuPont Chemical Company which published the method in 1958, claiming that it had saved them $1 million in its first year of use.

These project scheduling techniques model the project's activities and their relationships as a network. In the network, time flows from left to right. These techniques were originally developed in the 1950s – the two best known being CPM (Critical Path Method) and PERT (Program Evaluation Review Technique).

Both of these techniques used an *activity-on-arrow* approach to visualizing the project as a network where activities are drawn as arrows joining circles, or nodes, which represent the possible start and/or completion of an activity or set of activities. More recently a variation on these techniques, called *precedence networks*, has become popular. This method uses *activity-on-node* networks where activities are represented as nodes and the links between nodes represent precedence (or sequencing) requirements. This latter approach avoids some of the problems inherent in the activity-on-arrow representation and provides more scope for easily representing certain situations. It is this method that is adopted in the majority of computer applications currently available. These three methods are very similar and it must be admitted that many people use the same name (particularly CPM) indiscriminately to refer to any or all of the methods.

In the following sections of this chapter, we will look at the critical path method applied to precedence (activity-on-node) networks followed by a brief introduction to activity-on-arrow networks – a discussion of PERT will be reserved for Chapter 7 when we look at risk analysis.

Case Study **Examples**

In Chapter 2 we saw how Amanda identified that three new software components would need to be developed and a further component would need to be rewritten. Figure 6.7 shows the fragment of a network that she has developed as an activity-on-node network. Figure 6.8 shows how this network would look represented as an activity-on-arrow network. Study each of the networks briefly to verify that they are, indeed, merely different graphical representations of the same thing.

6.8 Formulating a Network Model

The first stage in creating a network model is to represent the activities and their interrelationships as a graph. In activity-on-node we do this by representing activities as nodes (boxes) in the graph – the lines between nodes represent dependencies.

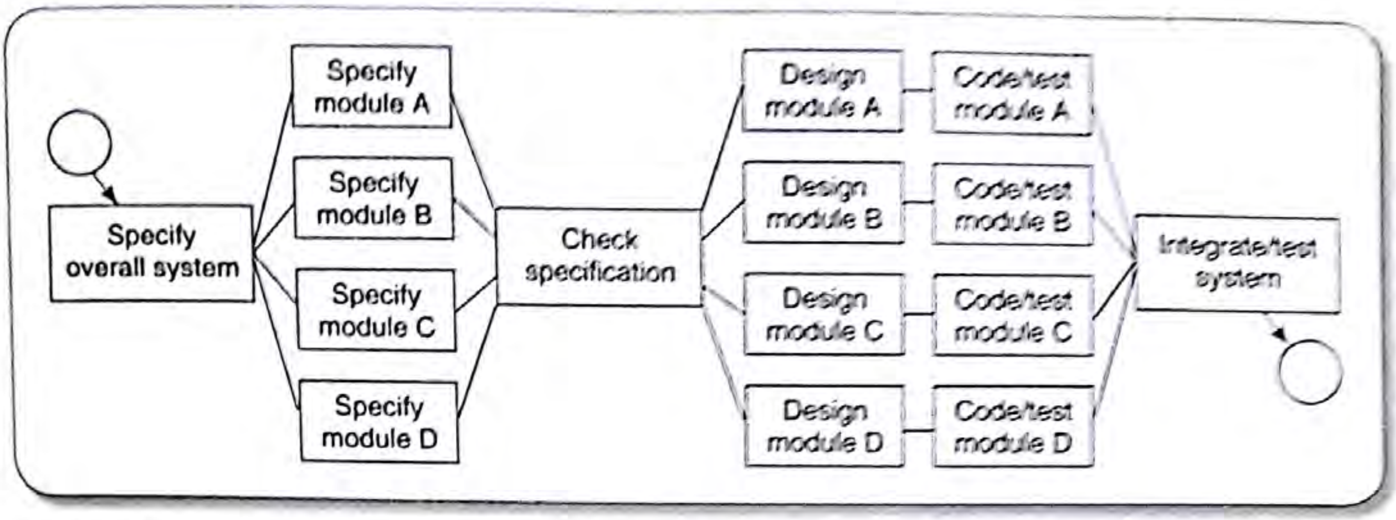


FIGURE 6.7 The IOE annual maintenance contracts project activity network fragment with a check-point activity added

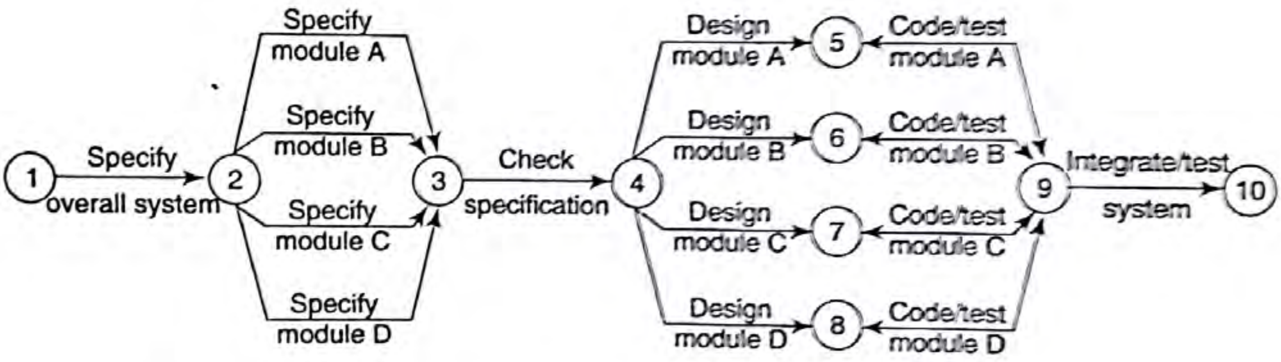


FIGURE 6.8 The IOE annual maintenance contracts project activity network fragment represented as a CPM network

Constructing precedence networks

Before we look at how networks are used, it is worth spending a few moments considering some rules for their construction.

A project network should have only one start node Although it is logically possible to draw a network with more than one starting node, it is undesirable to do so as it is a potential source of confusion. In such cases (for example, where more than one activity can start immediately the project starts) it is normal to invent a 'start' activity which has zero duration but may have an actual start date.

A project network should have only one end node The end node designates the completion of the project and a project may finish only once! Although it is possible to draw a network with more than one end node, it will almost certainly lead to confusion if this is done. Where the completion of a project depends upon more than one 'final' activity it is normal to invent a 'finish' activity.

A node has duration A node represents an activity and, in general, activities take time to execute. Notice, however, that the network in Figure 6.7 does not contain any reference to durations. This network drawing merely represents the logic of the project – the rules governing the order in which activities are to be carried out.

Later we will look at the possibility of 'lag' between activities.

Links normally have no duration Links represent the relationships between activities. In Figure 6.9 installation cannot start until program testing is complete. Program testing cannot start until both coding and data take-on have been completed.

Precedents are the immediate preceding activities In Figure 6.9, the activity 'Program test' cannot start until both 'Code' and 'Data take-on' have been completed and activity 'Install' cannot start until 'Program test' has finished. 'Code' and 'Data take-on' can therefore be said to be precedents of 'Program test', and 'Program test' is a precedent of 'Install'. Note that we do not speak of 'Code' and 'Data take-on' as precedents of 'Install' – that relationship is implicit in the previous statement.

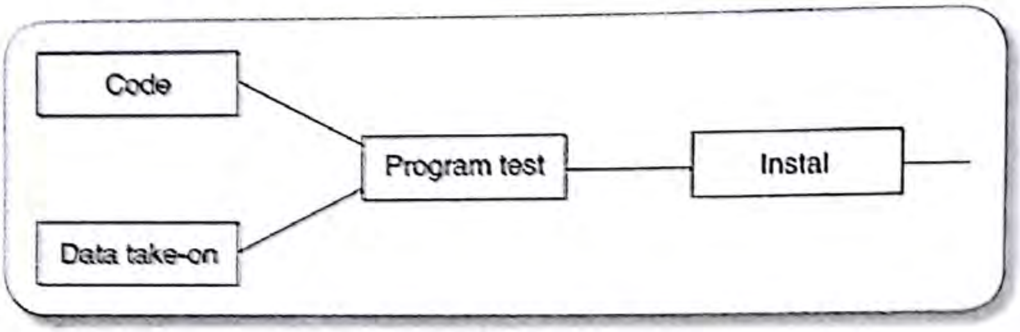


FIGURE 6.9 Fragment of a precedence network

Time moves from left to right If at all possible, networks are drawn so that time moves from left to right. It is rare that this convention needs to be flouted but some people add arrows to the lines to give a stronger visual indication of the time flow of the project.

A network may not contain loops Figure 6.10 demonstrates a loop in a network. A loop is an error in that it represents a situation that cannot occur in practice. While loops, in the sense of iteration, may occur in practice, they cannot be directly represented in a project network. Note that the logic of Figure 6.10 suggests that program testing cannot start until the errors have been corrected.

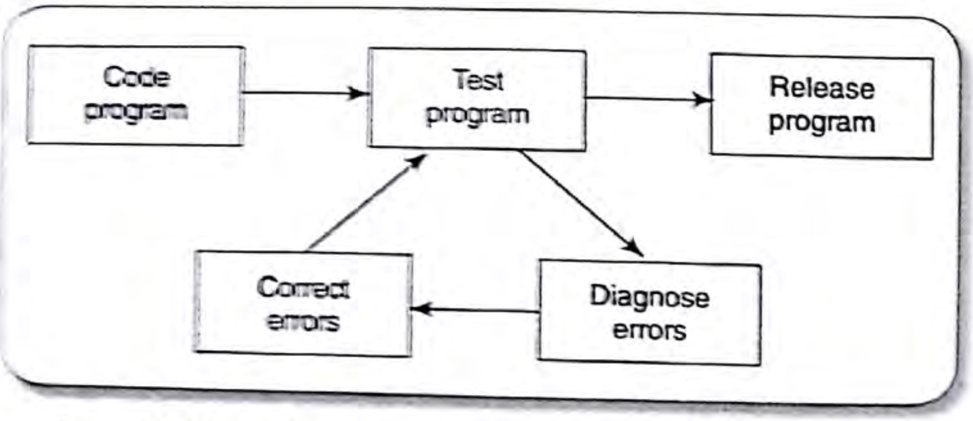


FIGURE 6.10 A loop represents an impossible sequence

If we know the number of times we expect to repeat a set of activities, a test– diagnose–correct sequence, for example, then we can draw that set of activities as a straight sequence, repeating it the appropriate number of times. If we do not know how many times a sequence is going to be repeated then we cannot calculate the duration of the project unless we adopt an alternative strategy such as redefining the complete sequence as a single activity and estimating how long it will take to complete it.

Although it is easy to see the loop in this simple network fragment, very large networks can easily contain complex loops which are difficult to spot when they are initially constructed. Fortunately, all network planning applications will detect loops and generate error messages when they are found.

A network should not contain dangles A dangling activity such as 'Write user manual' in Figure 6.11 should not exist as it is likely to lead to errors in subsequent analysis. Indeed, in many cases dangling activities indicate errors in logic when activities are added as an afterthought. If, in Figure 6.11, we mean to indicate that the project is complete once the software has been installed *and* the user manual written then we should redraw the network with a final completion activity – which, at least in this case, is probably a more accurate representation of what should happen. The redrawn network is shown in Figure 6.12.

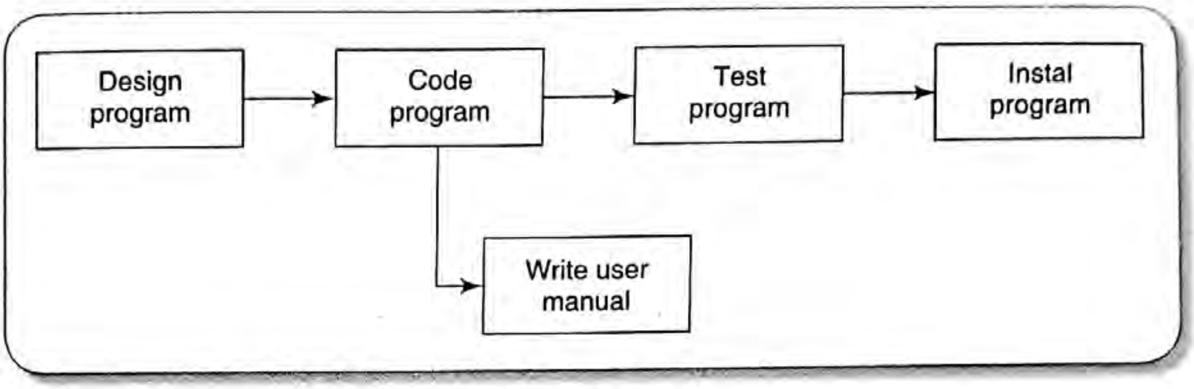


FIGURE 6.11 A dangle

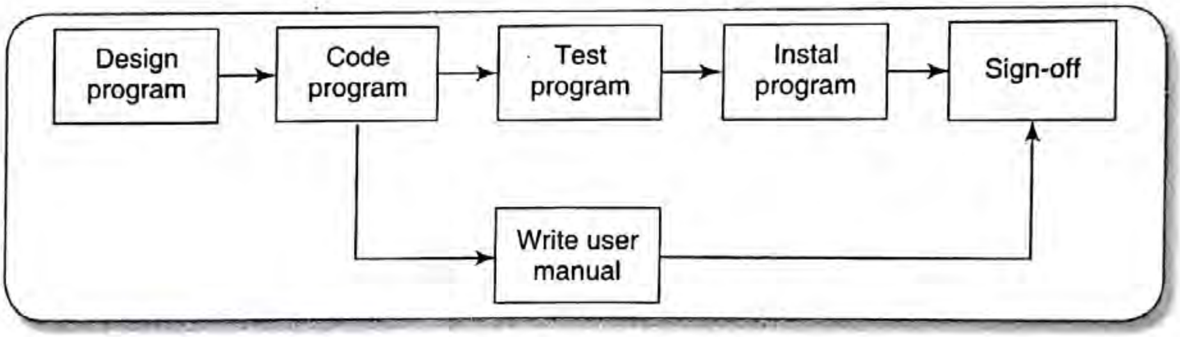


FIGURE 6.12 Resolving the dangle

Representing lagged activities

We might come across situations where we wish to undertake two activities in parallel so long as there is a lag between the two. We might wish to document amendments to a program as it is being tested – particularly if evaluating a prototype. In such a case we could designate an activity 'test and document amendments'. This would, however, make it impossible to show that amendment recording could start, say, one day after testing had begun and finish a little after the completion of testing.

Where activities can occur in parallel with a time lag between them, we represent the lag with a duration on the linking arrow as shown in Figure 6.13. This indicates that documenting amendments can start one day after the start of prototype testing and will be completed two days after prototype testing is completed.

Documenting amendments may take place alongside prototype testing so long as it starts at least one day later and finishes two days later.

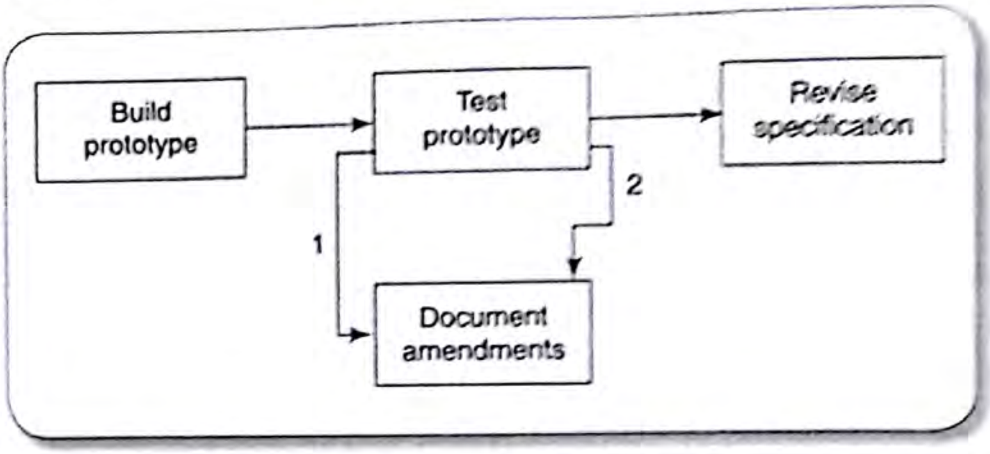


Figure 6.13 Indicating lags

Hammock activities

Hammock activities are activities which, in themselves, have zero duration but are assumed to start at the same time as the first 'hammocked' activity and to end at the same time as the last one. They are normally used for representing overhead costs or other resources that will be incurred or used at a constant rate over the duration of a set of activities.

Labelling conventions

There are a number of differing conventions that have been adopted for entering information on an activity-on-node network. The one adopted here is shown on the left and is based on the British Standard BS 4335.

The activity label is usually a code developed to uniquely identify the activity and may incorporate a project code (for example, IoE/P/3 to designate one of the programming activities for IOE's annual maintenance contract project). The activity description will normally be a brief activity name such as 'Test take-on module'. The other items in our activity node will be explained as we discuss the analysis of a project network.

Earliest start	Duration	Earliest finish
Activity label, activity description		
Latest start	Float	Latest finish

6.9 Adding the Time Dimension

Having created the logical network model indicating what needs to be done and the interrelationships between those activities, we are now ready to start thinking about when each activity should be undertaken.

The critical path approach is concerned with two primary objectives: planning the project in such a way that it is completed as quickly as possible; and identifying those activities where a delay in their execution is likely to affect the overall end date of the project or later activities' start dates.

The method requires that for each activity we have an estimate of its duration. The network is then analysed by carrying out a *forward pass*, to calculate the earliest dates at which activities may commence and the project be completed, and a *backward pass*, to calculate the latest start dates for activities and the *critical path*.

In practice we would use a software application to carry out these calculations for anything but the smallest of projects. It is important, though, that we understand how the calculations are carried out in order to interpret the results correctly and understand the limitations of the method.

The description and example that follow use the small example project outlined in Table 6.1 – a project composed of eight activities whose durations have been estimated as shown in the table. Brigette at Brightmouth College has completed the software package evaluation and a software package has been chosen and approved. Now that the application software is known, the hardware needed as a platform can be acquired. Another task will be 'system configuration' – there are a number of parameters that will have to set in the application so that it runs satisfactorily for Brightmouth College. Once the parameters have been set, details of the employees who are to be paid will have to be set up on the new system. Enough information about the new system will now be available so that office procedures can be devised and documented. There are currently no staff currently dedicated to payroll administration so a payroll officer is to be recruited and then trained.

Exercise 6.1

Draw an activity network using precedence network conventions for the project specified in Table 6.1. When you have completed it, compare your result with that shown in Figure 6.14.

Figure 6.14 illustrates the network for the project specified in Table 6.1.

Table 6.1 An example project specification with estimated activity durations and precedence requirements

Activity		Duration (weeks)	Precedents
A	Hardware selection	6	
B	System configuration	4	
C	Install hardware	3	A
D	Data migration	4	B
E	Draft office procedures	3	B
F	Recruit staff	10	
G	User training	3	E, F
H	Install and test system	2	C, D

6.10 The Forward Pass

The forward pass is carried out to calculate the earliest dates on which each activity may be started and completed.

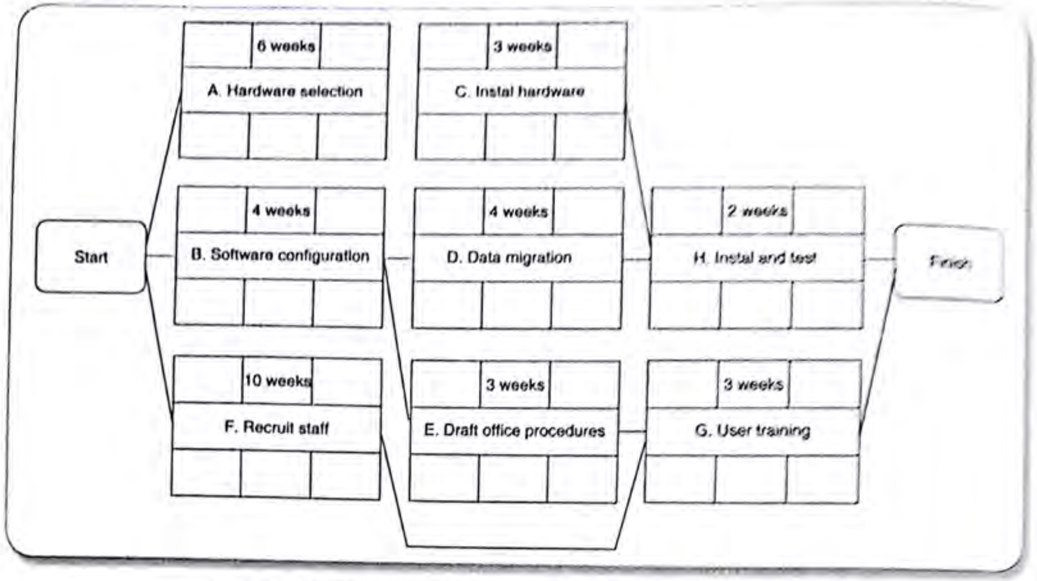


Figure 6.14 The precedence network for the example project

Where an actual start date is known, the calculations may be carried out using actual dates. Alternatively we can use day or week numbers and that is the approach we shall adopt here. By convention, dates indicate the end of a period and the project is therefore shown as starting at the end of week zero (or the beginning of week 1).

During the forward pass, earliest dates are recorded as they are calculated.

The forward pass rule: the earliest start date for an activity is the earliest finish date for the preceding activity. Where there is more than one immediately preceding activity we take the *latest* of the *earliest finish dates* for those activities.

The forward pass and the calculation of earliest start dates are carried out according to the following reasoning.

- Activities A, B and F may start immediately, so the earliest date for their start is zero.
- Activity A will take 6 weeks, so the earliest it can finish is week 6.
- Activity B will take 4 weeks, so the earliest it can finish is week 4.
- Activity F will take 10 weeks, so the earliest it can finish is week 10.
- Activity C can start as soon as A has finished so its earliest start date is week 6. It will take 3 weeks so the earliest it can finish is week 9.
- Activities D and E can start as soon as B is complete so the earliest they can each start is week 4. Activity D, which will take 4 weeks, can therefore finish by week 8 and activity E, which will take 3 weeks, can therefore finish by week 7.
- Activity G cannot start until both E and F have been completed. It cannot therefore start until week 10 – the later of weeks 7 (for activity E) and 10 (for activity F). It takes 3 weeks and finishes in week 13.
- Similarly, Activity H cannot start until week 9 – the later of the two earliest finish dates for the preceding activities C and D.

- The project will be complete when both activities H and G have been completed. Thus the earliest project completion date will be the later of weeks 11 and 13 – that is, week 13.

The results of the forward pass are shown in Figure 6.15.

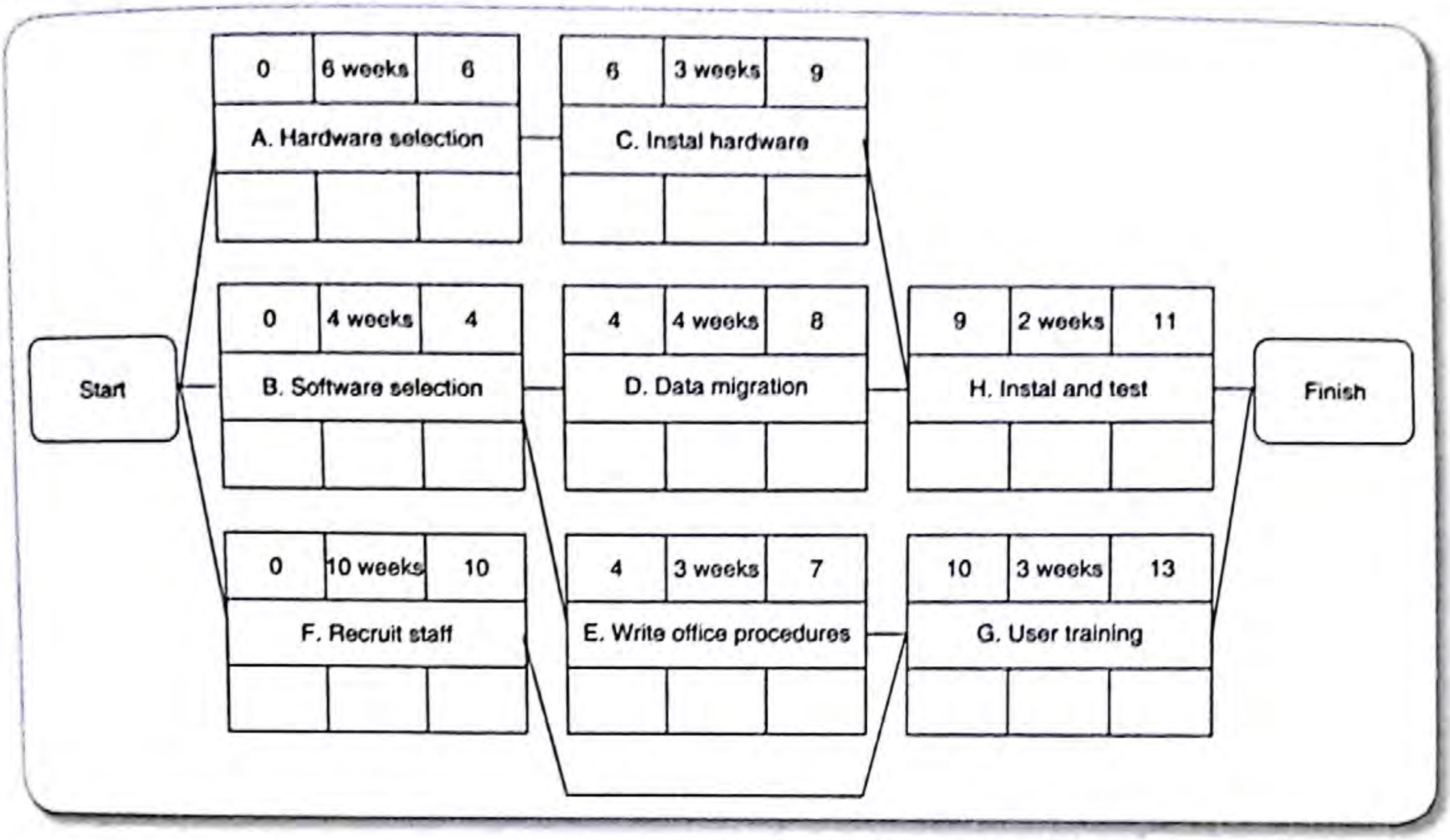


FIGURE 6.15 The network after the forward pass

6.11 Backward Pass

The second stage in the analysis of a critical path network is to carry out a backward pass to calculate the latest date at which each activity may be started and finished without delaying the end date of the project. In calculating the latest dates, we assume that the latest finish date for the project is the same as the earliest finish date – that is, we wish to complete the project as early as possible.

Figure 6.16 illustrates our network after carrying out the backward pass. The latest activity dates are calculated as follows.

- The latest completion date for activities G and H is assumed to be week 13.
- Activity H must therefore start at week 11 at the latest (13 – 2) and the latest start date for activity G is week 10 (13 – 3).
- The latest completion date for activities C and D is the latest date at which activity H must start – that is, week 11. They therefore have latest start dates of week 8 (11 – 3) and week 7 (11 – 4) respectively.
- Activities E and F must be completed by week 10 so their earliest start dates are weeks 7 (10 – 3) and 0 (10 – 10) respectively.
- Activity B must be completed by week 7 (the latest start date for both activities D and E) so its latest start is week 3 (7 – 4).

The backward pass rule: the latest finish date for an activity is the latest start date for the activity that commences immediately that activity is complete. Where more than one activity can commence we take the earliest of the latest start dates for those activities.

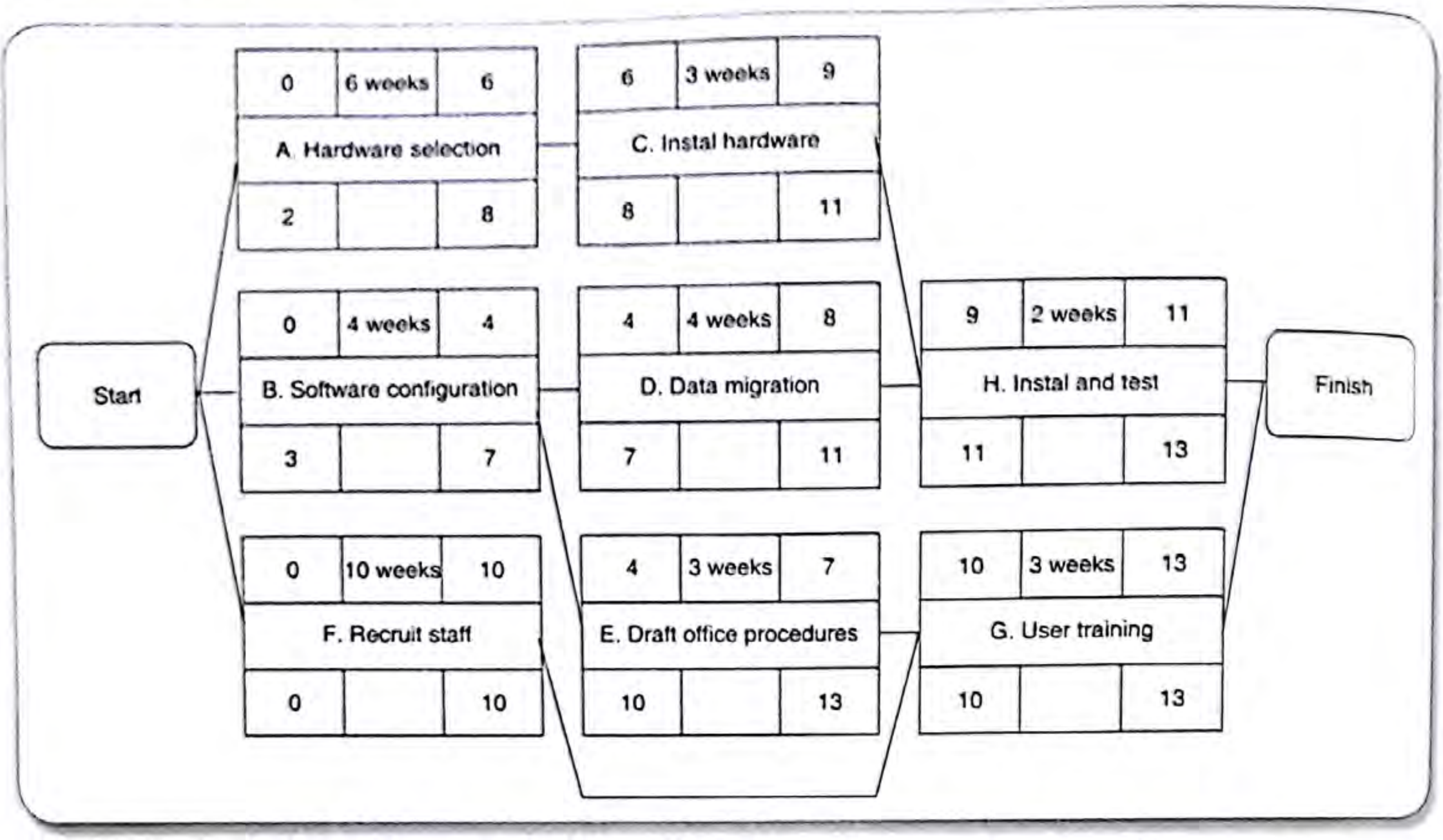


Figure 6.16 The network after the backward pass

- Activity A must be completed by week 8 (the latest start date for activity C) so its latest start is week 2 (8 – 6).
- The latest start date for the project start is the earliest of the latest start dates for activities A, B and F. This is week zero. This is, of course, not very surprising since it tells us that if the project does not start on time it won't finish on time.

6.12 Identifying the Critical Path

The critical path is the longest path through the network.

There will be at least one path through the network (that is, one set of successive activities) that defines the duration of the project. This is known as the *critical path*. Any delay to any activity on this critical path will delay the completion of the project.

This float is also known as total float to distinguish it from other forms of float – see Section 6.13.

The difference between an activity's earliest start date and its latest start date (or, equally, the difference between its earliest and latest finish dates) is known as the activity's *float* – it is a measure of how much the start or completion of an activity may be delayed without affecting the end date of the project. Any activity with a float of zero is critical in the sense that any delay in carrying out the activity will delay the completion date of the project as a whole. There will always be at least one path through the network joining those critical activities – this path is known as the critical path and is shown bold in Figure 6.17.

The significance of the critical path is two-fold.

- In managing the project, we must pay particular attention to monitoring activities on the critical path so that the effects of any delay or resource unavailability are detected and corrected at the earliest opportunity.

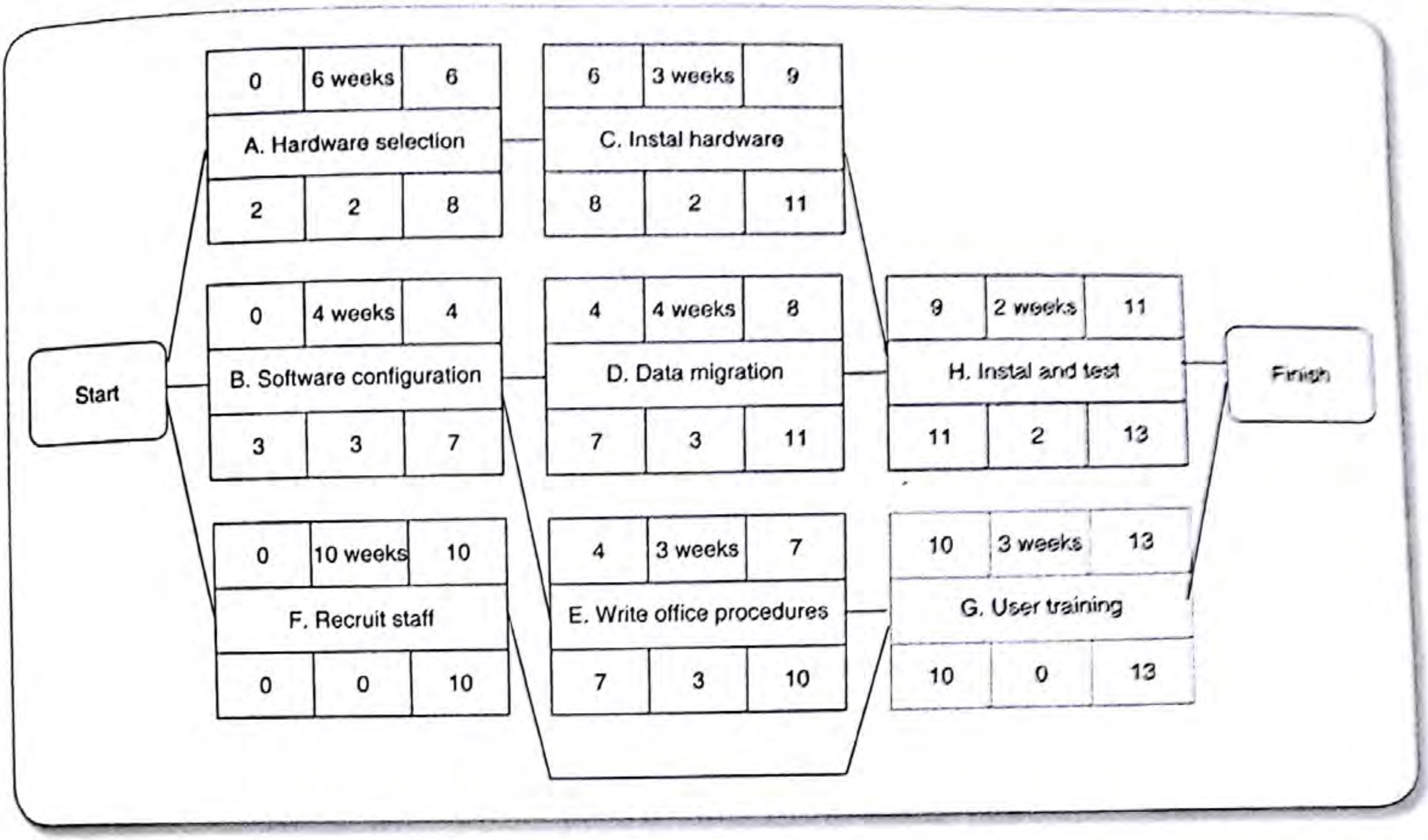


Figure 6.17 The critical path

- In planning the project, it is the critical path that we must shorten if we are to reduce the overall duration of the project.

Figure 6.17 also shows the *activity span*. This is the difference between the earliest start date and the latest finish date and is a measure of the maximum time allowable for the activity. However, it is subject to the same conditions of interpretation as activity float, which is discussed in the next section.

Exercise 6.2

Refer back to Amanda's CPM network illustrated in Figure 6.7.

Using the activity durations given in Table 6.2, calculate the earliest completion date for the project and identify the critical path on your network.

Table 6.2 Estimated activity durations for Amanda's network

Activity	Estimated duration (days)	Activity	Estimated duration (days)
Specify overall system	34	Design module C	4
Specify module A	20	Design module D	4

(Contd.)

Specify module B	15	Code/test module A	30
Specify module C	25	Code/test module B	28
Specify module D	15	Code/test module C	15
Check specification	2	Code/test module D	25
Design module A	7	System integration	6
Design module B	6		

6.13 Activity Float

Total float may only be used once.

Although the total float is shown for each activity, it really 'belongs' to a path through the network. Activities A and C in Figure 6.17 each have 2 weeks' total float. If, however, activity A uses up its float (that is, it is not completed until week 8) then activity B will have zero float (it will have become critical). In such circumstances it may be misleading and detrimental to the project's success to publicize total float!

There are a number of other measures of activity float, including the following:

- *Free float:* The time by which an activity may be delayed without affecting any subsequent activity. It is calculated as the difference between the earliest completion date for the activity and the earliest start date of the succeeding activity. This might be considered a more satisfactory measure of float for publicizing to the staff involved in undertaking the activities.
- *Interfering float:* The difference between total float and free float. This is quite commonly used, particularly in association with the free float. Once the free float has been used (or if it is zero), the interfering float tells us by how much the activity may be delayed without delaying the project end date – even though it will delay the start of subsequent activities.

Exercise 6.3

Calculate the free float and interfering float for each of the activities shown in the activity network (Figure 6.17).

6.14 Shortening the Project Duration

If we wish to shorten the overall duration of a project we would normally consider attempting to reduce activity durations. In many cases this can be done by applying more resources to the task – working overtime or procuring additional staff, for example. The critical path indicates where we must look to save time – if we are trying to bring forward the end date of the project, there is clearly no point in attempting to shorten non-critical activities. Referring to Figure 6.17, it can be seen that we could complete the project in week 12 by reducing the duration of activity F by one week (to 9 weeks).

As we reduce activity times along the critical path we must continually check for any new critical path emerging and redirect our attention where necessary.

There will come a point when we can no longer safely, or cost-effectively, reduce critical activity durations in an attempt to bring forward the project end date. Further savings, if needed, must be sought in a consideration of our work methods and by questioning the logical sequencing of activities. Generally, time savings are to be found by increasing the amount of parallelism in the network and the removal of bottlenecks (subject always, of course, to resource and quality constraints).

Exercise 6.4

Referring to Figure 6.17, suppose that the duration for activity F is shortened to 8 weeks. Calculate the end date for the project.

What would the end date for the project be if activity F were shortened to 7 weeks? Why?

6.15 Identifying Critical Activities

The critical path identifies those activities which are critical to the end date of the project; however, activities that are not on the critical path may become critical. As the project proceeds, activities will invariably use up some of their float and this will require a periodic recalculation of the network. As soon as the activities along a particular path use up their total float then that path will become a critical path and a number of hitherto non-critical activities will suddenly become critical.

For a more in-depth discussion of the role of the critical path in project monitoring, see Chapter 9.

It is therefore common practice to identify *near-critical* paths – those whose lengths are within, say, 10–20% of the duration of the critical path or those with a total float of less than, say, 10% of the project's uncompleted duration.

The importance of identifying critical and near-critical activities is that it is they that are most likely to be the cause of delays in completing the project. We shall see, in the next three chapters, that identifying these activities is an important step in risk analysis, resource allocation and project monitoring.

6.16 Activity-on-Arrow Networks

The developers of the CPM and PERT methods both originally used activity-on-arrow networks. Although now less common than activity-on-node networks, they are still used and introduce an additional useful concept – that of events. We will therefore take a brief look at how they are drawn and analysed using the same project example shown in Table 6.1.

In activity-on-arrow networks activities are represented by links (or arrows) and the nodes represent events of activities (or groups of activities) starting or finishing. Figure 6.18 illustrates our previous example (see Figure 6.14) drawn as an activity-on-arrow network.

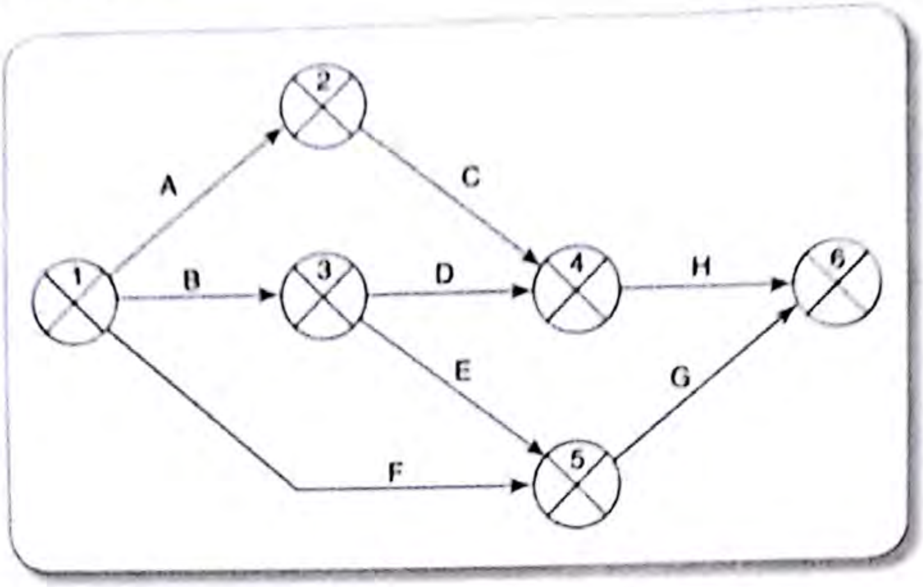


FIGURE 6.18 An activity-on-arrow network

Activity-on-arrow network rules and conventions

A project network may have only one start node This is a requirement of activity-on-arrow networks rather than merely desirable as is the case with activity-on-node networks.

A project network may have only one end node Again, this is a requirement for activity-on-arrow networks.

A link has duration A link represents an activity and, in general, activities take time to execute. Notice, however, that the network in Figure 6.18 does not contain any reference to durations. The links are not drawn in any way to represent the activity durations. The network drawing merely represents the logic of the project – the rules governing the order in which activities are to be carried out.

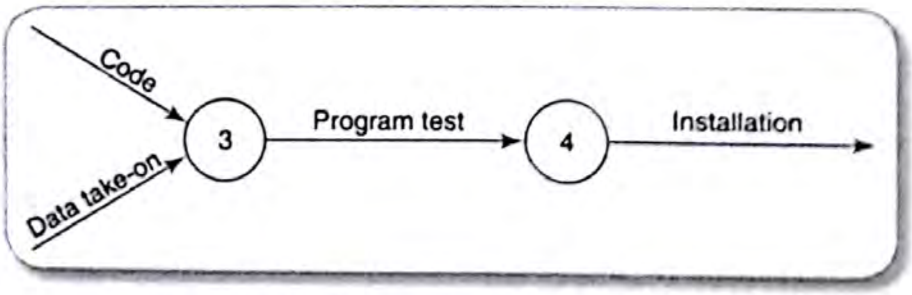


FIGURE 6.19 Fragment of a CPM network

Nodes have no duration Nodes are events and, as such, are instantaneous points in time. The source node is the event of the project becoming ready to start and the sink node is the event of the project becoming completed. Intermediate nodes represent two simultaneous events – the event of all activities leading into a node having been completed and the event of all activities leading out of that node being in a position to be started.

In Figure 6.19, node 3 is the event that both 'coding' and 'data take-on' have been completed and activity 'program test' is free to start. 'Installation' may be started only when event 4 has been achieved, that is, as soon as 'program test' has been completed.

Time moves from left to right As with activity-on-node networks, activity-on-arrow networks are drawn, if at all possible, so that time moves from left to right.

Nodes are numbered sequentially There are no precise rules about node numbering but nodes should be numbered so that head nodes (those at the 'arrow' end of an activity) always have a higher number than tail events (those at the 'non-arrow' end of an activity). This convention makes it easy to spot loops.

A network may not contain loops Figure 6.20 demonstrates a loop in an activity-on-arrow network. As discussed in the context of precedence networks, loops are either an error of logic or a situation that must be resolved by itemizing iterations of activity groups.

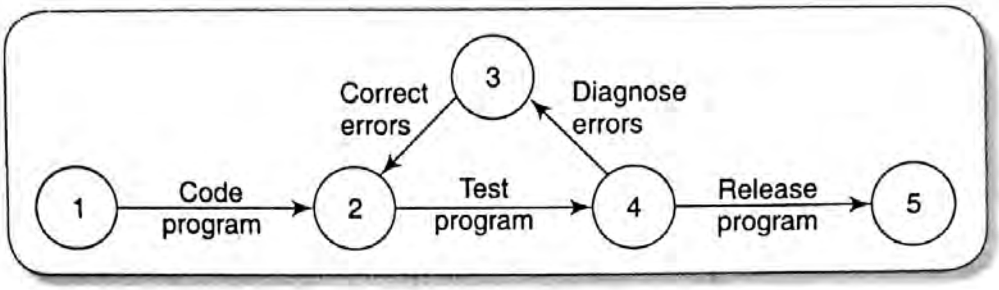


FIGURE 6.20 A loop represents an impossible sequence

Dangles are not allowed in activity-on-arrow networks.

A network may not contain dangles A dangling activity, such as 'Write user manual' in Figure 6.21, cannot exist, as it would suggest there are two completion points for the project. If, in Figure 6.21, node 5 represents the true project completion point and there are no activities dependent on activity 'Write user manual', then the network should be redrawn so that activity 'Write user manual' starts at node 2 and terminates at node 5 – in practice, we would need to insert a dummy activity between nodes 3 and 5. In other words, all events, except the first and the last, must have at least one activity entering them and at least one activity leaving them and all activities must start and end with an event.

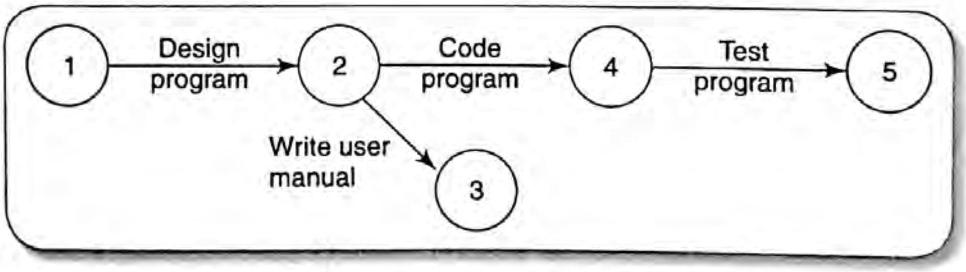


FIGURE 6.21 A dangle

Exercise 6.5

Take a look at the networks in Figure 6.22. State what is wrong with each of them and, where possible, redraw them correctly.

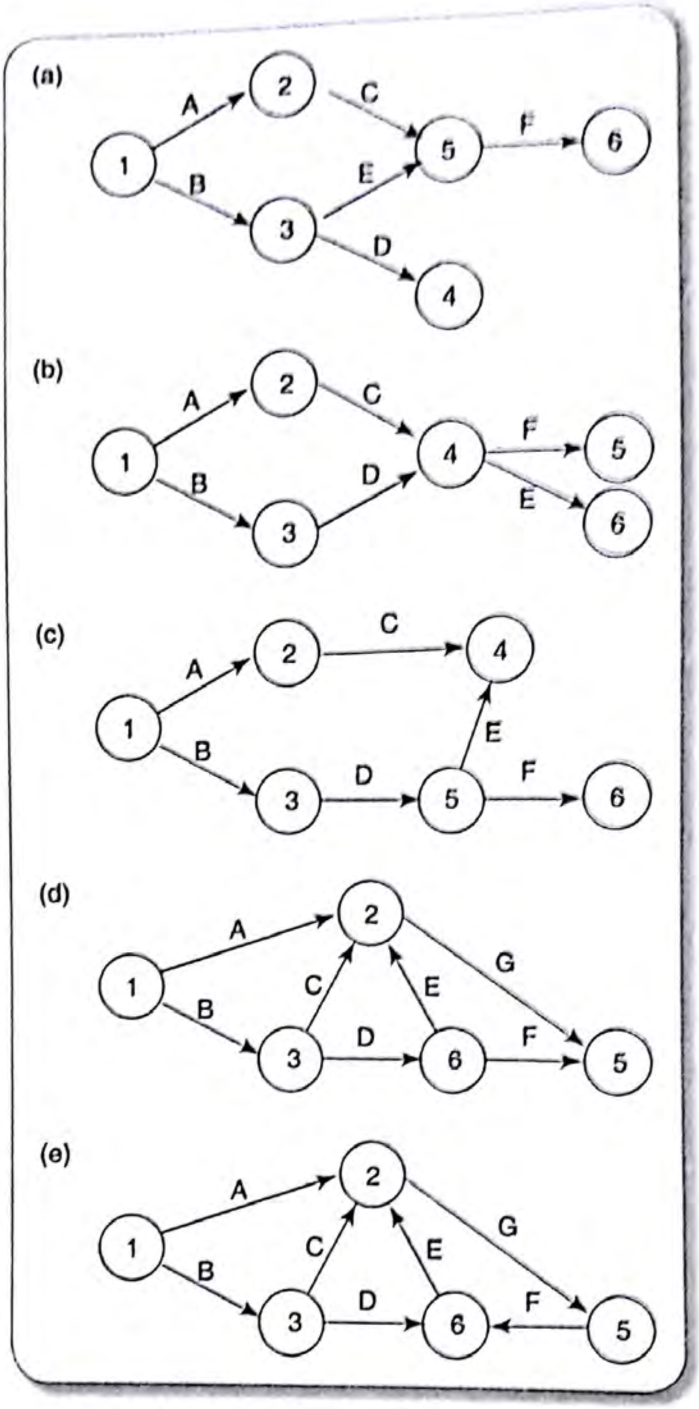


FIGURE 6.22 Some activity networks

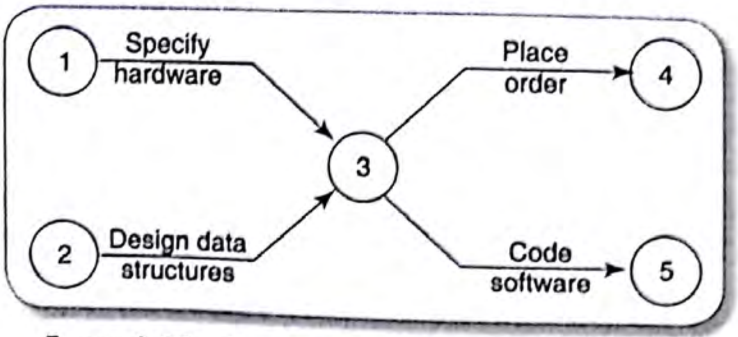


FIGURE 6.23 Two paths with a common node

Using dummy activities

When two paths within a network have a common event although they are, in other respects, independent, a logical error such as that illustrated in Figure 6.23 might occur.

Suppose that, in a particular project, it is necessary to specify a certain piece of hardware before placing an order for it and before coding the software. Before coding the software it is also necessary to specify the appropriate data structures, although clearly we do not need to wait for this to be done before the hardware is ordered.

Figure 6.23 is an attempt to model the situation described above, although it is incorrect in that it requires both hardware specification and data structure design to be completed before either an order may be placed or software coding may commence.

We can resolve this problem by separating the two (more or less) independent paths and introducing a dummy activity to link the completion of 'specify hardware' to the start of the activity 'code software'. This effectively breaks the link between data structure design and placing the order and is shown in Figure 6.24.

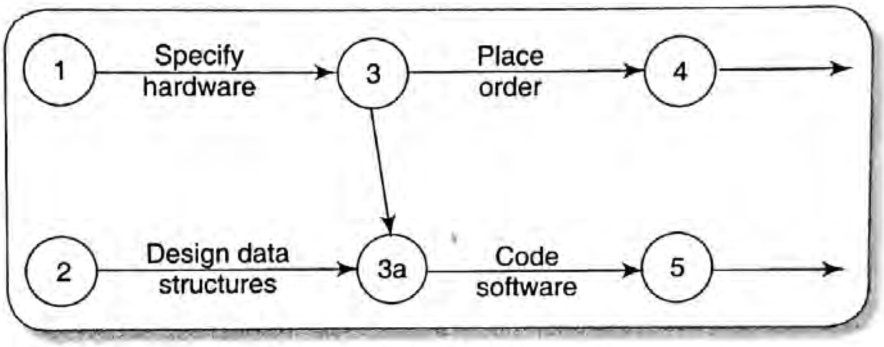


FIGURE 6.24 Two paths linked by a dummy activity

Dummy activities, shown as dotted lines on the network diagram, have a zero duration and use no resources. They are often used to aid in the layout of network drawings as in Figure 6.25. The use of a dummy activity where two activities share the same start and end nodes makes it easier to distinguish the activity end-points.

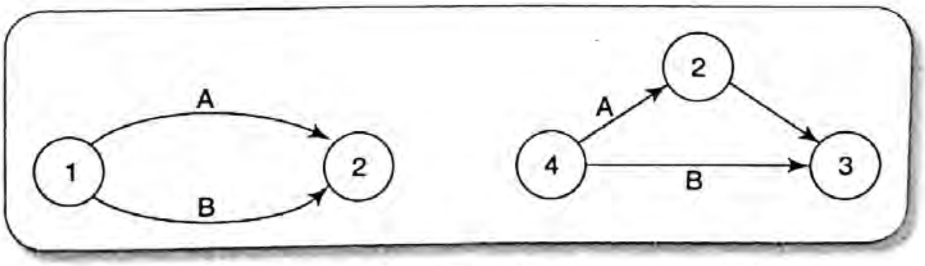


FIGURE 6.25 Another use of a dummy activity

These are problems that do not occur with activity-on-node networks.

Exercise 6.6

Take another look at Brigette's college payroll activity network fragment, which related to the earlier software selection process and which you developed in Exercise 3.4 (or take a look at the model answer in Figure B.2). Redraw this as an activity-on-arrow network.

Representing lagged activities

Activity-on-arrow networks are less elegant when it comes to representing lagged parallel activities. We need to represent these with pairs of dummy activities as shown in Figure 6.26. Where the activities are lagged because a stage in one activity must be completed before the other may proceed, it is likely to be better to show each stage as a separate activity.

Where parallel activities have a time lag we may show this as a 'ladder' of activities: documentation may proceed alongside prototype testing so long as it starts at least a day later and will finish two days after the completion of prototype testing.

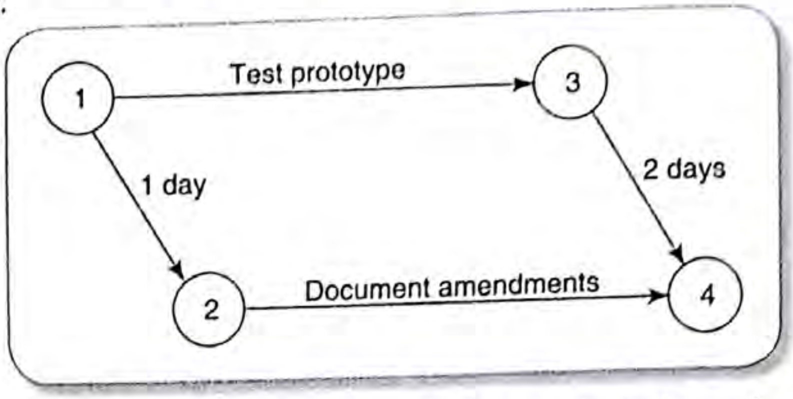
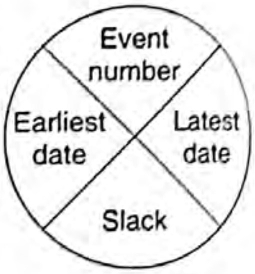


FIGURE 6.26 Using the ladder technique to indicate lags

Activity labelling



There are a number of differing conventions that have been adopted for entering information on an activity-on-arrow network. Typically the diagram is used to record information about the events rather than the activities – activity-based information (other than labels or descriptions) is generally held on a separate activity table.

One of the more common conventions for labelling nodes, and the one adopted here, is to divide the node circle into quadrants and use those quadrants to show the event number, the latest and earliest dates by which the event should occur, and the event slack (which will be explained later).

Network analysis

During the forward pass, earliest dates are recorded as they are calculated. For events, they are recorded on the network diagram and for activities they are recorded on the activity table.

The forward pass rule: the earliest date for an event is the earliest finish date for all the activities terminating at that event. Where more than one activity terminates at a common event we take the latest of the earliest finish dates for those activities.

Analysis proceeds in the same way as with activity-on-node networks, although the discussion places emphasis on the events rather than activity start and completion times.

The forward pass The forward pass is carried out to calculate the earliest date on which each event may be achieved and the earliest dates on which each activity may be started and completed. The earliest date for an event is the earliest date by which all activities upon which it depends can be completed. Using Figure 6.18 and Table 6.1, the calculation proceeds according to the following reasoning.

- Activities A, B and F may start immediately, so the earliest date for event 1 is zero and the earliest start date for these three activities is also zero.
- Activity A will take 6 weeks, so the earliest it can finish is week 6 (recorded in the activity table). Therefore the earliest we can achieve event 2 is week 6.
- Activity B will take 4 weeks, so the earliest it can finish and the earliest we can achieve event 3 is week 4.

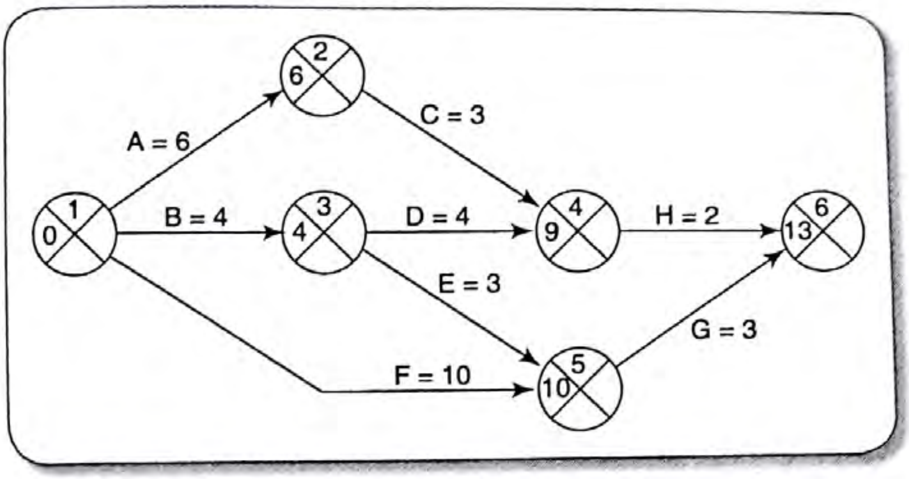


FIGURE 6.27 A CPM network after the forward pass

- Activity F will take 10 weeks, so the earliest it can finish is week 10 – we cannot, however, tell whether or not this is also the earliest date that we can achieve event 5 since we have not, as yet, calculated when activity E will finish.
- Activity E can start as early as week 4 (the earliest date for event 3) and, since it is forecasted to take 3 weeks, will be completed, at the earliest, at the end of week 7.
- Event 5 may be achieved when both E and F have been completed, that is, week 10 (the later of 7 and 10).
- Similarly, we can reason that event 4 will have an earliest date of week 9. This is the later of the earliest finish for activity D (week 8) and the earliest finish for activity C (week 9).
- The earliest date for the completion of the project, event 6, is therefore the end of week 13 – the later of 11 (the earliest finish for H) and 13 (the earliest finish for G).

The results of the forward pass are shown in Figure 6.27 and Table 6.3.

TABLE 6.3 Activity table after the forward pass

Activity	Duration (weeks)	Earliest start date	Latest start date	Earliest finish date	Latest finish date	Total float
A	6	0		6		
B	4	0		4		
C	3	6		9		
D	4	4		8		
E	3	4		7		
F	10	0		10		
G	3	10		13		
H	2	9		11		

The backward pass rule: the latest date for an event is the latest start date for all the activities that may commence from that event. Where more than one activity commences at a common event we take the earliest of the latest start dates for those activities.

The backward pass The second stage is to carry out a backward pass to calculate the latest date at which each event may be achieved, and each activity started and finished, without delaying the end date of the project. The latest date for an event is the latest date by which all immediately following activities must be started for the project to be completed on time. As with activity-on-node networks, we assume that the latest finish date for the project is the same as the earliest finish date – that is, we wish to complete the project as early as possible.

Figure 6.28 illustrates our network and Table 6.4 the activity table after carrying out the backward pass – as with the forward pass, event dates are recorded on the diagram and activity dates on the activity table.

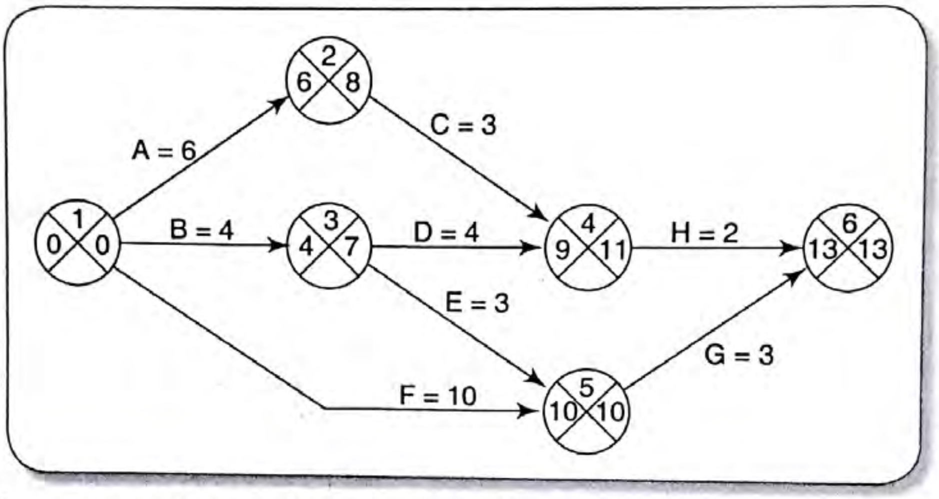
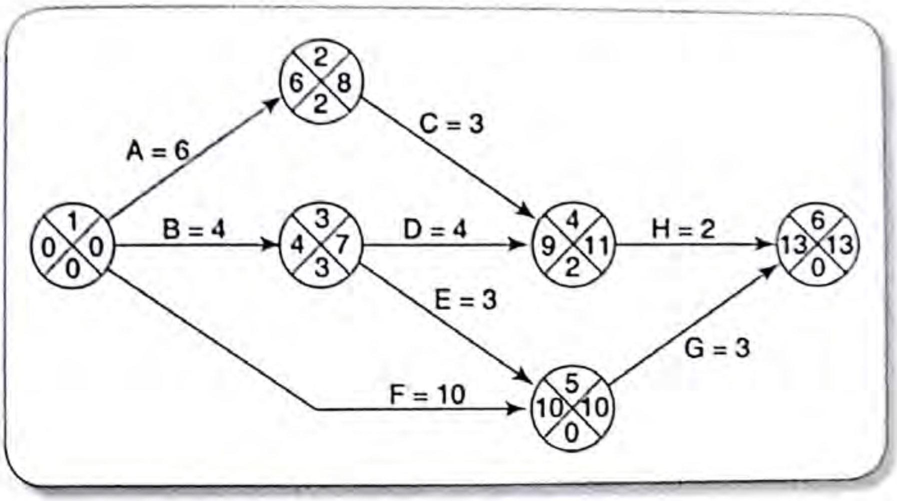


FIGURE 6.28 CPM network after the backward pass

TABLE 6.4 Activity table following the backward pass

Activity	Duration (weeks)	Earliest start date	Latest start date	Earliest finish date	Latest finish date	Total float
A	6	0	2	6	8	
B	4	0	3	4	7	
C	3	6	8	9	11	
D	4	4	7	8	11	
E	3	4	7	7	10	
F	10	0	0	10	10	
G	3	10	10	13	13	
H	2	9	11	11	13	

Identifying the critical path The critical path is identified in a way similar to that used in activity-on-node networks. We do, however, use a different concept, that of *slack*, in identifying the path. Slack is the difference between the earliest date and the latest date for an event – it is a measure of how late an event may be without affecting the end date of the project. The critical path is the path joining all nodes with a zero slack (Figure 6.29).



The critical path is the longest path through the network.

FIGURE 6.29 Critical path

Conclusion

In this chapter, we have discussed the use of the critical path method and precedence networks to obtain an ideal activity plan. This plan tells us the order in which we should execute activities and the earliest and latest we can start and finish them.

These techniques help us to identify which activities are critical to meeting a target completion date.

In order to manage the project we need to turn the activity plan into a schedule that will specify precisely when each activity is scheduled to start and finish. Before we can do this, we must consider what resources will be required and whether or not they will be available at appropriate times. As we shall see, the allocation of resources to an activity may be affected by how we view the importance of the task and the risks associated with it. In the next two chapters we look at these aspects of project planning before we consider how we might publish a schedule for the project.

Further Exercises

1. Draw an activity network using either activity-on-node or activity-on-arrow network conventions for each of the following projects:
   - Redecorating a room
   - Choosing and purchasing a desktop computer
   - Organizing and carrying out a survey of users' opinions of an information system
2. If you have access to a project planning application, use it to produce a project plan for the IOE annual maintenance contracts project. Base your plan on that used for Exercise 6.2 and verify that your application reports the same information as you calculated manually when you did the exercise.

3. Based on your answer to Exercise 6.2, discuss what options Amanda might consider if she found it necessary to complete the project earlier than day 104.
4. Create a precedence activity network using the following details:

Activity	Depends on	Duration (days)
A		5
B	A	7
C	B	6
D	A	5
E	D	10
F	B	15
G	B	8
H	G	8
I	C	4
J	G	4
K	E, F	5
L	I, H	3

5. Calculate the earliest and latest start and end dates and the float associated with each activity in the network you have created for further exercise 4 above. From this identify the critical path.
6. Draw up a precedence activity network for the following scenario: The specification of an ICT application is estimated as likely to take two weeks to complete. When this activity has been completed, work can start on three software modules, A, B and C. Design/coding of the modules will need 5, 10 and 10 days respectively. Modules A and B can only be unit-tested together as their functionality is closely associated. This joint testing should take about two weeks. Module C will need eight days of unit testing. When all unit testing has been completed, integrated system testing will be needed, taking a further three weeks. This testing will be based on the functionality described in the specification and will need 10 days of planning.
7. For the activity network in further exercise 6 above, derive the earliest and latest start dates for each activity and the earliest and latest finish dates. Work out the shortest project duration. If only two software developers were available for the design and coding of modules, what effect would this have on the project duration?
8. What are the limitations of the precedence and CPM activity network notations?
9. Consider a software project with five tasks T1–T5. Duration of the five tasks in weeks is 3, 2, 3, 5, and 2 respectively. T2 and T4 can start when T1 is complete. T3 can start when T2 is complete. T5 can start when both T3 and T4 are complete. Draw the CPM network representation of the project. When is the latest start date of the task T3? What is the float time of the task T4? Which tasks are on the critical path?

10. Consider a software project with five tasks that are denoted by T1, T2, T3, T4 and T5. Duration of these five tasks (in days) are 15, 10, 12, 25 and 10, respectively. T2 and T4 can start when T1 is complete. T3 can start when T2 is complete. T5 can start when both T3 and T4 are complete. What will be the latest start date of the task T3? What is the slack time of the task T4?

11. Why is it necessary for a project manager to decompose the tasks of a project using Work breakdown structure (WBS) into finer level tasks before constructing the task schedule? To what granularity level should the tasks be decomposed? Explain your answer.

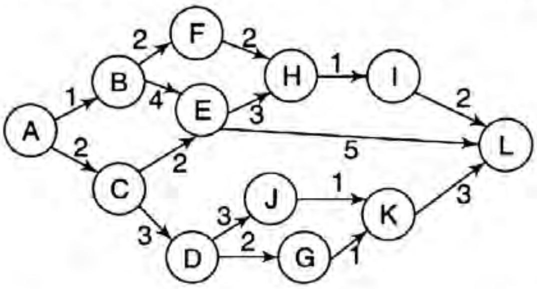
12. For each of the following questions, exactly one option is correct. Select the appropriate option.

    (i) Which one of the following charts would be the most useful to decompose the project activities into smaller tasks that are more meaningfully managed?

    (a) PERT chart (b) GANTT chart

    (c) Task network representation (d) Work breakdown structure

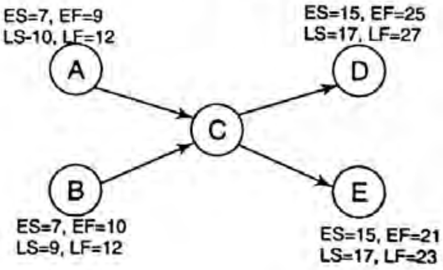
    (ii) Which one of the following is the critical path for the activity network given below?



    (a) A, B, F, H, G, I and L (b) A, B,F,H,I and L

    (c) A, C, D, J, K and L (d) A, C,D,G,K and L

    (iii) Consider a portion of the network diagram given below. What is the LF of activity F?



    (a) 10 (b) 11

    (c) 16 (d) 17

    (iv) In a PERT chart, in which one of the following situations is a dummy activity required?

    (a) In the PERT chart, two or more activities have the same ending events.

    (b) The PERT chart contains two or more activities that have identical starting and ending events.

    (c) In the PERT chart, two or more activities have different ending events.

    (d) In the PERT chart, two or more activities have the same starting events

(v) Using the data in the following table, what is the total project duration?

Activity	Duration	Predecessors
A	14	–
B	13	A
C	20	A
D	10	B,C

(a) 20 (b) 27

(c) 37 (d) 44

(vi) PERT method differs from CPM in which one of the following aspects?

(a) PERT uses statistical time durations whereas CPM uses deterministic time durations.

(b) PERT uses dummy activities whereas CPM does not.

(c) PERT uses free float, whereas CPM uses total float in critical path calculations.

(d) PERT uses activity on arc whereas CPM uses activity on node networks.

(vii) Which one of the following is true of a critical path in a PERT chart?

(a) It is the path having maximum number of tasks.

(b) It is the shortest path in terms of time.

(c) It is the longest path in terms of time.

(d) It is the path with the largest amount of slack time.

(viii) Which one of the following statements regarding critical paths in a PERT chart is true?

(a) A critical path through a PERT chart is any path through the chart that contains the least number of edges.

(b) Some activities on the critical path can have slack.

(c) Every PERT chart has exactly one critical path.

(d) It is possible that in the PERT chart for a project, there can be multiple critical paths, all having exactly the same duration.

(ix) In a PERT chart, an activity has an early start (ES) of 3 days, a late start (LS) of 13 days, an early finish (EF) of 16 days and a late finish (LF) of 26 days. Which one of the following can be inferred regarding this activity?

(a) It is on the critical path. (b) It is not progressing well.

(c) It is progressing well. (d) It is not on the critical path.

(x) Suppose you have estimated the nominal duration of your project to be 4 months and you have planned to complete the work by deploying three developers. However, the customer requests you to complete the work in 3 months. In this case, what will be the man-power requirement as per Putnam's results?

(a) 6 (b) 8

(c) 10 (d) 20

Answer questions (xi) and (xii) for a project whose activities, their precedence ordering, estimated time for completion are given in the following table.

Activity	Immediate follower	Estimated time in weeks
A	E, B	3
B	C, F	2
C	D, G	8
D	F	4
E	F	5
F	—	10
G	—	10

(xi) Which one of the following sequence of activities is on the critical path?

(a) A-E-F (b) A-B-C-G

(c) A-B-C-D-F (d) A-B-F

(xii) Which one of the following paths has the greatest slack time?

(e) A-E-F (f) A-B-C-G

(g) A-B-C-D-F (h) A-B-F

7 Risk Management

Learning Objectives

- Identify the factors putting a project at risk
- Categorize and prioritize actions for risk elimination or containment
- Quantify the likely effects of risk on project timescales

7.1 Introduction

In Chapter 6 we saw how, at IOE, Amanda planned how the software for the new annual maintenance contracts application was to be produced. This included estimating how long each task would take – see Figure 6.7 and Table 6.2. Her plan was based on the assumption that three experienced programmers were available for the coding of modules A, B, C and D. However, suppose two developers then left for better-paid jobs, and so far only one replacement has been recruited, who happens to be a trainee.

In some work environments 'problems' in this context are referred to as 'issues'.

In the case of Brigette and the Brightmouth payroll implementation project, imagine that a payroll package has been purchased. However, a new requirement emerges that the payroll database should be accessed by a new application that calculates the staff costs for each course delivered by the college. Unfortunately, the purchased payroll application does not allow this access.

Amanda and Brigette will have to deal with these *problems* as part of the monitoring and control process that will be outlined in Chapter 9. In this chapter we consider whether the two project leaders could have foreseen that these problems were likely to occur and made plans to deal with them. In other words, could these problems have been identified as *risks*?

7.2 Risk

PM-BOK defines risk as '*an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives*'. PRINCE2, the UK government-sponsored project management standard, defines risk as '*the chance of exposure to the adverse consequences of future events*'. The two definitions differ, as the first includes situations where a future uncertainty actually works in our favour and presents us with an opportunity. We will return to this later in the chapter.

PM-BOK stands for Project Management Body of Knowledge, a project management standard published by the Project Management Institute in the USA.

The key elements of a risk follow.

- *It relates to the future* The future is inherently uncertain. Some things which seem obvious when a project is over, for example that the costs were underestimated or that a new technology was overly difficult to use, might not have been so obvious during planning.
- *It involves* ***cause*** *and* ***effect*** For example, a 'cost over-run' might be identified as a risk, but 'cost over-run' describes some damage, but does not say what causes it. Is it, for example, an inaccurate estimate of effort, the use of untrained staff, or a poor specification? Both the cause (or *hazard*), such as 'inexperienced staff', and a particular type of negative outcome, such as 'lower productivity', should be defined for each risk.

The ISPL risk model (formerly Euromethod) refers to hazards as 'situational factors'.

Exercise 7.1

Match the following causes – (a) to (d) – to their possible effects – (i) to (iv). The relationships are not necessarily one-to-one. Explain the reasons for each match.

Causes

(a) Staff inexperience

(b) Lack of top management commitment

(c) New technology

(d) Users uncertain of their requirements

Effects

(i) Testing takes longer than planned

(ii) Planned effort and time for activities exceeded

(iii) Project scope increases

(iv) Time delays in getting changes to plans agreed

The boundary between risk management and 'normal' software project management is hazy. For example, when we were selecting the best general approach to a project – see Chapter 4 – one consideration was the possible consequences of future adverse events. As will be seen in Chapter 13, most of the techniques used to assure the quality of software, such as reviews and testing, are designed to reduce the risk of faults in project deliverables. Risk management is not a self-contained topic within project management. The key role of risk management is considering uncertainty remaining after a plan has been formulated. Every plan is based on assumptions and risk management tries to plan for and control the situations where those assumptions become incorrect. Risk planning is carried out in Steps 3 and 6 (Figure 7.1).

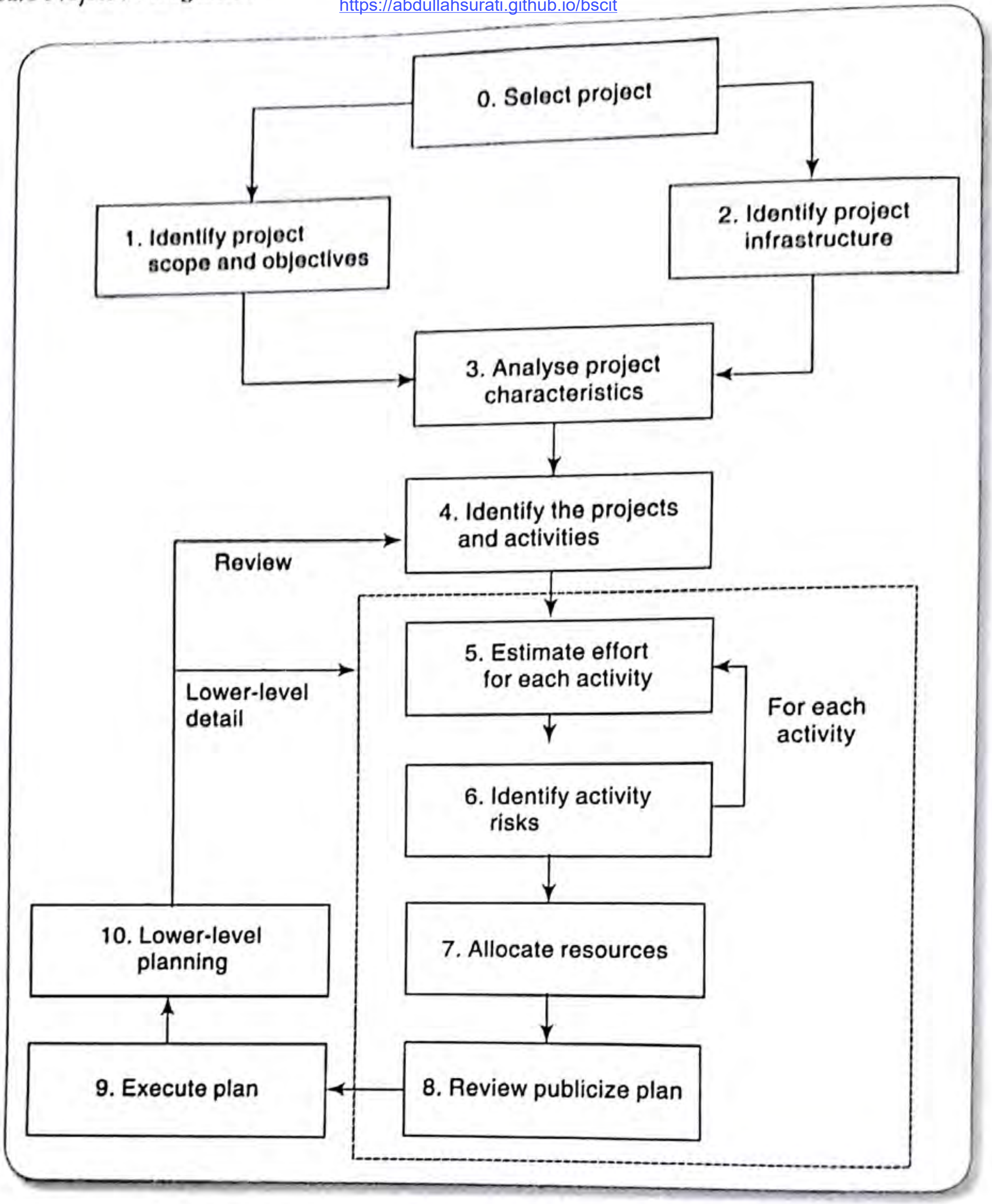

0. Select project
1. Identify project scope and objectives
2. Identify project infrastructure
3. Analyse project characteristics
4. Identify the projects and activities
Review
5. Estimate effort for each activity
Lower-level detail
For each activity
6. Identify activity risks
7. Allocate resources
10. Lower-level planning
9. Execute plan
8. Review publicize plan

FIGURE 7.1 Risk planning is carried out primarily in Steps 3 and 6

7.3 Categories of Risk

An ICT project manager is normally given the objective of installing the required application by a specified deadline and within an agreed budget. Other objectives might be set, especially with regard to quality requirements. *Project risks* are those that could prevent the achievement of the objectives given to the project manager and the project team.

As we noted in Chapter 2, there could be risks that an application after successful implementation is a business failure. Thus if an e-commerce site is established to sell a product, the site might be correctly implemented, but customers fail to use the site because of the uncompetitive prices demanded. Dealing with these *business risks* is likely to be outside the direct responsibilities of the application implementation team. However, the failure to meet any project objective could have a negative impact on the business case for the project. For example, an increase in development cost might mean that the income (or savings) generated by the delivered application no longer represents a good return on the increased investment.

Risks have been categorized in other ways. Kalle Lyytinen and his colleagues, for instance, have proposed a *sociotechnical model* of risk, a diagrammatic representation of which appears in Figure 7.2.

See K. Lyytinen, L. Mathiassen and J. Ropponen (1996) 'A framework for risk management' *Journal of Information Technology*, 11(4).

The box labelled '*Actors*' refers to all the people involved in the development of the application in question. A typical risk in this area is that high staff turnover leads to expertise of value to the project being lost.

In Figure 7.2, the box labelled '*Technology*' encompasses both the technology used to implement the application and that embedded in the delivered products. Risks here could relate to the appropriateness of the technologies and to possible faults within them, especially if they are novel.

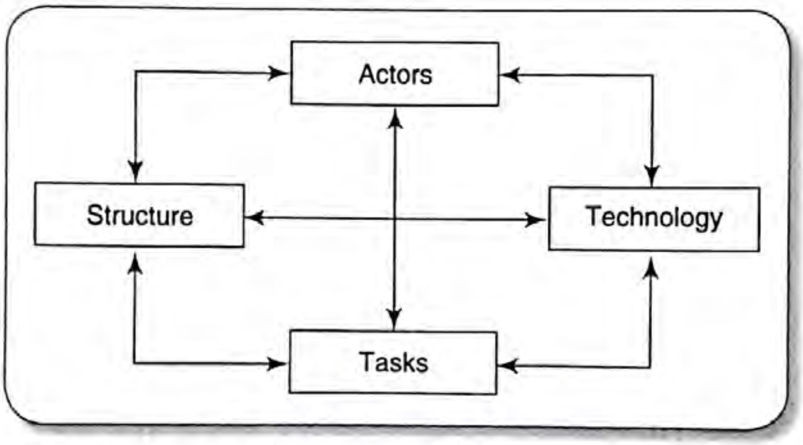


FIGURE 7.2 Lyytinen–Mathiassen–Ropponen risk framework

'*Structure*' describes the management structures and systems, including those affecting planning and control. For example, the implementation might need user participation in some tasks, but the responsibility for managing the users' contribution might not be clearly allocated.

'*Tasks*' relates to the work planned. For instance, the complexity of the work might lead to delays because of the additional time required integrate the large number of components.

In Figure 7.2 all boxes are interlinked. Risks often arise from the relationships between factors – for example between technology and people. If a development technology is novel then the developers might not be experienced in its use and delay results. The novelty of the new technology is really a characteristic of the developers: once they are used to the technology, it is no longer 'novel'.

Exercise 7.2

In the cases of the Brightmouth payroll implementation project and the IOE annual maintenance contracts development project, identify one risk for each of the four categories in Figure 7.2.

7.4 Risk Management Approaches

Risk management approaches can broadly be classified into reactive and proactive approaches. The latter approach is much more effective in risk handling and, therefore, used wherever possible. In the following, we briefly discuss these two approaches.

Reactive approaches

Reactive approaches take no action until an unfavourable event occurs. Once an unfavourable event occurs, these approaches try to contain the adverse effects associated with the risk and take steps to prevent future occurrence of the same risk events. An example of such a risk management strategy can be the following. Consider a project in which the server hosting the project data crashes. Once this risk event has occurred, the team members may put best effort to recover the data and also initiate the practice of taking regular backups, so that in future such a risk event does not recur. It is similar to calling the emergency fire-fighting service once a fire has been noticed, and then installing fire-fighting equipment in all the rooms of the building to be able to instantly handle fire the next time it is noticed. It can be seen that the main objective of this is to minimize the damage due to the risk and take steps to prevent future recurrence of the risk.

Proactive approaches

The proactive approaches try to anticipate the possible risks that the project is susceptible to. After identifying the possible risks, actions are taken to eliminate the risks. If a risk cannot be avoided, these approaches suggest making plans to contain the effect of the risk. For example, if man power turnover is anticipated (i.e. some personnel may leave the project), then thorough documentation may be planned. Also, more than one developer may work on a work item and also some stand-by man power may be planned. Obviously, proactive approaches incur lower cost and time overruns when risk events occur and, therefore, are much more preferred by teams. However, when some risks cannot be anticipated, a reactive approach is usually followed.

7.5 A Framework for Dealing with Risk

Planning for risk includes these steps:

(i) Risk identification

(ii) Risk analysis and prioritization

(iii) Risk planning

(iv) Risk monitoring

Steps (i) to (iii) above will probably be repeated. When risks that could prevent a project success are identified, plans can be made to reduce or remove their threat. The plans are then reassessed to ensure that the original risks are reduced sufficiently and no new risks inadvertently introduced. Take the risk that staff inexperience with a new technology could lead to delays in software development. To reduce this risk, consultants expert in the new technology might be recruited. However, the use of consultants might introduce the new risk that knowledge about the new technology is not transferred to the permanent staff, making subsequent software maintenance problematic. Having identified this new risk, further risk reduction activities can be planned.

7.6 Risk Identification

The two main approaches to the identification of risks are the use of *checklists* and *brainstorming*.

Checklists are simply lists of the risks that have been found to occur regularly in software development projects. A specialized list of software development risks by Barry Boehm appears in Table 7.1 in a modified version. Ideally a group of representative project stakeholders examines a checklist identifying risks applicable to their project. Often the checklist suggests potential countermeasures for each risk.

Table 7.1 Software project risks and strategies for risk reduction

Risk	Risk reduction techniques
Personnel shortfalls	Staffing with top talent; job matching; teambuilding; training and career development; early scheduling of key personnel
Unrealistic time and cost estimates	Multiple estimation techniques; design to cost; incremental development; recording and analysis of past projects; standardization of methods
Developing the wrong software functions	Improved software evaluation; formal specification methods; user surveys; prototyping; early user manuals
Developing the wrong user interface	Prototyping; task analysis; user involvement
Gold plating	Requirements scrubbing; prototyping; cost–benefit analysis; design to cost
Late changes to requirements	Stringent change control procedures; high change threshold; incremental development (deferring changes)
Shortfalls in externally supplied components	Benchmarking; inspections; formal specifications; contractual agreements; quality assurance procedures and certification
Shortfalls in externally performed tasks	Quality assurance procedures; competitive design or prototyping; contract incentives
Real-time performance shortfalls	Simulation; benchmarking; prototyping; tuning; technical analysis
Development technically too difficult	Technical analysis; cost–benefit analysis; prototyping; staff training and development

This top ten list of software risks is based on one presented by Barry Boehm in his *Tutorial on Software Risk Management*, IEE Computer Society, 1989.

Project management methodologies, such PRINCE2, often recommend that on completion of a project a review identifies any problems during the project and the steps that were (or should have been) taken to resolve or avoid them. These problems could in some cases be added to an organizational risk checklist for use with new projects.

The 'lessons learnt' report differs from a 'post implementation review' (PIR). It is written on project completion and focuses on project issues. A PIR, produced when the application has been operational for some time, focuses on business benefits.

Brainstorming

Ideally, representatives of the main stakeholders should be brought together once some kind of preliminary plan has been drafted. They then identify, using their individual knowledge of different parts of the project, the problems that might occur. This collaborative approach may generate a sense of ownership in the project.

'Brainstorming' is also mentioned in Chapter 13 in connection with quality circles.

Brainstorming might be used with Brigette's Brightmouth payroll implementation project as she realizes that there are aspects of college administration of which she is unaware. She therefore suggests to the main stakeholders in the project, who include staff from the finance office and the personnel office, that they meet and discuss where the risks facing the project lie.

7.7 Risk Assessment

A common problem with risk identification is that a list of risks is potentially endless. A way is needed of distinguishing the damaging and likely risks. This can be done by estimating the *risk exposure* for each risk using the formula:

$$risk\ exposure = (potential\ damage) \times (probability\ of\ occurrence)$$

Using the most rigorous – but not necessarily the most practical – approach, the potential damage would be assessed as a money value. Say a project depended on a data centre vulnerable to fire. It might be estimated that if a fire occurred a new computer configuration could be established for £500,000. It might also be estimated that where the computer is located there is a 1 in 1000 chance of a fire actually happening, that is a probability of 0.001.

The risk exposure in this case would be:

$$£500{,}000 \times 0.001 = £500$$

A crude way of understanding this value is as the minimum sum an insurance company would require as a premium. If 1000 companies, all in the same position, each contributed £500 to a fund then, when the 1 in 1000 chance of the fire actually occurred, there would be enough money to cover the cost of recovery.

Exercise 7.3

What conditions would have to exist for the risk pooling arrangement described above to work?

The calculation of risk exposure above assumes that the amount of damage sustained will always be the same. However, it is usually the case that there could be varying amounts of damage. For example, as software development proceeds, more software is created, and more time would be needed to re-create it if it were lost.

With some risks, there could be not only damage but also gains. The testing of a software component is scheduled to take six days, but is actually done in three days. A team leader might therefore feel justified in producing a probability chart like the one in Figure 7.3. This shows the probability of a task being completed in four days (5%), then five days (10%), and so on. The accumulated probability for the seventh day (65%) means that there is a 65% chance that the task will be finished on or before the seventh day.

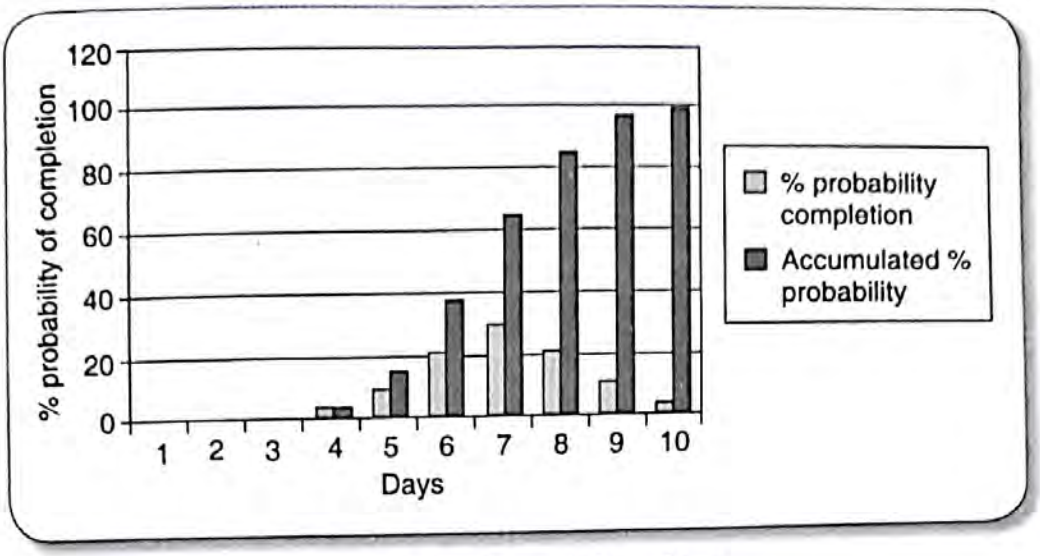


FIGURE 7.3 Probability chart

Clients would almost certainly insist we pick one of the days as the target. This target could be 'aggressive', for instance only five days in the above scenario, but with an 85% chance of failure according to the chart. A safer estimate would be eight days which would have a probability of failure of only 15%. We will return to this point later on in this chapter.

In Figure 7.3 the 'loss' is effectively being measured in days rather than money. In this context, days, or some other unit of personal effort, is often used as a *surrogate* for a financial loss.

Most managers resist very precise estimates of loss or of the probability of something occurring, as such figures are usually guesses. Barry Boehm has suggested that, because of this, both the risk losses and the probabilities be assessed using relative scales in the range 0 to 10. The two figures could then be multiplied together to get a notional risk exposure. Table 7.2 provides an example, based on Amanda's IOE group accounts project, of where this has been done. This value could be used to prioritize the importance of risks, although more sophisticated risk calculations are not possible.

TABLE 7.2 Part of Amanda's risk exposure assessment

Ref	Hazard	Likelihood	Impact	Risk
R1	Changes to requirements specification during coding	8	8	64
R2	Specification takes longer than expected	3	7	21
R3	Significant staff sickness affecting critical path activities	5	7	35
R4	Significant staff sickness affecting non-critical activities	10	3	30
R5	Module coding takes longer than expected	4	5	20
R6	Module testing demonstrates errors or deficiencies in design	4	8	32

Boehm suggests that planners focus attention on the 10 risks with the highest risk exposure scores. For smaller projects – including the final-year projects of computing students – the focus could be on a smaller number of risks.

Even using indicative numbers in the range 0 to 10, rather than precise money values and probabilities, is not completely satisfactory. The values are likely to be subjective, and different analysts might pick different numbers. Another approach is to use qualitative descriptions of the possible impact and the likelihood of each risk – see Tables 7.3 and 7.4 for examples. Consistency between assessors is facilitated by associating each qualitative description with a range of values.

See P. Goodwin and G. Wright (2004) *Decision Analysis for Management Judgement*, Wiley, for further discussion of this issue.

Table 7.3 Qualitative descriptors of risk probability and associated range values

Probability level	Range
High	Greater than 50% chance of happening
Significant	30–50% chance of happening
Moderate	10–29% chance of happening
Low	Less than 10% chance of happening

Table 7.4 Qualitative descriptors of impact on cost and associated range values

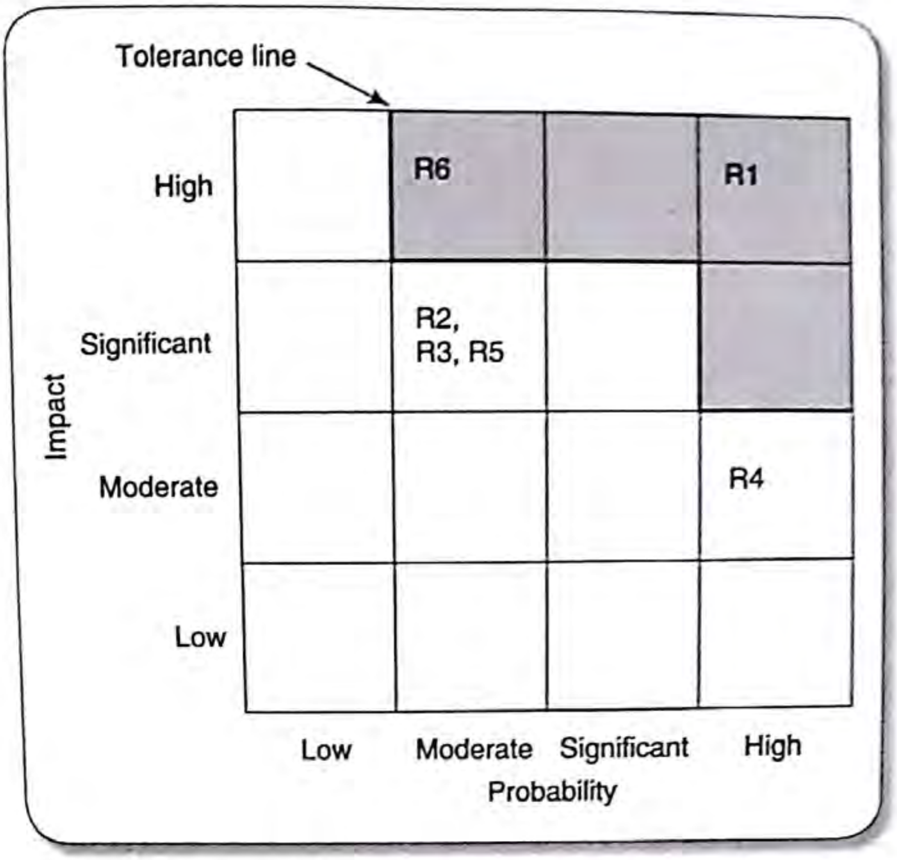
Impact level	Range
High	More than 30% above budgeted expenditure
Significant	20 to 29% above budgeted expenditure
Moderate	10 to 19% above budgeted expenditure
Low	Within 10% of budgeted expenditure.

In Table 7.4, the potential amount of damage has been categorized in terms of its impact on *project costs*. Other tables could show the impact of risks on *project duration* or on the *quality of the project deliverables*.

To some extent, the project manager, in conjunction with the project sponsor, can choose whether the damage inflicted by a risk affects cost, duration or the quality of deliverables. In Amanda's list of risks in Table 7.2, R5 refers to the coding of modules taking longer than planned. This would have an impact on both the duration of the project and the costs, as more staff time would be needed. A response might be adding software developers and splitting the remaining development work between them. This will increase costs, but could save the planned completion date. Another option is to save both duration and staff costs by reducing software testing before the software is released. This is likely to be at the price of decreased quality in the project deliverable.

Where the potential damage and likelihood of a risk are defined by qualitative descriptors, the risk exposure cannot be calculated by multiplying the two factors together. In this case, the risk exposure is indicated by the position of the risk in a matrix – see Figure 7.4. These matrices have variously been called *probability impact grids* or *summary risk profiles*.

In Figure 7.4, some of the cells in the top right of the matrix have been zoned off by a *tolerance line*. Risks that appear within this zone have a degree of seriousness that calls for particular attention.



Impact	Low	Moderate	Significant	High
High		R6		R1
Significant		R2, R3, R5		
Moderate				R4
Low				

FIGURE 7.4 Probability impact matrix

Chapter 5 stressed the need for frequent reassessment of effort and duration estimates during a project. This applies to risk exposure as well, as some risks apply only at certain stages. A risk might be that key users are unavailable when needed to supply details of their requirements. As requirements are gathered, so this risk will diminish until it is no longer significant. In general, the element of uncertainty will lessen as a project progresses and more is learnt by the developers about user requirements and any new technology. This would be reflected in lower risk probabilities. On the other hand, the potential damage will tend to increase as the amount invested in the project grows. If you type a substantial report using a word processor and neglect to take back-ups, as each day adds more text to the report, it also adds to the number of days needed to re-key the report in the event of file loss.

The term *risk proximity* is used to describe this attribute of risk.

7.8 Risk Planning

Having identified the major risks and allocated priorities, the task is to decide how to deal with them. The choices discussed will be:

- Risk acceptance
- Risk avoidance
- Risk reduction and mitigation
- Risk transfer

Risk acceptance

This is the do-nothing option. We will already, in the risk prioritization process, have decided to ignore some risks in order to concentrate on the more likely or damaging. We could decide that the damage inflicted by some risks would be less than the costs of action that might reduce the probability of a risk happening.

Risk avoidance

Some activities may be so prone to accident that it is best to avoid them altogether. If you are worried about sharks then don't go into the water. For example, given all the problems with developing software solutions from scratch, managers might decide to retain existing clerical methods, or to buy an off-the-shelf solution.

Risk reduction

It must be appreciated that each risk reduction action is likely to involve some cost. This is discussed in the next section.

Here we decide to go ahead with a course of action despite the risks, but take precautions that reduce the probability of the risk.

This chapter started with a scenario where two of the staff scheduled to work on Amanda's development project at IOE departed for other jobs. If this has been identified as a risk, steps might have been taken to reduce possible departures of staff. For instance, the developers might have been promised generous bonuses to be paid on successful completion of the project.

Recall that Brigette had a problem at Brightmouth College: after the purchase of the payroll package, a requirement for the payroll database to be accessed by another application was identified. Unfortunately, the application that had been bought did not allow such access. An alternative scenario might have been that Brigette identified this as a possible risk early on in the project. She might have come across Richard Fairley's four COTS (commercial off-the-shelf) software acquisition risks – see Table 7.5 – where one risk is difficulty in integrating the data formats and communication protocols of different applications. Brigette might have specified that the selected package must use a widely accepted data management system like Oracle that allows easier integration.

Table 7.5 Fairley's four commercial off-the-shelf (COTS) software acquisition risks

Integration	Difficulties in integrating the data formats and communication protocols of different applications.
Upgrading	When the supplier upgrades the package, the package might no longer meet the users' precise requirements. Sticking with the old version could mean losing the supplier's support for the package.
No source code	If you want to enhance the system, you might not be able to do so as you do not have access to the source code.
Supplier failures or buyouts	The supplier of the application might go out of business or be bought out by a rival supplier.

See R. Fairley (1994) 'Risk management for software projects' *IEEE Software* 11(3) 57–67.

Risk mitigation can sometimes be distinguished from risk reduction. *Risk reduction* attempts to reduce the likelihood of the risk occurring. *Risk mitigation* is action taken to ensure that the impact of the risk is lessened when it occurs. For example, taking regular back-ups of data storage would reduce the impact of data corruption but not its likelihood. Mitigation is closely associated with contingency planning which is discussed presently.

Risk transfer

In this case the risk is transferred to another person or organization. With software projects, an example of this would be where a software development task is outsourced to an outside agency for a fixed fee. You might expect the supplier to quote a higher figure to cover the risk that the project takes longer than the 'average' expected time. On the other hand, a well-established external organization might have productivity advantages as its developers are experienced in the type of development to be carried out. The need to compete with other software development specialists would also tend to drive prices down.

Risk transfer is what effectively happens when you buy insurance.

7.9 Risk Management

Contingency

Risk reduction activities would appear to have only a small impact on reducing the probability of some risks, for example staff absence through illness. While some employers encourage their employees to adopt a healthy lifestyle, it remains likely that some project team members will at some point be brought down by minor illnesses such as flu. These kinds of risk need a *contingency plan*. This is a planned action to be carried out if the particular risk materializes. If a team member involved in urgent work were ill then the project manager might draft in another member of staff to cover that work.

The preventative measures that were discussed under the 'Risk reduction' heading above will usually incur some cost regardless of the risk materializing or not. The cost of a contingency measure will only be incurred if the risk actually materializes. However, there may be some things that have to be done in order for the contingency action to be feasible. An obvious example is that back-ups of a database have to be taken if the contingency action when the database is corrupted is to restore it from back-ups. There would be a cost associated with taking the back-ups.

Exercise 7.4

In the case above where staff could be absent through illness, what preconditions could facilitate contingency actions such as getting other team members to cover on urgent tasks? What factors would you consider in deciding whether these preparatory measures would be worthwhile?

Deciding on the risk actions

Five generic responses to a risk have been discussed above. For each actual risk, however, specific actions have to be planned. In many cases experts have produced lists recommending practical steps to cope with the likelihood of particular risks; see, for example, Boehm's 'top ten' software engineering risks in Table 7.1.

Whatever the countermeasures that are considered, they must be cost-effective. On those occasions where a risk exposure value can be calculated as a financial value using the (*value of damage*) × (*probability of occurrence*) formula – recall Section 7.7 – the cost-effectiveness of a risk reduction action can be assessed by calculating the *risk reduction leverage* (*RRL*).

$$\textit{risk reduction leverage} = (RE_{before} - RE_{after})/(\textit{cost of risk reduction})$$

RE_{before} is the risk exposure, as explained in Section 7.7, before risk reduction actions have been taken. RE_{after} is the risk exposure after taking the risk reduction action. An RRL above 1.00 indicates that the reduction in risk exposure achieved by a measure is greater than its cost. To take a rather unrealistic example, it might cost £200,000 to replace a hardware configuration used to develop a software application. There is a 1% chance of a fire (because of the particular location of the installation, say). The risk exposure would be 1% of £200,000, that is £2,000. Installing fire alarms at a cost of £500 would reduce the chance of fire to 0.5%. The new risk exposure would be £1,000, a reduction of £1,000 on the previous exposure. The RRL would be (2000 – 1000)/500, that is 2.0, and the action would therefore be deemed worthwhile.

Earlier in this chapter, we likened risk exposure to the amount you might pay to an insurance company to cover a risk. To continue the analogy, an insurance company in the above example might be willing to reduce the premium you pay to have cover against fire from £2,000 to £1,000 if you installed fire alarms. As the fire alarms would cost you only £500 and save £1,000, the cost would clearly be worthwhile.

Exercise 7.5

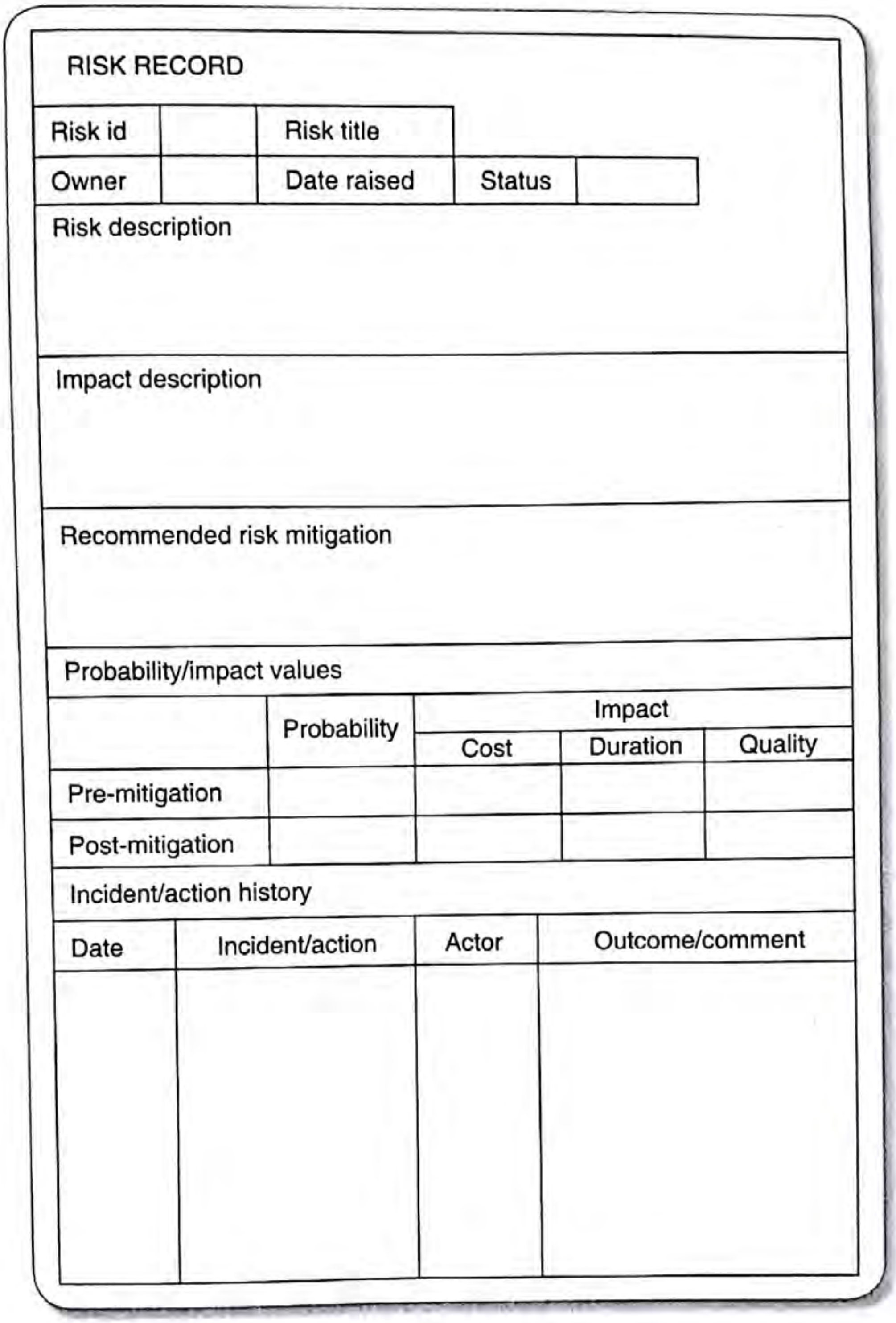
Assume that the likelihood of one of your valuable team members leaving the project midway is 0.5. In case the member actually leaves, there is a 25% chance that the project would miss the delivery date. You consider the customer's consequent displeasure to be equivalent to £50,000 in monetary terms. To counter the risk, you can recruit a fresh engineer at a salary of £2000 per month for six months, to essentially act as a back-up for the valuable team member. Also, assume that the contribution of the back-up engineer to the project, if the regular engineer does not leave, would be 0.2 of the employment duration. After employing the back-up engineer, the probability of missing the project deadline is expected to be only about 10%. Would it be a good idea to employ the back-up engineer?

Creating and maintaining the risk register

When the project planners have picked out and examined what appear to be the most threatening risks to the project, they need to record their findings in a *risk register*. The typical content of such a register is shown in Figure 7.5. After work starts on the project more risks will emerge and be added to the register. At regular intervals, probably as part of the project control life cycle described in Chapter 9, the risk register should be reviewed and amended. Many risks threaten just one or two activities, and when the project staff have completed these the risk can then be 'closed' as no longer relevant. In any case, as noted earlier, the probability and impact of a risk are likely to change during the course of the project.

7.10 Evaluating Risks to the Schedule

In Section 7.7, we showed a probability chart – Figure 7.3. This illustrated the point that a forecast of the time needed to do a job is most realistically presented as a graph of likelihood of a range of figures, with the most



RISK RECORD

Risk id		Risk title			
Owner		Date raised		Status	

Risk description

Impact description

Recommended risk mitigation

Probability/impact values

	Probability	Impact		
		Cost	Duration	Quality
Pre-mitigation				
Post-mitigation				

Incident/action history

Date	Incident/action	Actor	Outcome/comment

FIGURE 7.5 Risk register page

likely duration as the peak and the chances of the job taking longer or shorter shown as curves sloping down on either side of the peak. Thus we can show that a job might take five days but that there is a small chance it might need four or six days, and a smaller chance of three or seven days, and so on. If a task in a project takes longer than planned, we might hope that some other task might take less and thus compensate for this delay. In the following sections we will examine PERT, a technique which takes account of the uncertainties in the durations of activities within a project. We will also touch upon Monte Carlo simulation, which is a more powerful and flexible tool that tackles the same problem.

A drawback to the application of methods like PERT is that in practice there is a tendency for developers to work to the schedule even if a task could be completed more quickly. Even if tasks are completed earlier than planned, project managers are not always quick to exploit the opportunities to start subsequent activities earlier than scheduled. Critical chain management will be explored as a way of tackling this problem.

7.11 Boehm's Top 10 Risks and Counter Measures

Boehm has identified the top 10 risks that a typical project suffers from and has recommended a set of countermeasures for each. We briefly review these in the following.

Barry W. Boehm, 'Software Risk Management: Principles and Practices,' *IEEE Software*, Volume 8, Issue 1, January 1991.

1. **Personnel shortfall:** This risk concerns shortfall of project personnel. The shortfall may show up as either project personnel may lack some specific competence required for the project tasks or personnel leaving the project (called manpower turnover) before project completion. The countermeasures suggested include staffing with top talent, job matching, team building, and cross-training of personnel.
2. **Unrealistic schedules and budgets:** The suggested counter measures include the project manager working out the detailed milestones and making cost and schedule estimations based on it. Other counter measures are incremental development, software reuse, and requirements scrubbing. It may be mentioned that requirements scrubbing involves removing the overly complex and unimportant requirements, in consultation with the customers.
3. **Developing the wrong functions:** The suggested countermeasures include user surveys and user participation, developing prototypes and eliciting user feedback, and early production users' manuals and getting user feedback on it.
4. **Developing the wrong user interface:** The countermeasures suggested for this risk include prototyping, scenarios and task analysis, and user participation.
5. **Gold-plating:** Gold-plating as discussed in Chapter 1, concerns development of features that the team members consider nice to have and, therefore, decide to develop those even though the customer has not expressed any necessity for those. The countermeasures suggested for this risk includes requirements scrubbing, prototyping and cost-benefit analysis.
6. **Continuing stream of requirements changes:** The countermeasures suggested for this risk include incremental development, high change threshold and information hiding.
7. **Shortfalls in externally-furnished components:** This concerns the risk that the components developed by third party are not up to the mark. The countermeasures suggested for this risk include benchmarking, inspections, reference checking and compatibility analysis.
8. **Shortfalls in externally performed tasks:** This concerns the risk that the work performed by the contractors may not be up to the mark. The countermeasures suggested for this risk include reference checking, pre-award audits, award-fee contracts, competitive design or prototyping and team building.
9. **Real-time performance shortfalls:** The countermeasures suggested for this risk include simulation, benchmarking, modelling, prototyping, instrumentation and tuning.
10. **Straining computer science capabilities:** The countermeasures suggested for this risk include technical analysis, cost-benefit analysis and prototyping.

Risk Mitigation, Monitoring, and Management (RMMM) Plan

It is usually advisable for the project manager to develop a risk mitigation, monitoring and management (RMMM) plan for a project. An important component of this document is a *risk table*. Each row of the table contains the name of the risk, its probability and its impact on the project. For each risk in the risk table, the specific conditions or events that need to be monitored to check whether the risk has actually occurred is mentioned. The possible ways in which the risk can be avoided (mitigation) is also documented. A contingency plan to contain the effect of the risk is also documented.

7.12 Applying the PERT Technique

Using PERT to evaluate the effects of uncertainty

PERT was developed to take account of the uncertainty surrounding estimates of task durations. It was developed in an environment of expensive, high-risk and state-of-the-art projects – not that dissimilar to many of today's large software projects.

The method is very similar to the CPM technique (indeed many practitioners use the terms PERT and CPM interchangeably) but, instead of using a single estimate for the duration of each task, PERT requires three estimates.

- *Most likely time*: the time we would expect the task to take under normal circumstances. We shall identify this by the letter *m*.
- *Optimistic time*: the shortest time in which we could expect to complete the activity, barring outright miracles. We shall use the letter *a* for this.
- *Pessimistic time*: the worst possible time, allowing for all reasonable eventualities but excluding 'acts of God and warfare' (as they say in most insurance exclusion clauses). We shall call this *b*.

PERT (Program Evaluation and Review Technique) was published in the same year as CPM. Developed for the Fleet Ballistic Missiles Program, it is said to have saved considerable time in development of the Polaris missile.

PERT then combines these three estimates to form a single expected duration, t_e, using the formula

$$t_e = \frac{a + 4m + b}{6}$$

Exercise 7.6

Table 7.6 provides additional activity duration estimates for the network shown in Figure 6.29. There are new estimates for *a* and *b* and the original activity duration estimates have been used as the most likely times, *m*. Calculate the expected duration, t_e, for each activity.

Table 7.6 PERT activity time estimates

Activity	Optimistic (*a*)	Activity durations (weeks). Most likely (*m*)	Pessimistic (*b*)
A	5	6	8
B	3	4	5

C	2	3	3
D	3.5	4	5
E	1	3	4
F	8	10	15
G	2	3	4
H	2	2	2.5

Using expected durations

The expected durations are used to carry out a forward pass through a network, using the same method as the CPM technique. In this case, however, the calculated event dates are not the earliest possible dates but the dates by which we expect to achieve those events.

Exercise 7.7

Before reading further, use your calculated expected activity durations to carry out a forward pass through the network (Figure 6.29) and verify that the project duration is 13.5 weeks. What does an expected duration of 13.5 weeks mean in terms of the completion date for the project?

The PERT network illustrated in Figure 7.6 indicates that we expect the project to take 13.5 weeks. In Figure 7.6 we have used an activity-on-arrow network as this form of presentation makes it easier to separate visually the estimated activity data (expected durations and, later, their standard deviations) from the calculated data (expected completion dates and target completion dates). The method can, of course, be equally well supported by activity-on-node diagrams.

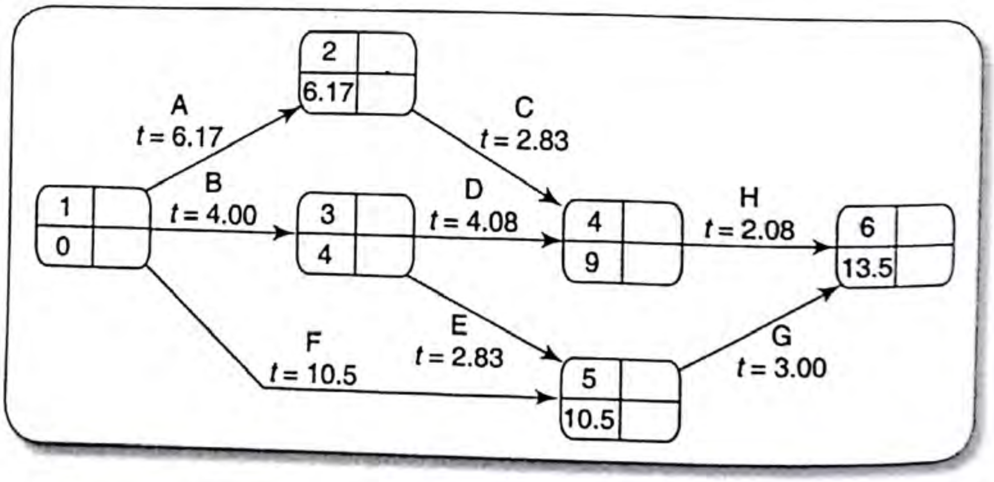


FIGURE 7.6 The PERT network after the forward pass

Unlike the CPM approach, the PERT method does not indicate the earliest date by which we could complete the project but the expected (or most likely) date. An advantage of this approach is that it places an emphasis on the uncertainty of the real world. Rather than being tempted to say '*the completion date for the project is. . .*' we are led to say '*we expect to complete the project by. . .*'.

It also focuses attention on the uncertainty of the estimation of activity durations. Requesting three estimates for each activity emphasizes the fact that we are not certain what will happen – we are forced to take into account the fact that estimates are approximate.

Even number	Target date
Expected date	Standard deviation

The PERT event labelling convention adopted here indicates event number and its target date along with the calculated values for expected time and standard deviation.

Activity standard deviations

A quantitative measure of the degree of uncertainty of an activity duration estimate may be obtained by calculating the standard deviation s of an activity time, using the formula

$$s = \frac{b-a}{6}$$

This standard deviation formula is based on the rationale that there are approximately six standard deviations between the extreme tails of many statistical distributions.

The activity standard deviation is proportional to the difference between the optimistic and pessimistic estimates, and can be used as a ranking measure of the degree of uncertainty or risk for each activity. The activity expected durations and standard deviations for our sample project are shown in Table 7.7.

The likelihood of meeting targets

The main advantage of the PERT technique is that it provides a method for estimating the probability of meeting or missing target dates. There might be only a single target date – the project completion – but we might wish to set additional intermediate targets.

Table 7.7 Expected times and standard deviations

Activity	**Activity durations (weeks)**				
	Optimistic (a)	**Most likely (m)**	**Pessimistic (b)**	**Expected (t_e)**	**Standard deviation (s)**
A	5	6	8	6.17	0.50
B	3	4	5	4.00	0.33
C	2	3	3	2.83	0.17
D	3.5	4	5	4.08	0.25
E	1	3	4	2.83	0.50
F	8	10	15	10.50	1.17
G	2	3	4	3.00	0.33
H	2	2	2.5	2.08	0.08

Suppose that we must complete the project within 15 weeks at the outside. We expect it will take 13.5 weeks but it could take more or, perhaps, less. In addition, suppose that activity C must be completed by week 10, as it is to be carried out by a member of staff who is scheduled to be working on another project, and that event 5 represents the delivery of intermediate products to the customer, which must take place by week 10. These three target dates are shown on the PERT network in Figure 7.7.

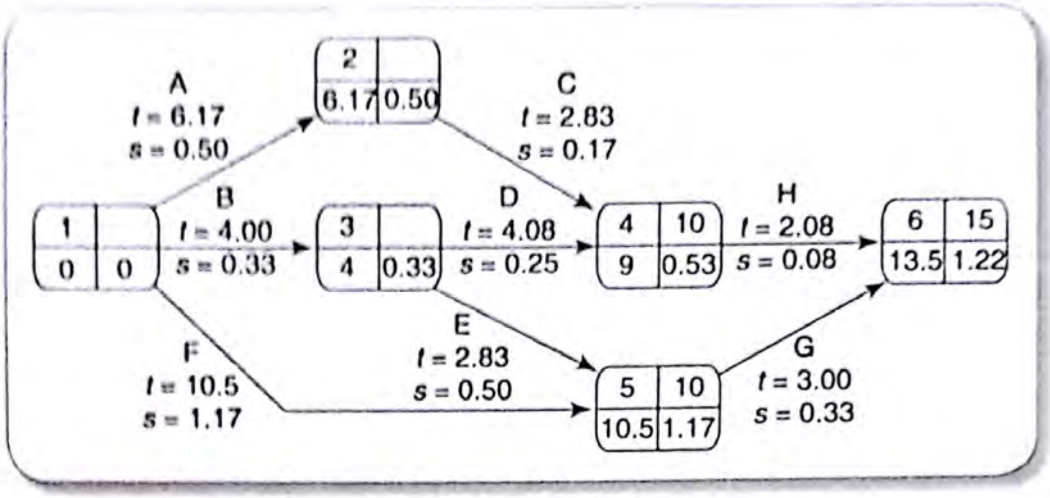


FIGURE 7.7 The PERT network with three target dates and calculated event standard deviations

The PERT technique uses the following three-step method for calculating the probability of meeting or missing a target date:

- calculate the standard deviation of each project event;
- calculate the z value for each event that has a target date;
- convert z values to a probabilities.

Calculating the standard deviation of each project event

The square of the standard deviation is known as the variance. Standard deviations may not be added together but variances may

Standard deviations for the project events can be calculated by carrying out a forward pass using the activity standard deviations in a manner similar to that used with expected durations. There is, however, one small difference – to add two standard deviations we must add their squares and then find the square root of the sum. Exercise 7.8 illustrates the technique. One practical outcome of this is that the contingency time to be allocated to a sequence of activities as a whole would be less than the sum of the contingency allowances for each of the component activities. This has implications that can be exploited in critical chain project management, which are discussed in the next section.

Exercise 7.8

The standard deviation for event 3 depends solely on that of activity B. The standard deviation for event 3 is therefore 0.33.

For event 5 there are two possible paths, B + E or F. The total standard deviation for path B + E is $\sqrt{(0.33^2 + 0.50^2)} = 0.6$ and that for path F is 1.17; the standard deviation for event 5 is therefore the greater of the two, 1.17.

Verify that the standard deviations for each of the other events in the project are as shown in Figure 7.7.

Calculating the z values

The z value is calculated for each node that has a target date. It is equivalent to the number of standard deviations between the node's expected and target dates. It is calculated using the formula

$$z = \frac{T - t_e}{s}$$

where t_e is the expected date and T the target date.

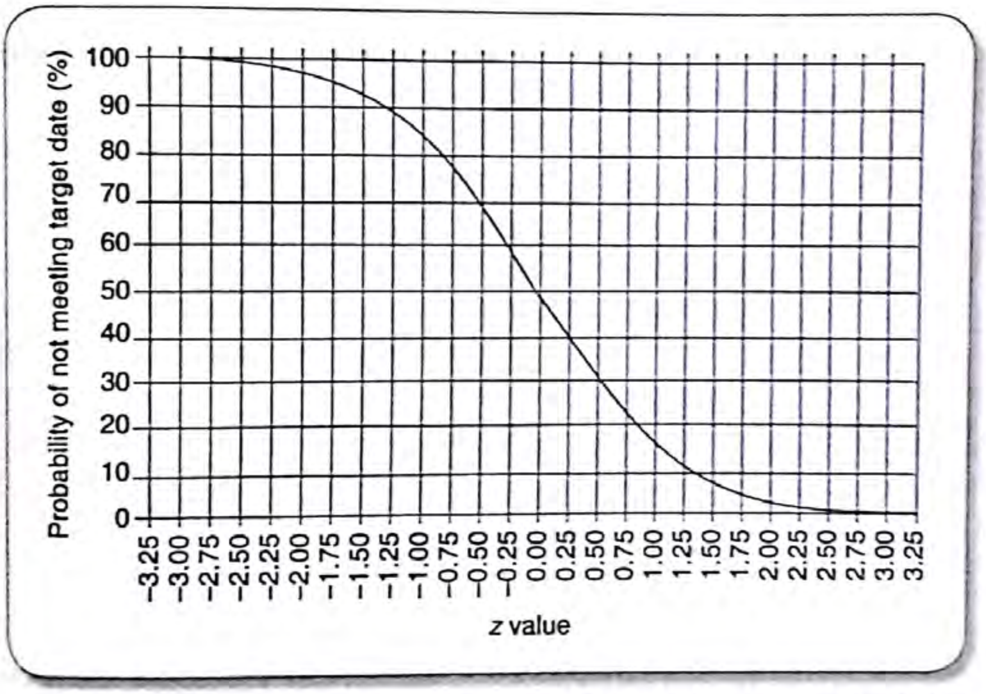
Exercise 7.9

The z value for event 4 is $(10 - 9.00)/0.53 = 1.8867$.

Calculate the z values for the other events with target dates in the network shown in Figure 7.7.

Converting z values to probabilities

A z value may be converted to the probability of not meeting the target date by using the graph in Figure 7.8.



This graph is the equivalent of tables of z values, also known as standard normal deviates, which may be found in most statistics textbooks.

Figure 7.8 The probability of obtaining a value within z standard deviations of the mean for a normal distribution

Exercise 7.10

The z value for the project completion (event 6) is 1.23. Using Figure 7.8 we can see that this equates to a probability of approximately 11%, that is, there is an 11% risk of not meeting the target date of the end of week 15.

Find the probabilities of not achieving events 4 or 5 by their target dates of the end of week 10. What is the likelihood of completing the project by week 14?

Advantages of PERT

We have seen that by requesting multi-valued activity duration estimates and calculating expected dates, PERT focuses attention on the uncertainty of forecasting. We can use the technique to calculate the standard deviation for each task and use this to rank them according to their degree of risk. Using this ranking, we can see, for example, that activity F is the one regarding which we have greatest uncertainty, whereas activity C should, in principle, give us relatively little cause for concern.

If we use the expected times and standard deviations for forward passes through the network we can, for any event or activity completion, estimate the probability of meeting any set target. In particular, by setting target dates along the critical path, we can focus on those activities posing the greatest risk to the project's schedule.

7.13 Monte Carlo Simulation

As an alternative to the PERT technique, we can use Monte Carlo simulation approach. Monte Carlo simulation are a class of general analysis techniques that are valuable to solve any problem that is complex, nonlinear, or involves more than just a couple of uncertain parameters. Monte Carlo simulations involve repeated random sampling to compute the results. Since this technique is based on repeated computation of random numbers, it becomes easier to use this technique when available as a computer program.

When Monte Carlo simulation is used to analyse the risk of not meeting the project deadline, the project completion time is first modelled as a mathematical expression involving the probability distributions of the completion times of various project activities and their precedence relationships. Activity durations can be specified in a variety of forms, depending upon the information available. If, for example, we have historic data available about the durations of similar activities as shown in the probability chart in Figure 7.4, we might be able to specify durations as pertinent probability distributions. With less information available, we should, at least, be able to provide three time estimates as used by PERT.

Monte Carlo simulation essentially evaluates a range of input values generated from the specified probability distributions of the activity durations. It then calculates the results repeatedly; each time using a different set of random values generated from the given probability functions. Depending upon the number of probabilistic parameters and the ranges specified for them, a Monte Carlo simulation could involve thousands or even millions of calculations to complete. After the simulation results are available, these are analysed, summarized and represented graphically, possibly using a histogram as shown in Figure 7.9. The main steps involved in carrying out Monte Carlo simulation for a project consisting of *n* activities are as follows:

- *Step 1:* Express the project completion time in terms of the duration of the *n* activities ($x_{i,\ i=1,\ n}$ and their dependences as a precedence graph, $d = f(x_1, x_2, \ldots, x_n)$.
- *Step 2:* Generate a set of random inputs, $x_{i1}, x_{i2}, \ldots, x_{in}$ using specified probability distributions.
- Step 3: Evaluate the project completion time expression and store the result in d_i.
- *Step 4:* Repeat Steps 2 and 3 for the specified number of times.
- *Step 5:* Analyze the results $d_{i,\ i=1,n}$; summarize and display using a histogram as the one shown in Figure 7.9.

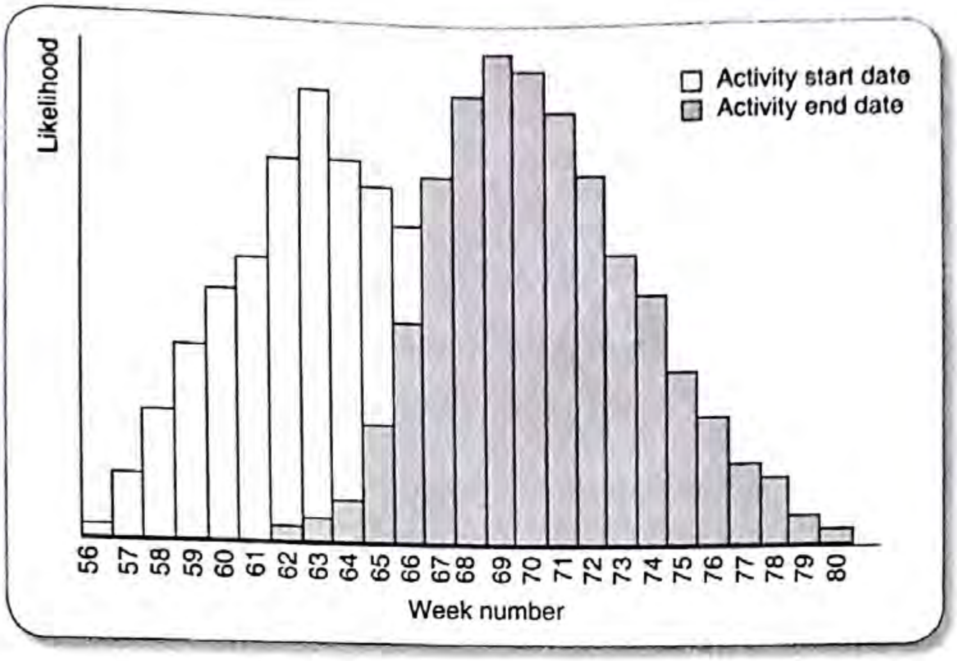


Figure 7.9 Risk profile for an activity generated using Monte Carlo simulation

To appreciate the advantage of Monte Carlo simulations over a manual approach, consider the following. In the manual approach, a few combinations of each project duration are chosen (such as best case, worst case, and most likely case), and the results recorded for each selected scenario. In contrast, in Monte Carlo simulation, hundreds or thousands of possible random sampling of probability distribution functions of the activity durations are considered as samples for evaluation of the project completion time expression to produce outcomes. Monte Carlo simulation is expected to give a more realistic result than manual analysis of a few cases, especially because manual analysis implicitly gives equal weights to all scenarios.

7.14 Critical Chain Concepts

This chapter has stressed the idea that the forecast for the duration of an activity cannot in reality be a single number, but must be a range of durations that can be displayed on a graph such as Figure 7.3. However, we would want to pick one value in that range which would be the *target*.

The duration chosen as the target might be the one that seems to be the *most likely*. Imagine someone who cycles to work each day. It may be that on average it takes them about 45 minutes to complete the journey, but on some days it could be more and on others it could be less. These journey times could be plotted on a graph like the one in Figure 7.3. If the cyclist had a very important meeting at work, it is likely that they would give themselves more time – say an extra 15 minutes – than the average 45 minutes to make sure that they arrived in time. In the discussion above on the PERT risk technique the most likely duration was the middle value and the pessimistic estimate was the equivalent of the 45 + 15 = 60 minutes.

Of course, there will be some days when the cyclist will beat the average of 45 minutes. When a project is actually being executed, the project manager will be forced to focus on the activities where the actual durations exceed the target. Activities which are actually completed before the target date are likely to be overlooked. These early completions, properly handled, could put some time in hand that might still allow the project to meet its target completion date if the later activities are delayed.

Figure 7.10 shows the findings of Michiel van Genuchten, a researcher who analysed the reasons for delays in the completion of software development tasks. This bar chart shows that about 30% of activities were finished on time, while 9% were a week early and 17% were a week late. The big jump of 21 percentage points between being a week early and being on time is compatible with the 'Parkinson's Law' principle that '*work expands to fill the time available*'. This tendency should not be blamed on inherent laziness. van Genuchten found that the most common reason for delay was the time that had to be spent on non-project work. It seems that developers used spare time provided by generous estimates to get on with other urgent work.

Michiel van Genuchten (1991) 'Why is software late? An empirical study of reasons for delay in software development', *IEEE Transactions in Software Engineering* 17(6) 582–90.

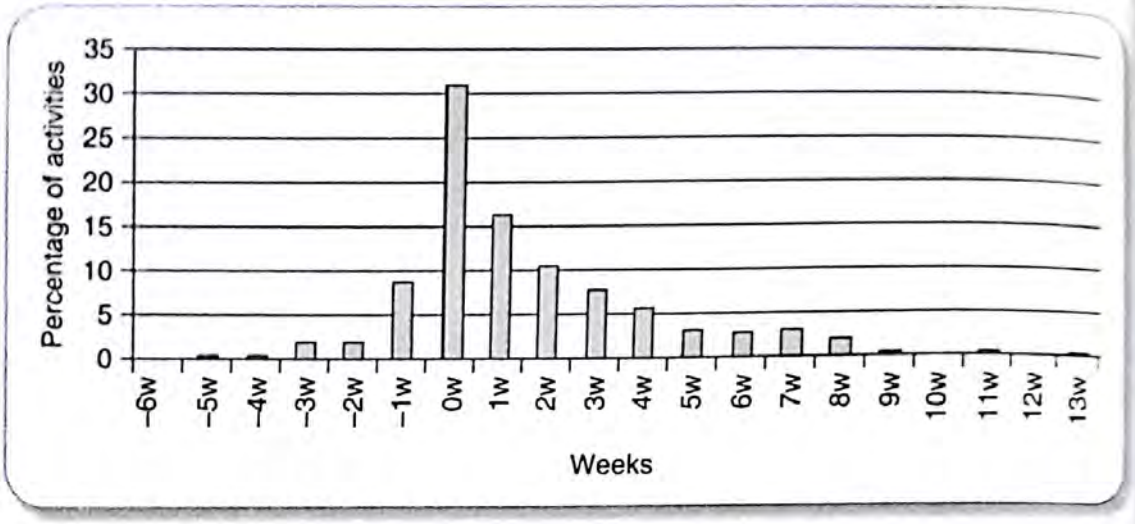


FIGURE 7.10 Percentage of activities early or late (after van Genuchten, 1991)

A good introduction is L. P. Leach (1999) 'Critical chain project management improves project performance' *Project Management Journal* 30(2) 39–51.

One approach which attempts to solve some of these problems is the application of the *critical chain* concept originally developed by Eliyahu Goldratt. In order to demonstrate the principles of this approach, the example shown in Figure 7.7 will be reworked as a Gantt chart. Figure 7.11 shows what the Gantt chart for this project might look like if a 'traditional approach' were adopted, but we have already adopted the most likely durations.

The general steps in the Critical Chain approach are explained in the following sections.

Deriving 'most likely' activity durations

The target date generated by critical chain planning is one where it is estimated that there is a 50% chance of success – this approximates to the expected time identified in the PERT risk method. In some explanations of critical chain project planning it is suggested that the most likely activity duration can be identified by halving the estimates provided. This is based on the assumption that the estimates given to the planner will be 'safe' ones based on a 95% probability of them being achieved. If you look at Figure 7.3, the 95% estimate would be 9 days and half of that (4.5 days) would not be a reasonable target as it would have a probability of only 10% of success. It also assumes that a probability profile has a bell-shaped normal distribution (like the example in Figure 7.3). If you look at the distribution which resulted from van Genuchten's research – see Figure 7.10 – you can see that it is certainly not bell-shaped. Other critical chain experts suggest deducting 33% from the safe estimate to get the target estimate – which seems less unreasonable.

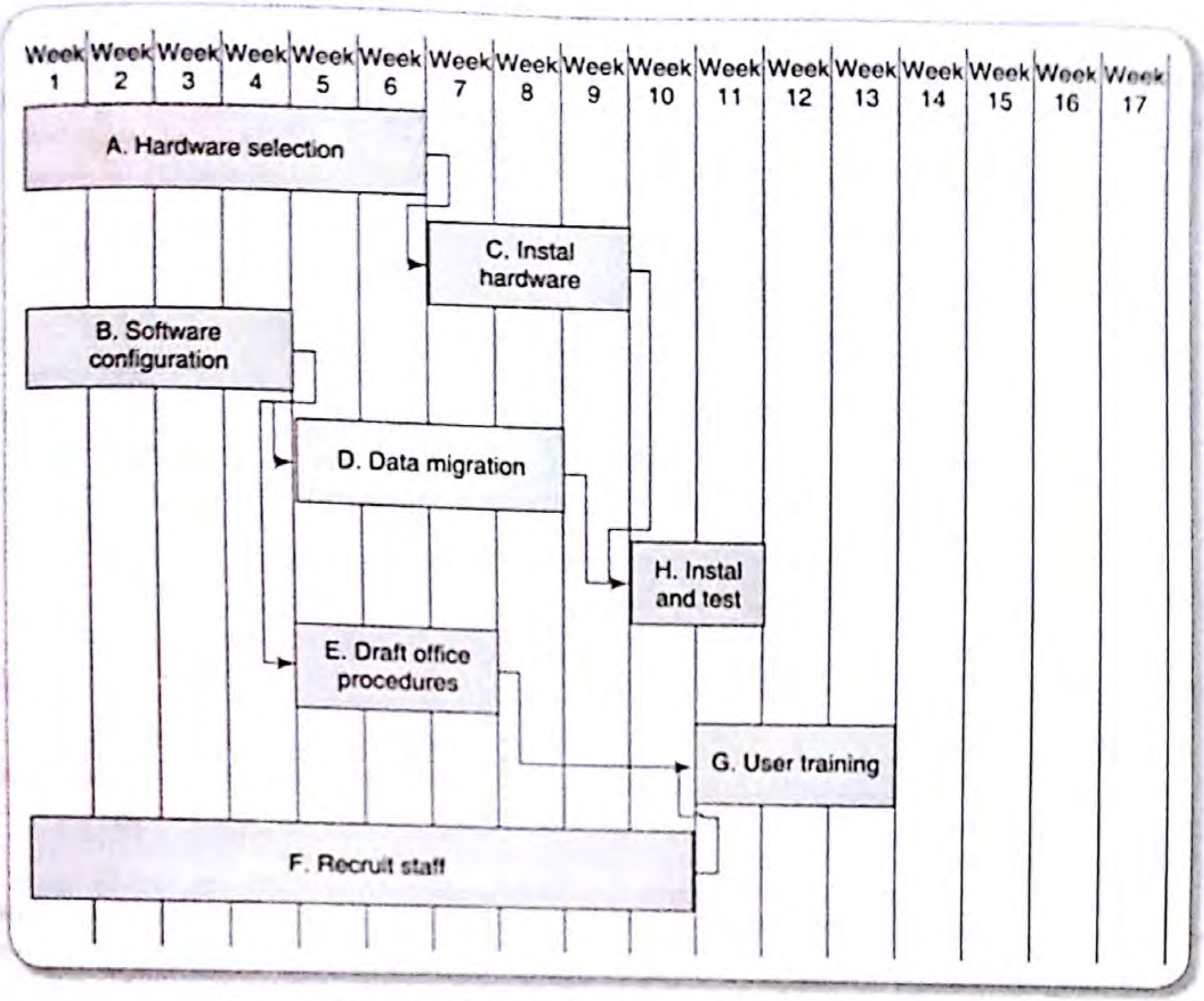


FIGURE 7.11 Gantt chart – 'traditional' planning approach

However, what appear to be arbitrary managerial reductions in the estimates may not be a good way to motivate developers, especially if these staff supplied the estimates in the first place. A better approach would be to ask developers to supply two estimates. One of these would be a 'most likely' estimate and the other would include a safety margin or comfort zone. From now on we are going to assume that this is what has happened. In fact we will use the figures already presented in Table 7.6 in this new role (Table 7.8).

Using latest start dates for activities

Working backwards from the target completion date, each activity is scheduled to start as late as possible. Among other things, this should reduce the chance of staff being pulled off the project on to other work. It is also argued – with some justification according to van Genuchten's research above – that most developers would tend to start work on the task at the latest start time anyway. However, it does make every activity 'critical'. If one is late the whole project is late. That is why the next steps are needed.

Table 7.8 Most likely and comfort zone estimates (days)

Activity	Most likely	Plus comfort zone	Comfort zone
A	6	8	2
B	4	5	1
C	3	3	0
D	4	5	1
E	3	4	1
F	10	15	5
G	3	4	1
H	2	2.5	0.5

Inserting project and feeder buffers

To cope with activity overruns, a *project buffer* is inserted at the end of the project before the target completion date. One way of calculating this buffer is as the equivalent of 50% of the sum of lengths of the 'comfort zones' that have been removed from the *critical chain*. The critical chain is the longest chain of activities in the project, taking account of both task and resource dependencies. This is different from the *critical path* as the latter only takes account of task dependencies. A *resource dependency* is where one activity has to wait for a resource (usually a person in software development) which is being used by another activity to become available. If an activity on this critical chain is late, it will push the project completion date further into the project buffer. That the buffer should be 50% of the total comfort zones for critical chain activities is based on the grounds that if the estimate for an activity was calculated as having a 50% chance of being correct, the buffer would only need to be called upon by the 50% of cases where the estimate was not correct.

An alternative proposal is to sum the squares of the comfort zones and then take the square root of the total. This is based on the idea that each comfort zone is the equivalent to the standard deviation of the activity – go back and look at the section headed *Calculating the standard deviation of each project event* in Section 7.12. This method of calculation still produces a figure which is less than simply summing all the comfort zones. This is justified on the grounds that the contingency time needed for a group of activities is less than the sum of the individual contingency allowances as the success of some activities will compensate for the shortfalls in others.

Buffers are also inserted into the project schedule where a subsidiary chain of activities feeds into the critical chain. These *feeding buffers* could once again be set at 50% of the length of the 'comfort zone' removed from the subsidiary or *feeding chain*.

Worked example

Figure 7.12 shows the results of this process. The critical chain in this example happens to be the same as the critical path, that is activities F and G which have comfort zones of 5 weeks and 1 week respectively, making a total of 6 weeks. The project buffer is therefore 3 weeks.

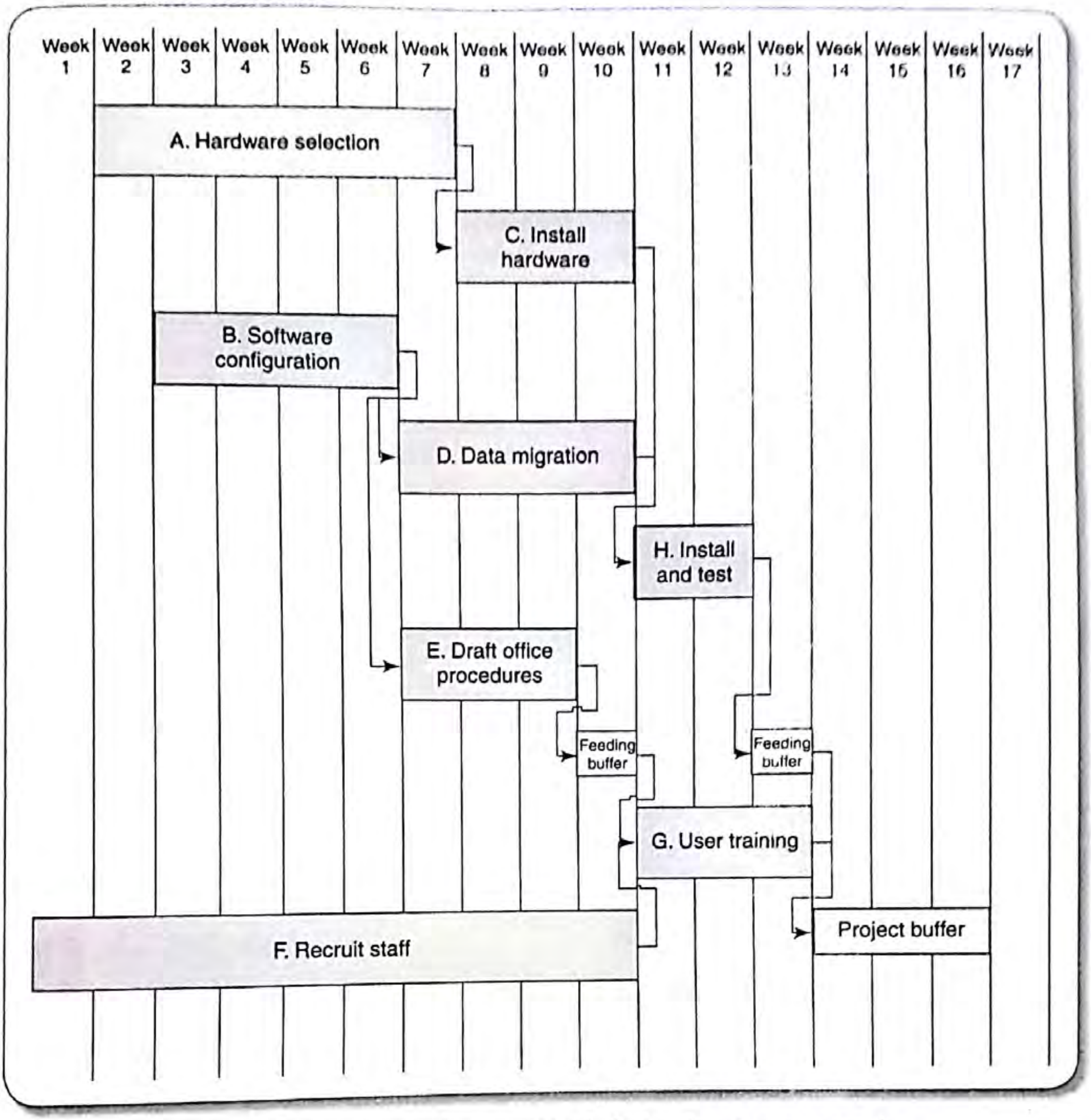


Figure 7.12 Gantt chart – critical chain planning approach

Subsidiary chains feed into the critical chain where activity H links into the project buffer and where activity E links into G which is part of the critical chain. Feeding buffers are inserted at these points. For the first buffer the duration would be 50% of the saved comfort zones of A, C and H, that is (2 + 0 + 0.5)/2 = 1.25 weeks. It could be argued that B, D and H could form a feeder chain which also has a combined comfort zone of (1 + 1 + 0.5)/2 = 1.25 weeks. In the situations where there are parallel alternative paths on a feeder chain, the practice is to base the feeding buffer on whichever comfort zone total is greater. This because if one or other or both parallel paths were late they could still use the same buffer. (Imagine that in the example above there are two cyclists who live 45 minutes away from work and they both have the same important meeting – they might each add a 15-minute comfort zone to the ride on that day but that 15 minutes could effectively be the same 15 minutes between 7.45 and 8.00 a.m. in the morning). It could be argued that the feeding buffer and the final project buffer could also be merged, but explanations of critical chain planning, such as that of Larry Leach (see above), make clear that this is not to be done. This could be because a delay penetrating the feeding buffer time does not affect the completion date of the project, while penetrating the project buffer does.

In the second place, where a feeder chain of activities joins the critical chain, the feeder buffer would be 50% of the comfort zones of activities B and E, that is 1 week.

Project execution

When the project is executed, the following principles are followed:

- No chain of tasks should be started earlier than scheduled, but once it has been started it should be finished as soon as possible – this invokes the *relay race principle*, where developers should be ready to start their tasks as soon as the previous, dependent, tasks are completed.
- Buffers are divided into three zones: green, amber and red, each of an even (33%) size:
  - *green*, where no action is required if the project completion date creeps into this zone;
  - *amber*, where an action plan is formulated if the project completion dates moves into this zone;
  - *red*, where the action plan above is executed if the project penetrates this zone.

See, for example, D. Trietsch (2005) 'Why a critical path by any other name would smell less sweet' *Project Management Journal* 36(1) 27–36 and T. Raz *et al.* (2003) 'A critical look at critical chain project management' *Project Management Journal* 34(4) 24–32.

Critical chain planning concepts have the support of a dedicated group of enthusiasts. However, the full application of the model has attracted controversy on various grounds. Our personal view is that the ideas of:

- requiring two estimates: the most likely duration/effort and the safety estimate which includes additional time to deal with problems that could arise with the task, and
- placing the contingency time, based on the 'comfort zone' which is the difference between the most likely and safety estimates, in common buffers rather than associating it with individual activities are sound ones that could usefully be absorbed into software project management practice.

Conclusion

In this chapter, we have seen how to identify and manage the risks that might affect the success of a project. Risk management is concerned with assessing and prioritizing risks and drawing up plans for addressing those risks before they become problems.

This chapter has also described techniques for estimating the effect of risk on the project's activity network and schedule.

Many of the risks affecting software projects can be reduced by allocating more experienced staff to those activities that are affected. In the next chapter we consider the allocation of staff to activities in more detail.

Further Exercises

1. Fiona is a final-year computing undergraduate student who in her third year undertook a placement with the ICT department of an insurance company as a support analyst and then a network manager. The placement year was very busy and rewarding as the company saw ICT as providing business advantage in what was a very dynamic and aggressively competitive sector. The project that Fiona proposes to do in her final year will use the insurance company as a client. The proposed project involves gathering requirements for an application that records details of change requests for operational systems made by users and then tracks the subsequent progress of the change. Having gathered the requirements she is to design the application, then build and implement it. Identify possible risks in the proposed project of which Fiona should take account.

2. Mo is a systems analyst who is gathering requirements for an application which will record details of the training undertaken by fire-fighters in the client fire brigade. Details of the training units successfully completed by fire-fighters are to be input to the application by trainers who are themselves senior and active fire-fighters. Mo needs to interview a trainer to obtain his/her requirements. Because of the senior fire-fighters' other duties the interview has to be arranged two weeks in advance. There is then a 20% chance of the fire-fighter being unable to attend the interview because of an emergency call-out. Each week that the project is delayed costs the fire brigade approximately £1,000.

   (a) Provide an estimate of the risk exposure (as a financial value) for the risk that the senior fire-fighter might not be able to attend at the times needed.

   (b) Suggest possible risk mitigation actions.

3. In Exercise 7.2, you were asked to identify risks under the four headings of Actors, Technology, Structure and Tasks for the IOE annual maintenance contracts and the Brightmouth College payroll scenarios. Now identify risks for each scenario that relate to pairs of domains, for example Actors–Technology, Actors–Tasks, and so on.

4. The Wet Holiday Company specializes in the provision of holidays which involve water sports of various types. There are three major divisions with the following lines of business:

   - Boat holidays on canals
   - Villa holidays in various parts of the Mediterranean which involve sailing in some way
   - Canoeing holidays in France

   Wet Holiday feels that they are particularly appealing to a young active market and that having the facility for customers to book via the web is essential. They call in ICT consultants to advise them on their IT strategy. The consultants advise them that before they can have a web presence, they need to have a conventional ICT-based booking system to support their telesales operation first. Because of the specialized nature of their business, an off-the-shelf application would not be suitable and they would need to have a specially written software application, based on a client–server architecture. The top priority needs to be given to a system to support villa holiday bookings because this has the largest number of customers and generates the most revenue.

   Wet Holiday have some in-house IT development staff, but these are inexperienced in client–server technology. To meet this shortfall, contractors are employed.

   It turns out that development takes much longer than planned. Much of this delay occurs at acceptance testing when the users find many errors and performance shortcomings, which require extensive rework. Part of the problem relates to getting the best performance out of the new architecture: this has a particular impact on response time which are initially unacceptable to staff who are dealing with customers over the phone. The contractors are not closely monitored and some of the code that they produce is found to have many careless mistakes and to be poorly structured and documented. This makes it difficult to make changes to the software after the contractors have left on the expiry of their contracts.

The villa booking system can only be implemented at the beginning of a holiday season and the deadline for the beginning of the 2002 to 2003 season is missed, leading to a 12-month delay in the implementation. The delay in implementation seems to encourage the users to ask for further modifications to the original requirements, which adds even more to development costs.

The delays in implementing this application mean that the other scheduled IT development, for other lines of business, have to be put back. Managers of customer-facing business functions at Wet Holiday are suggesting that the whole IT function should be completely outsourced.

(a) Identify the problems that were faced by Wet Holiday, and describe actions that could have been taken to avoid or reduce them.

(b) Use your findings in (a) to create a risk checklist for future projects.

5. Below are details of a project. All times are in days.

Activity	Depends on	Optimistic time	Most likely	Pessimistic
A	–	8	10	12
B	A	10	15	20
C	B	5	7	9
D	–	8	10	12
E	D, C	3	6	9

Using the activity times above:

- Calculate the expected duration and standard deviation for each activity.
- Identify the critical path.
- Draw up an activity diagram applying critical chain principles for this project:
  - Locate the places where buffers will need to be located.
  - Assess the size of the buffers.
  - Start all activities as late as possible.

6. Below are details of a project. All times are in days.

Activity	Depends on	Most likely	Plus safety
A		10	14
B	A	5	7
C	B	15	21

D	A	3	5
E	A	8	12
F	F	20	22
G	D	6	8
H	C, F, G	10	14

(a) Using (i) the most likely and then (ii) the safety estimates:

- Calculate the earliest and latest start and end days and float for each activity.
- Identify the critical path.

(b) Draw up an activity diagram applying critical chain principles for this project:

- Locate the places where buffers will need to be located.
- Assess the size of the buffers.
- Start all activities as late as possible.

7 In this chapter the application of risk management to software development projects has been strongly advocated. In practice, however, managers are often reluctant to apply the techniques. What do you think might be the reasons for this?

8. Suppose you are the project manager of a large software development project. List three common types of risks that your project might suffer. Point out the main steps that you would follow to effectively manage risks in your project.

9. Schedule slippage is a very common form of risk that almost every project manager has to deal with. Suppose you are the project manager of a medium-sized project. Explain how you would manage the risk of schedule slippage.

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

(i) Which one of the following is the correct sequence of activities recommended by a typical proactive risk management framework?

(a) Risk control, risk identification and risk assessment

(b) Risk assessment, risk identification and risk control

(c) Risk identification, risk assessment and risk control

(d) Risk identification, risk control and risk assessment

(e) Risk assessment, risk control and risk identification

(ii) Which one of the following is an important objective of risk exposure analysis?

(a) Collecting information that can be used for future risk analysis

(b) Defining risk avoidance strategies for various risks

(c) Estimating the impact of the risk on the project

(d) Assessing risk response strategies for the identified risks

(iii) Suppose fours risks named R1, R2, R3 and R4 have been identified and assigned the probabilities of occurrence of 0.1, 0.2, 0.3 and 0.4, respectively. The likely damages due to the four risks are ₹50,000, ₹100,000, ₹70,000 and ₹60,000, respectively. Which risk has the highest risk exposure?

(a) R1 (b) R2

(c) R3 (d) R4

(iv) Which one of the following is not a Risk Response strategy for mitigating or controlling risks?

(a) Mitigation (b) Simulation

(c) Avoidance (d) Acceptance

(v) Which one of the following is the most appropriate sequence of strategies that can be adopted for dealing with positive risks?

(a) Avoid, mitigate, transfer and accept (b) Transfer, mitigate, avoid and exploit

(c) Exploit, share, enhance and accept (d) Mitigate, enhance, exploit and accept

(vi) Purchasing insurance cover can be considered to be an example of which one of the following risk handling strategies?

(a) Mitigation (b) Transfer

(c) Acceptance (d) Avoidance

(vii) Which one of the following can be considered to be the most accurate definition of proactive risk management?

(a) Monitoring risks throughout the project and taking appropriate actions to contain them

(b) Identifying, analysing and prioritizing risks and developing risk response plans

(c) Developing a risk management plan to prevent occurrence of various types of risks

(d) Mitigating, transferring or accepting risks as and when a risk becomes reality

(viii) Which one of the following techniques is not suggested by Boehm to handle the risk of gold-plating?

(a) Requirements scrubbing (b) Cross training of personnel

(c) Cost-benefit analysis (d) Prototyping

(ix) Assume that you are the project manager for a software development project. Sunrise Engineering Works, a hardware vendor has intimated you that a problem in customs clearance is preventing your network equipment from being delivered on time and may get delayed by several months. For handling this risk, you have arranged for leasing a network equipment from a local company as an interim arrangement. Which one of the following risk response strategies have you adopted?

(a) Transference (b) Acceptance

(c) Mitigation (d) Avoidance

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:

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

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

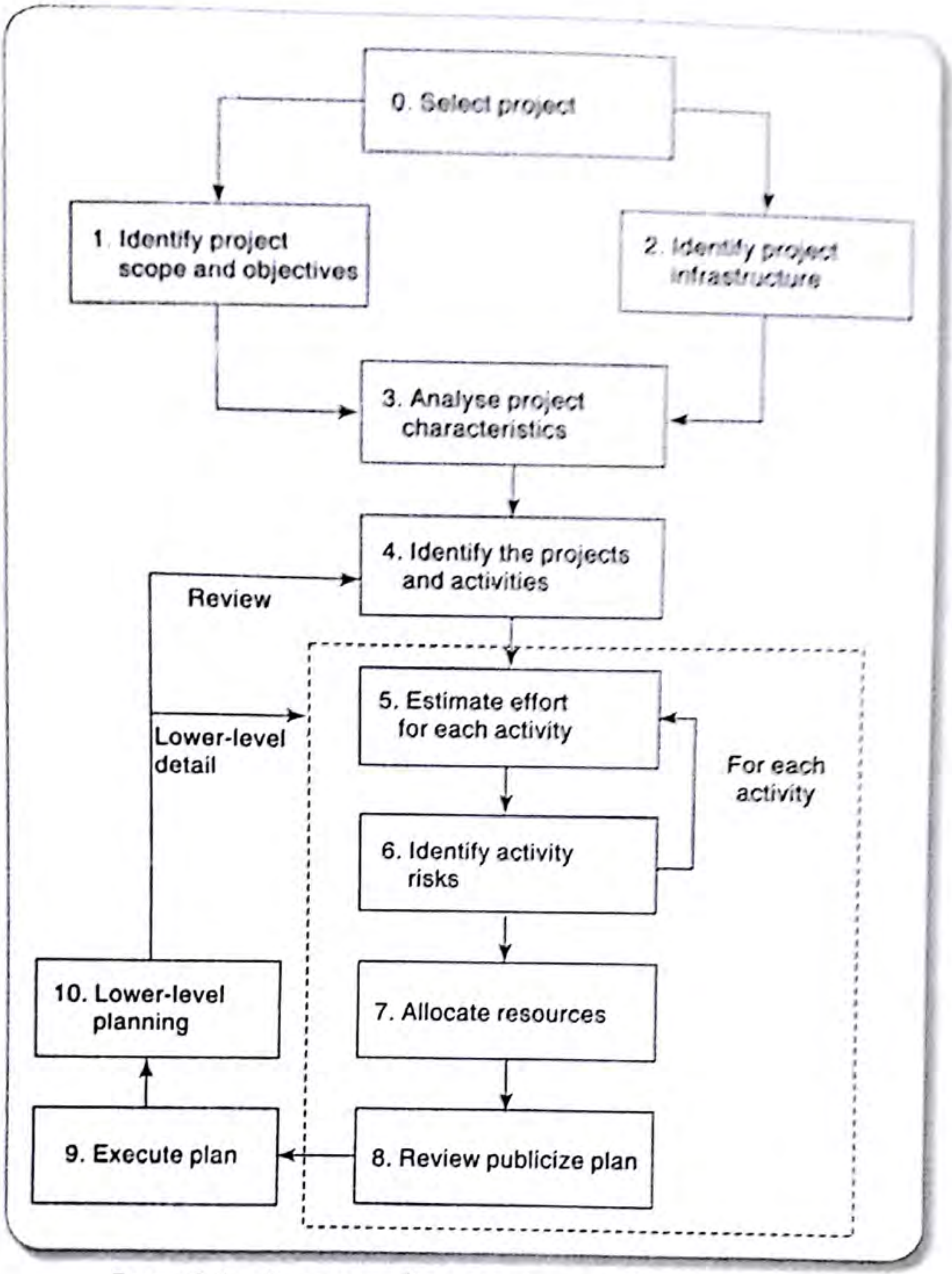

0. Select project
1. Identify project scope and objectives
2. Identify project infrastructure
3. Analyse project characteristics
4. Identify the projects and activities
Review
5. Estimate effort for each activity
Lower-level detail
For each activity
6. Identify activity risks
7. Allocate resources
10. Lower-level planning
9. Execute plan
8. Review publicize plan

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.

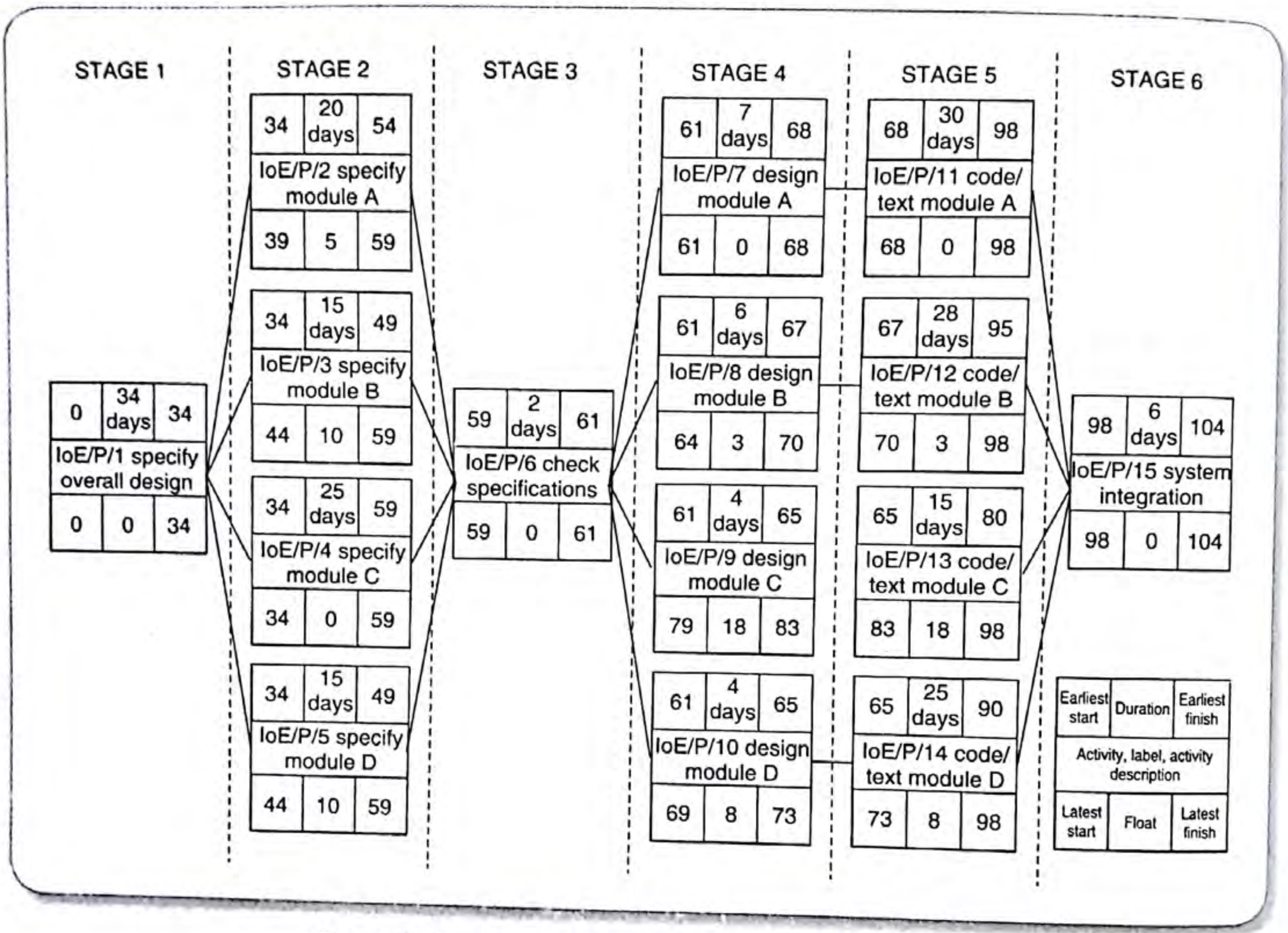


Figure 8.2 Amanda's IOE precedence network

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.

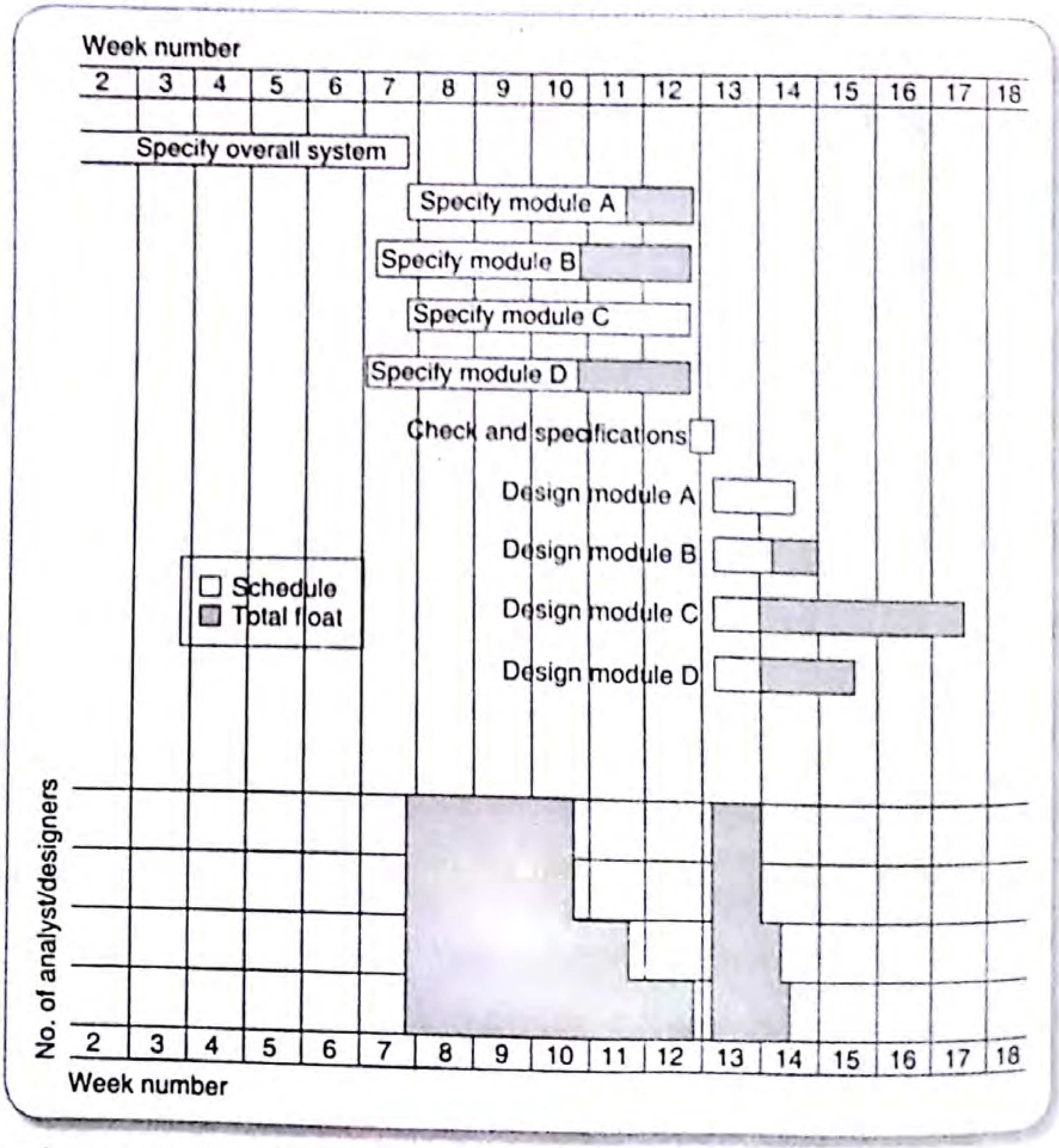


FIGURE 8.3 Part of Amanda's bar chart and resource histogram for analyst/designers

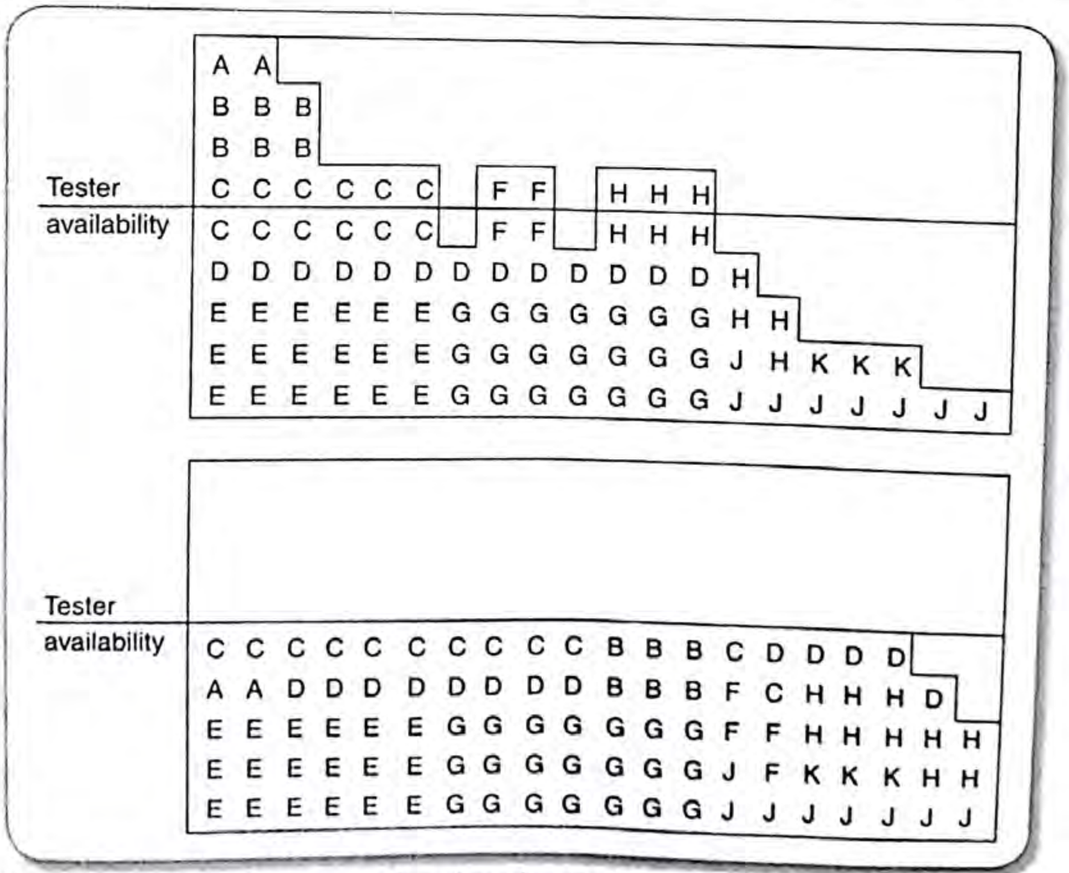
Changing the level of resources on a project over time, particularly personnel, generally adds to the cost of a project. Recruiting staff has costs and, even where staff are transferred internally, time will be needed for familiarization with the new project environment.

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.



```
             A A
             B B B
             B B B
Tester       C C C C C C   F F   H H H
availability C C C C C C   F F   H H H
             D D D D D D D D D D D D D H
             E E E E E E G G G G G G G H H
             E E E E E E G G G G G G G J H K K K
             E E E E E E G G G G G G G J J J J J J J

Tester
availability C C C C C C C C C C B B B C D D D D
             A A D D D D D D D D B B B F C H H H D
             E E E E E E G G G G G G G F F H H H H H
             E E E E E E G G G G G G G J F K K K H H
             E E E E E E G G G G G G G J J J J J J J
```

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.

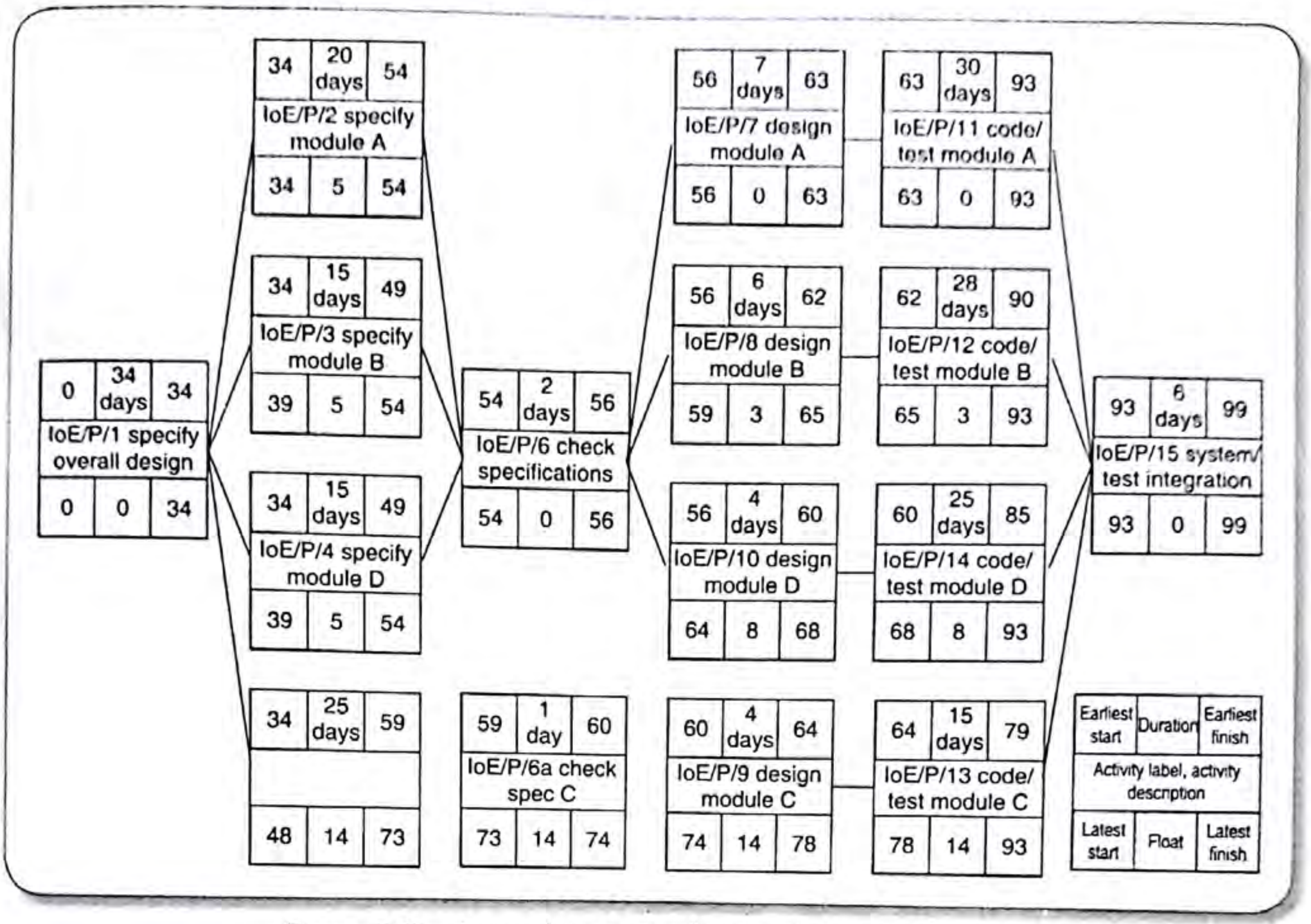


Figure 8.5 Amanda's revised precedence network

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.

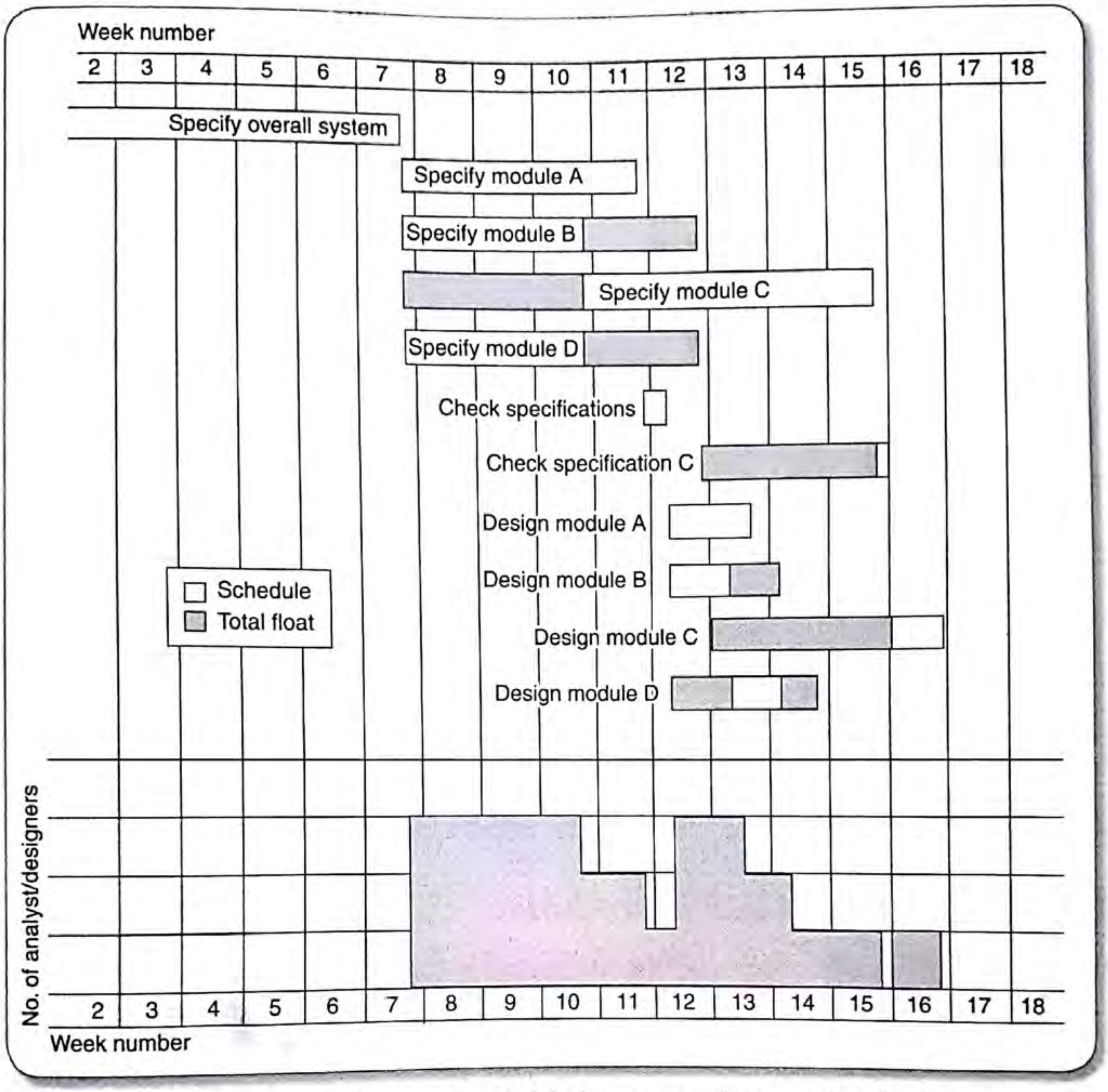


FIGURE 8.6 Amanda's project scheduled to require three analyst/designers

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.
- *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

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

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.

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.

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

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.

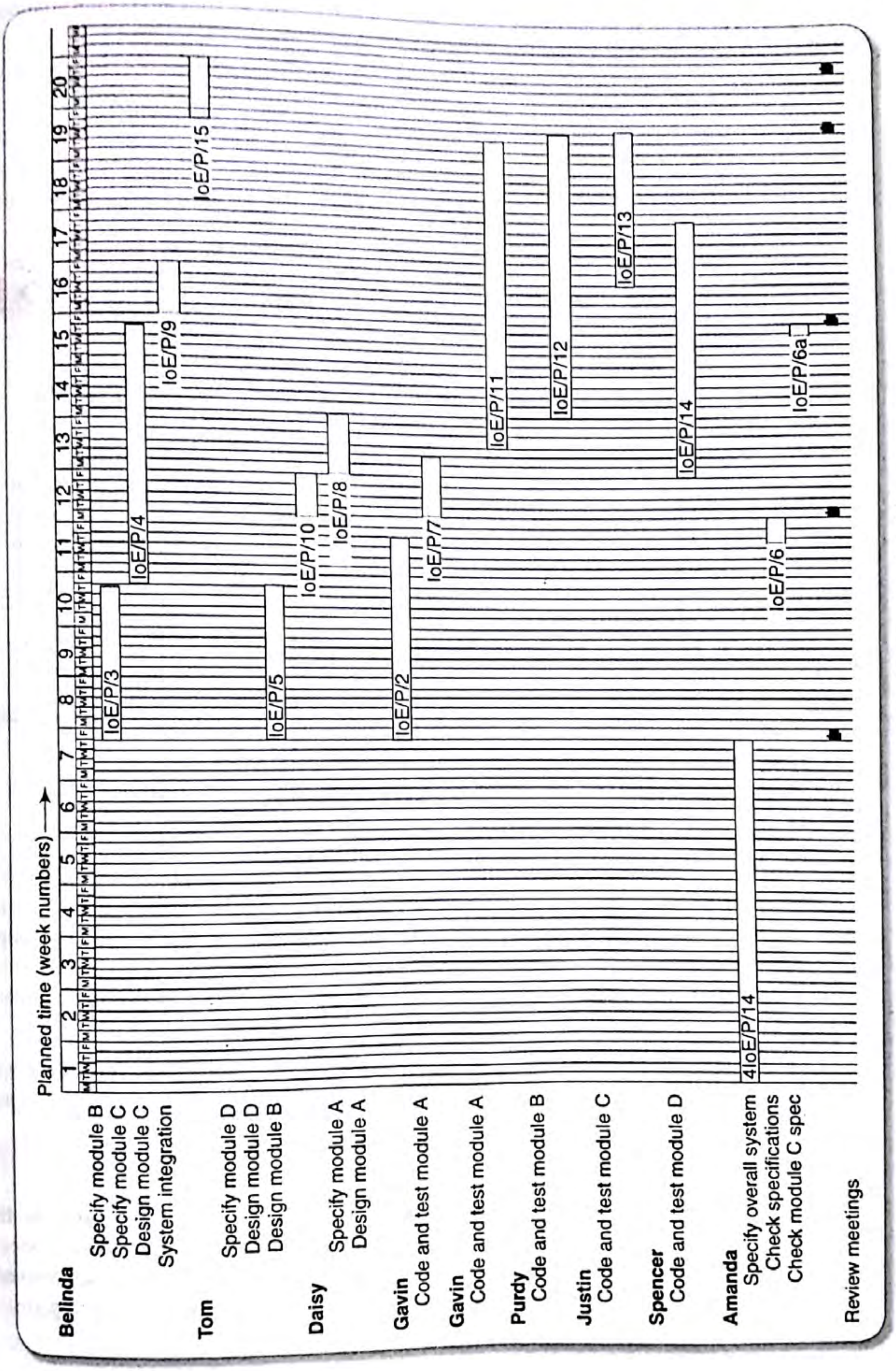


FIGURE 8.7 Amanda's work schedule

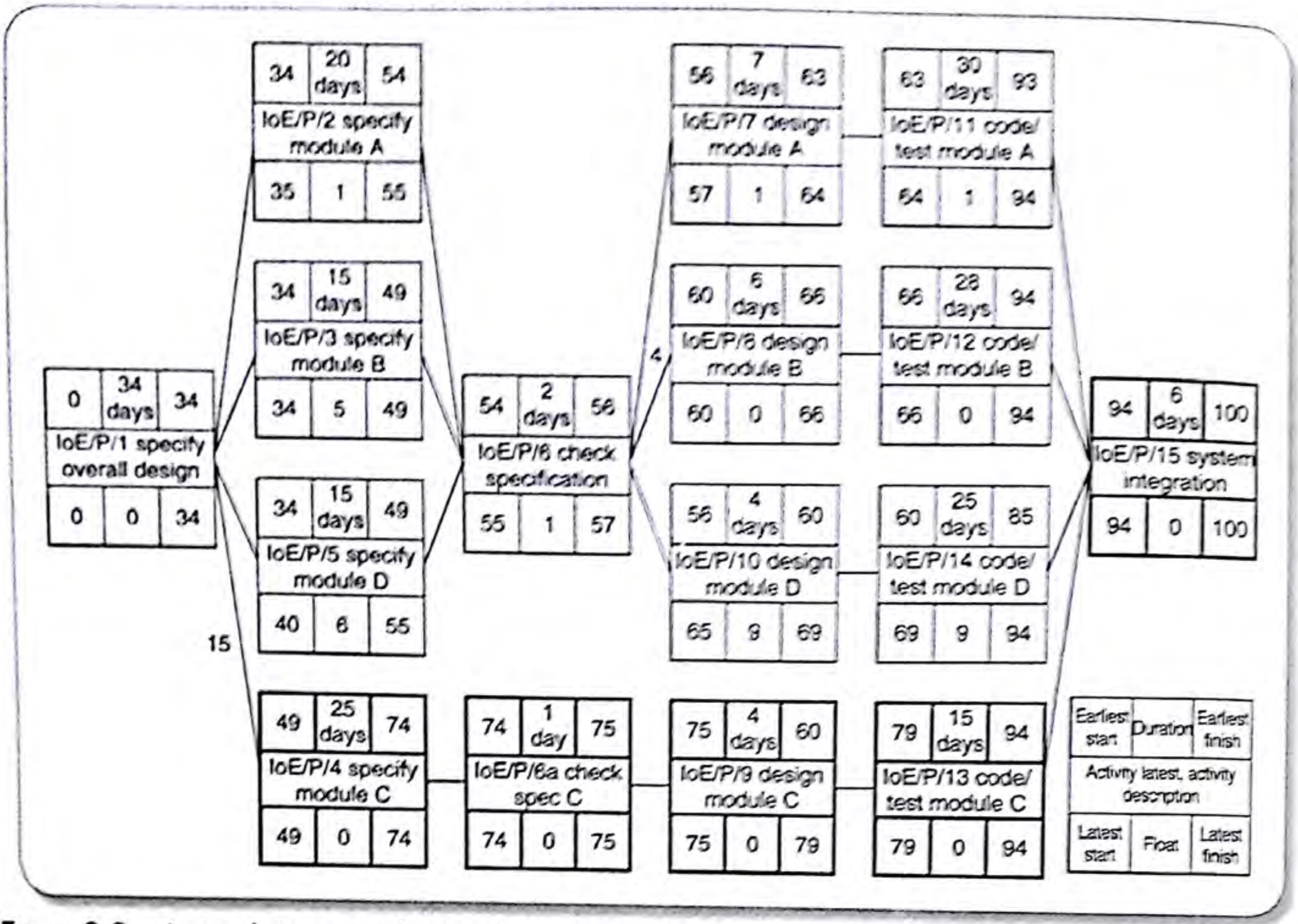


FIGURE 8.8 Amanda's revised precedence network showing scheduled start and completion dates

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.

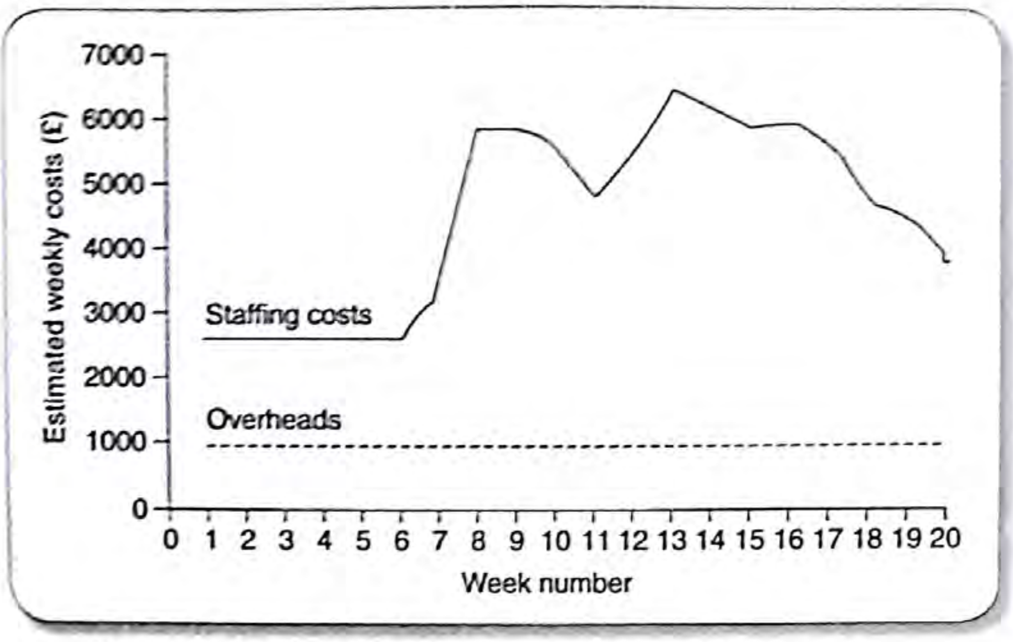


Figure 8.9 Weekly project costs for the IOE project

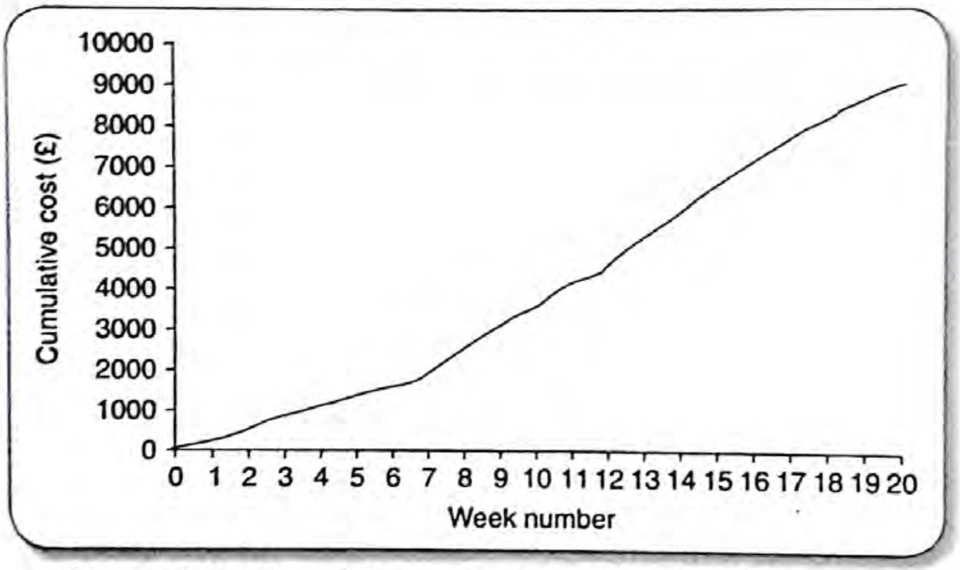


Figure 8.10 Cumulative project costs for the IOE project

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).

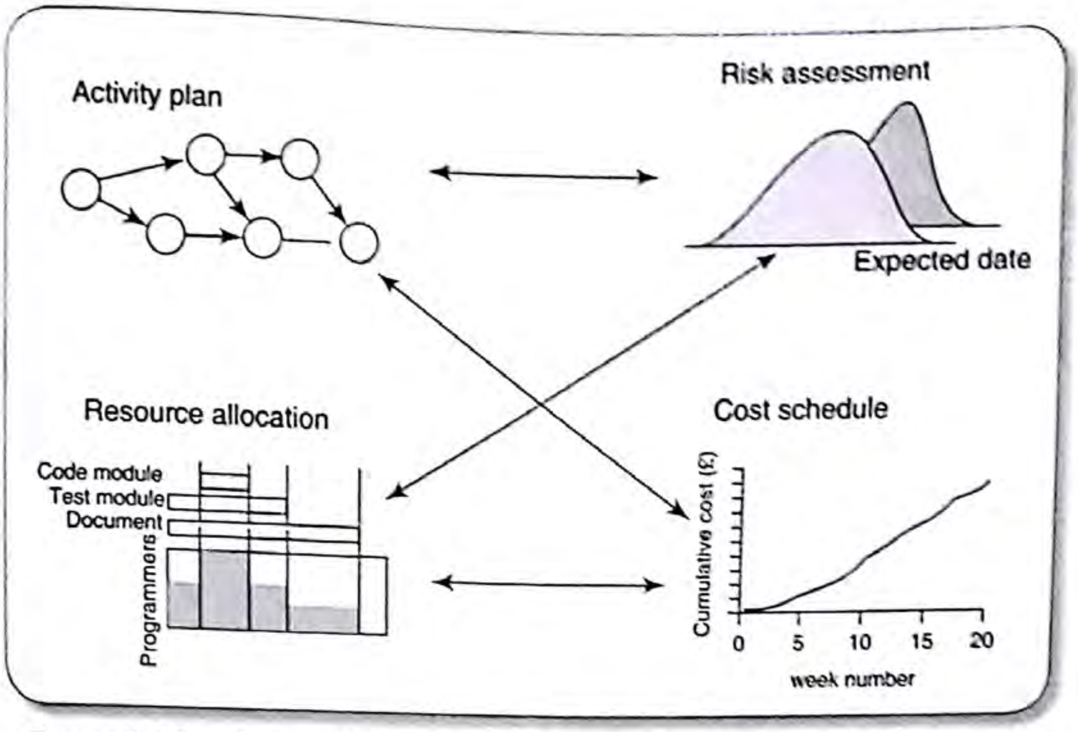


FIGURE 8.11 Successful project scheduling is not a simple sequence

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.

9 Monitoring and Control

Learning Objectives

- Monitor the progress of projects
- Assess the risk of slippage
- Visualize and assess the state of a project
- Revise targets to correct or counteract drift
- Control changes to a project's requirements

9.1 Introduction

Once work schedules have been published and the project is started, attention must be focused on progress. This requires monitoring of what is happening, comparison of actual achievement against the schedule and, where necessary, revision of plans and schedules to bring the project as far as possible back on target.

In earlier chapters we have stressed the importance of producing plans that can be monitored – for example, ensuring that activities have clearly defined and visible completion points. We will discuss how information about project progress is gathered and what actions must be taken to ensure that a project meets its targets.

The final part of this chapter discusses how we can deal with changes that are imposed from outside – in particular, changes in requirements.

9.2 Creating the Framework

Exercising control over a project and ensuring that targets are met is a matter of regular monitoring – finding out what is happening and comparing it with targets. There may be a mismatch between the planned outcomes and the actual ones. Replanning may then be needed to bring the project back on target. Alternatively, the target could have to be revised. Figure 9.1 illustrates a model of the project control cycle and shows how, once the initial project plan has been published, project control is a continual process of monitoring progress against that plan and, where necessary, revising the plan to take account of deviations. It also illustrates the important steps that must be taken after completion of the project so that the experience gained in any one project can feed into the planning stages of future projects, thus allowing us to learn from past mistakes.

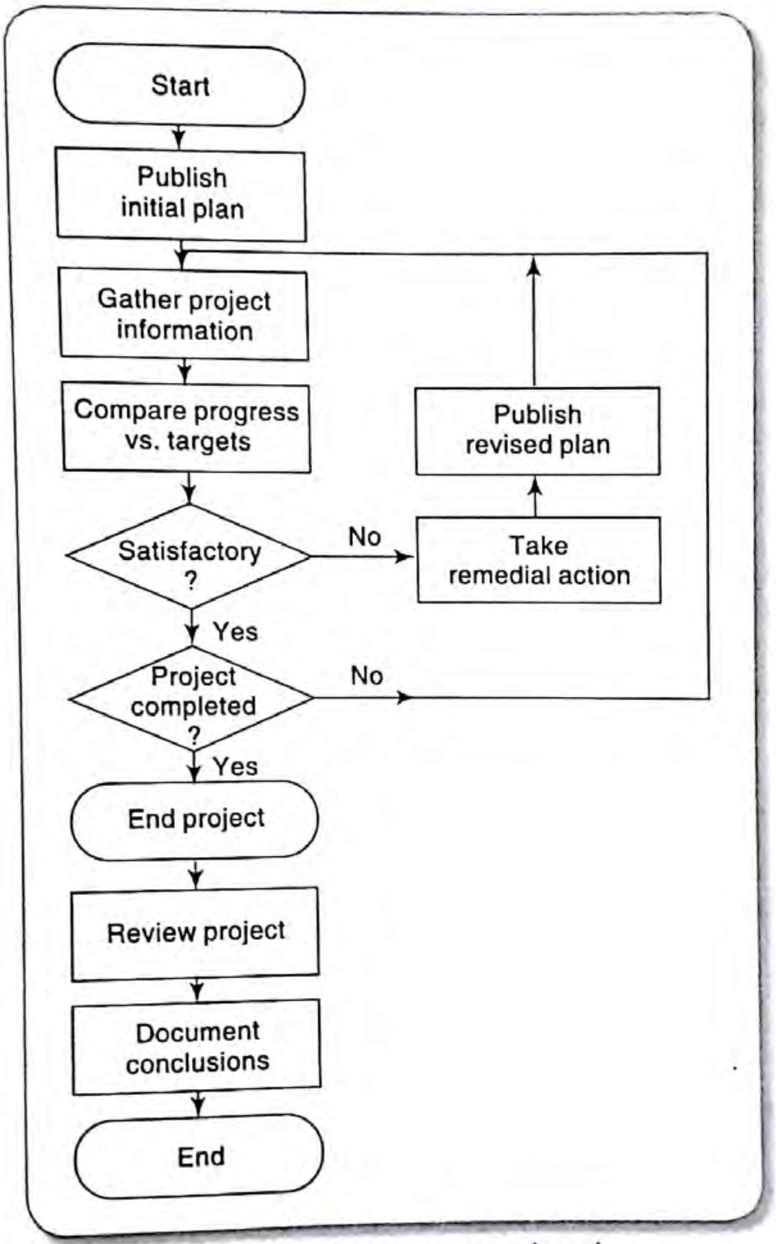


FIGURE 9.1 Project control cycle

In practice we are normally concerned with four types of shortfall – delays in meeting target dates, shortfalls in quality, inadequate functionality, and costs going over target. In this chapter we are mainly concerned with the first and last of these.

See Chapter 13 for a discussion on software quality.

Responsibility

The overall responsibility for ensuring satisfactory progress on a project is often the role of the *project steering committee, project management board* or, in PRINCE2, *Project Board.* Day-to-day responsibility will rest with the project manager and, in all but the smallest of projects, aspects of this can be delegated to team leaders.

The concept of a reporting hierarchy was introduced in Chapter 1.

Figure 9.2 illustrates the typical reporting structure found with medium and large projects. With small projects (employing around half a dozen or fewer staff) individual team members usually report directly to the project manager, but in most cases team leaders will collate reports on their section's progress and forward summaries to the project manager. These, in turn, will be incorporated into project-level reports for the steering committee and, via them or directly, progress reports for the client.

In a PRINCE2 environment, there may be a Project Assurance function reporting to the Project Board and independent of the Project Manager.

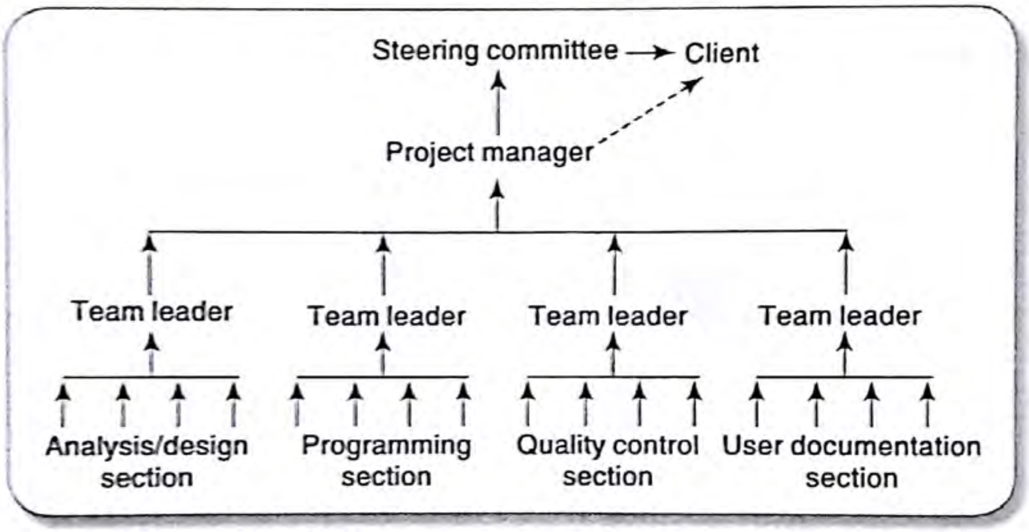


FIGURE 9.2 Project reporting structures

Chapter 12 will explore communication in a more general project context.

Reporting may be oral or written, formal or informal, and regular or ad hoc – see Table 9.1. Informal communication is necessary and important, but any such informal reporting of project progress must be complemented by formal reporting procedures – and it is those we are concerned with in this chapter.

TABLE 9.1 Categories of reporting

Report type	Examples	Comment
Oral formal regular	Weekly or monthly progress meetings	While reports may be oral, formal written minutes should be kept
Oral formal ad hoc	End-of-stage review meetings	While largely oral, likely to receive and generate written reports
Written formal regular	Job sheets, progress reports	Normally weekly using forms
Written formal ad hoc	Exception reports, change reports	
Oral informal ad hoc	Canteen discussion, social interaction	Often provides early warning; must be backed up by formal reporting

Assessing progress

Some information used to assess project progress will be collected routinely, while other information will be triggered by specific events. Wherever possible, this information should be objective and tangible – whether or not a particular report has been delivered, for example. Sometimes, however, assessment will have to depend on estimates of the proportion of the current activity that has been completed.

Setting checkpoints

It is essential to set a series of checkpoints in the initial activity plan. Checkpoints may be:

- Regular (monthly, for example)
- Tied to specific events such as the production of a report or other deliverable

The PRINCE2 standard described in Appendix A has its own terminology.

Taking snapshots

The frequency of progress reports will depend upon the size and degree of risk of the project. Team leaders, for example, may want to assess progress daily (particularly when employing inexperienced staff) whereas project managers may find weekly or monthly reporting appropriate. In general, the higher the level, the less frequent and less detailed the reporting needs to be.

At the level of individual developers, however, strong arguments exist for the formal weekly collection of information. This ensures that information is provided while memories are still relatively fresh and provides a mechanism for individuals to review and reflect upon their progress. If reporting is to be weekly then it makes sense to have basic units of work that last about a week.

Recall that in Chapter 4, Beck recommended weekly work cycles in an XP environment.

Major, or project-level, progress reviews will generally take place at particular points during the life of a project – commonly known as *review points* or *control points*. PRINCE2, for example, designates a series of checkpoints where the status of work in a project or for a team is reviewed. At the end of each project Stage, PRINCE2 provides for an End Stage Assessment where an assessment of the project and consideration of its future are undertaken.

9.3 Collecting the Data

As a rule, managers will try to break down long activities into more controllable tasks of one or two weeks' duration. However, it will still be necessary to gather information about partially completed activities and, in particular, forecasts of how much work is left to be completed. It can be difficult to make such forecasts accurately.

Exercise 9.1

A software developer working on Amanda's project has written the first 250 lines of a Java program that is estimated to require 500 lines of code. Explain why it would be unreasonable to assume that the programming task is 50% complete.

How might you make a reasonable estimate of how near completion it might be?

Where there is a series of products, partial completion of activities is easier to estimate. Counting the number of record specifications or screen layouts produced, for example, can provide a reasonable measure of progress.

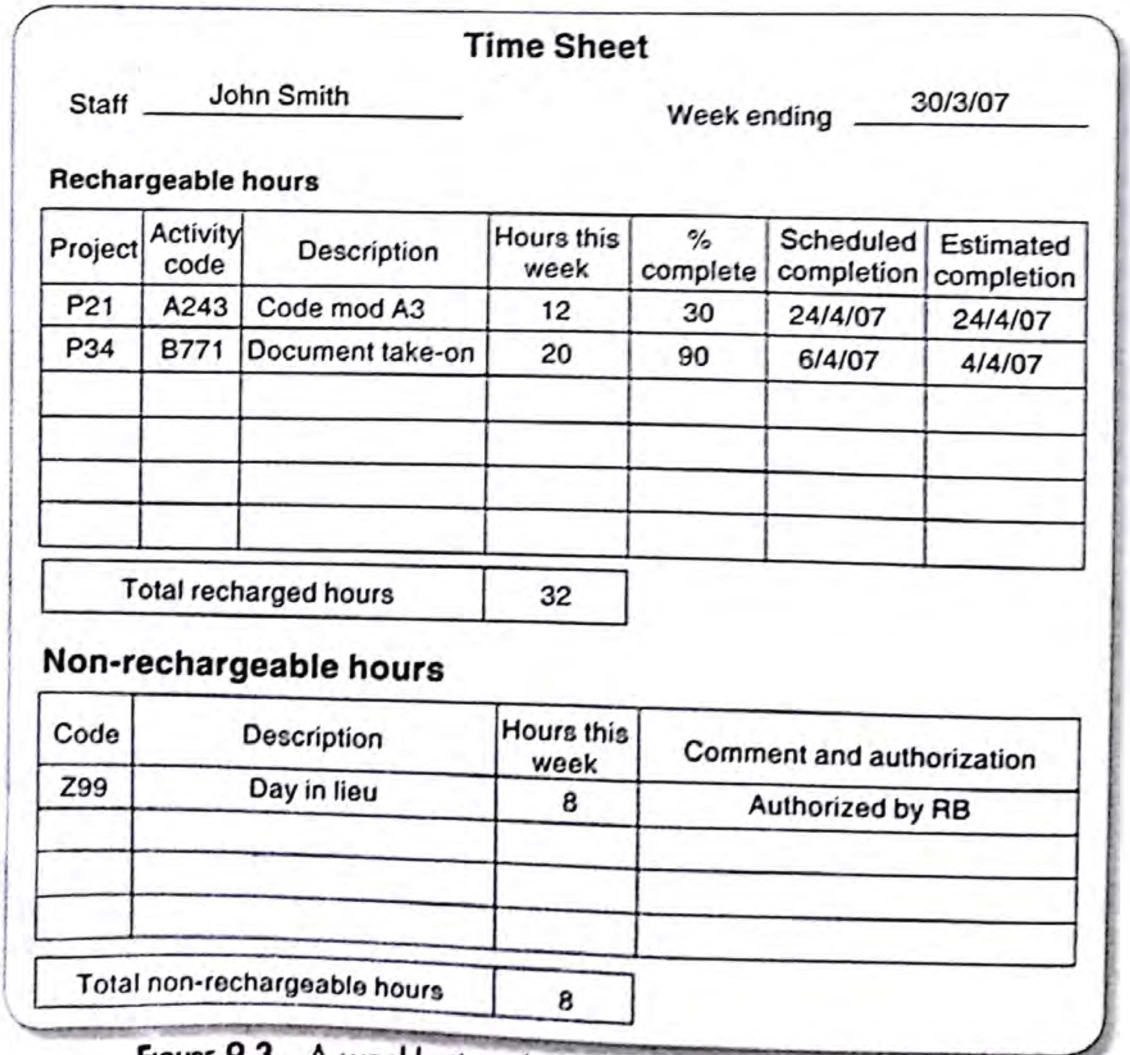
In some cases, intermediate products can be used as in-activity milestones. The first successful compilation of a program, for example, might be considered a milestone even though it is not a final product.

Partial completion reporting

Many organizations use standard accounting systems with weekly timesheets to charge staff time to individual jobs. The staff time booked to a project indicates the work carried out and the charges to the project. It does not, however, tell the project manager what has been produced or whether tasks are on schedule.

It is therefore common to adapt or enhance existing accounting data collection systems to meet the needs of project control. Weekly timesheets, for example, are frequently adapted by breaking jobs down to activity level and requiring information about work done in addition to time spent. Figure 9.3 shows an example of a report form, in this case requesting information about likely slippage of completion dates as well as estimates of completeness. Other reporting templates are possible. For example,

Weekly timesheets are a valuable source of information about resources used. They are often used to provide information about what has been achieved. However, requesting partial completion estimates where they cannot be obtained from objective measures encourages the 99%



Time Sheet

Staff John Smith Week ending 30/3/07

Rechargeable hours

Project	Activity code	Description	Hours this week	% complete	Scheduled completion	Estimated completion
P21	A243	Code mod A3	12	30	24/4/07	24/4/07
P34	B771	Document take-on	20	90	6/4/07	4/4/07

Total recharged hours	32

Non-rechargeable hours

Code	Description	Hours this week	Comment and authorization
Z99	Day in lieu	8	Authorized by RB

Total non-rechargeable hours	8

FIGURE 9.3 A weekly timesheet and progress review form

rather than ask for estimates of percentage complete, some managers would prefer to ask for the number of hours already worked on the task and an estimate of the number of hours needed to finish the task off.

Red/amber/green (RAG) reporting

One popular way of overcoming the objections to partial completion reporting is to avoid asking for estimated completion dates, but to ask instead for the team members' estimates of the likelihood of meeting the planned target date.

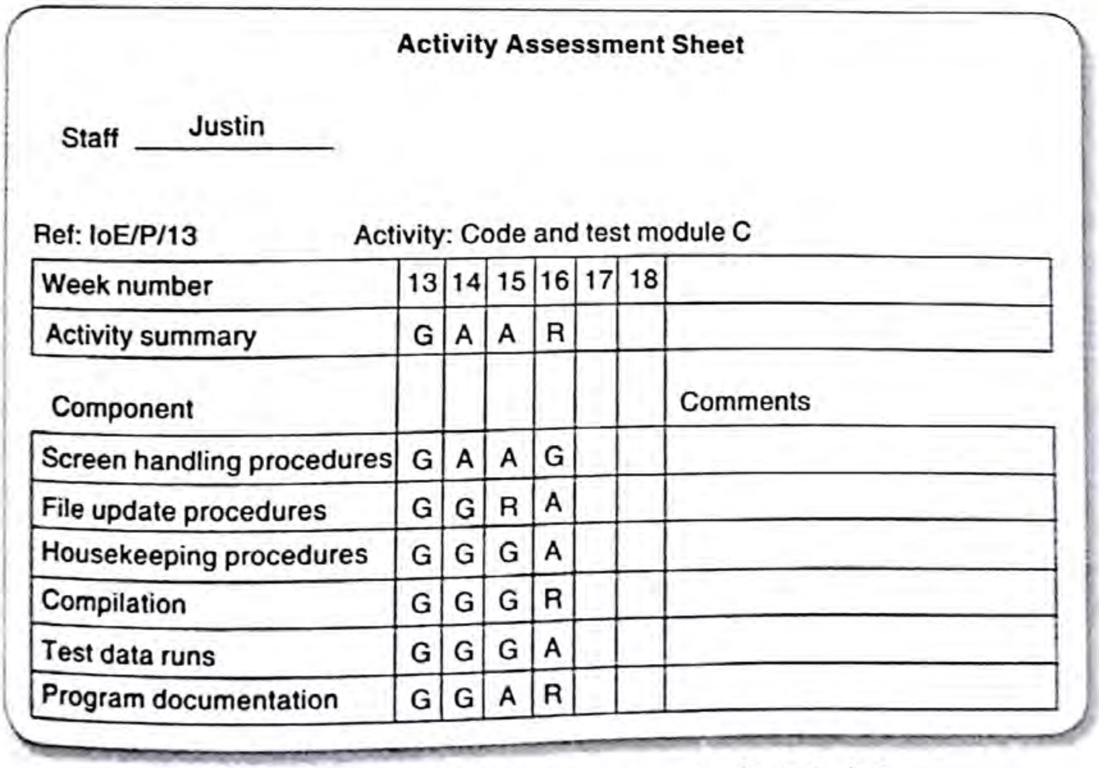
Complete syndrome – tasks are reported as on time until 99% complete, and then stay at 99% complete until finished.

One way of doing this is the traffic-light method. This consists of the following steps:

- Identify the key (first level) elements for assessment in a piece of work
- Break these key elements into constituent elements (second level)
- Assess each of the second-level elements on the scale *green* for 'on target', *amber* for 'not on target but recoverable', and *red* for 'not on target and recoverable only with difficulty'
- Review all the second-level assessments to arrive at first-level assessments
- Review first- and second-level assessments to produce an overall assessment

There are a number of variations on the traffic-light technique. The version described here is in use in IBM and is described in A. Down, M. Coleman and P. Absolon (1994) *Risk Management for Software Projects*, McGraw-Hill.

For example, Amanda decides to use a version of the traffic-light method for reviewing activities on the IOE project. She breaks each activity into a number of component parts (deciding, in this case, that a further breakdown is unnecessary) and gets the team members to complete a return at the end of each week. Figure 9.4 illustrates Justin's completed assessment at the end of week 16.



Activity Assessment Sheet

Staff Justin

Ref: IoE/P/13 Activity: Code and test module C

Week number	13	14	15	16	17	18	
Activity summary	G	A	A	R			
Component							Comments
Screen handling procedures	G	A	A	G			
File update procedures	G	G	R	A			
Housekeeping procedures	G	G	G	A			
Compilation	G	G	G	R			
Test data runs	G	G	G	A			
Program documentation	G	G	A	R			

FIGURE 9.4 A traffic-light assessment of IoE/P/13

Note that this form refers only to uncompleted activities. Justin would still need to report activity completions and the time spent on activities.

Traffic-light assessment highlights only risk of non-achievement; it is not an attempt to estimate work done or to quantify expected delays.

Following completion of assessment forms for all activities, the project manager uses these as a basis for evaluating the overall status of the project. Any critical activity classified as amber or red will require further consideration and often leads to a revision of the project schedule. Non-critical activities are likely to be considered as a problem if they are classified as red, especially if all their float is likely to be consumed.

9.4 Review

From a manager's perspective, review of work products is an important mechanism for monitoring the progress of a project and ensuring the quality of the work products.

Every project is developed through iterations over a large number of work products such as requirements document, design document, project plan document, code, etc. Each of these work products can have a large number of defects in them due to mistakes committed by the development team members. It is necessary to eliminate as many defects in these work products to realize a product of acceptable quality. Testing is an effective defect removal mechanism. However, testing is applicable to only executable code. How can the defects from the non-executable work products such as requirements document and design document be removed? Review is a very effective technique to remove defects from all work products including code. In fact, review has been acknowledged to be more cost-effective in removing defects as compared to testing. Early review techniques focused on code and systematic review techniques were developed for this specific purpose. But over the years, review techniques have become extremely popular and have been generalized for use with other work products.

Utility of review

Besides being a cost-effective defect removal mechanism, review of any work product has several other benefits including the following mentioned below:

- Review usually helps to identify any deviation from standards, including issues that might affect maintenance of the software.
- Reviewers suggest ways to improve the work product such as using algorithms that are more time or space efficient, specific work simplifications, better technology opportunities that can be exploited, etc.
- In addition to defect identification, a review meeting often provides learning opportunities to not only the author of a work product, but also the other participants of the review meeting. The lessons acquired from a review meeting allows participants to avoid committing similar defects that were discussed in the review meeting and also allows them to make use of the best practices that were suggested.
- The review participants gain a good understanding of the work product under review, making it easier for them to interface or use the work product in their work.

Exercise 9.2

For removing bugs from code, would review or testing be more cost-effective? Explain the reason behind your answer.

Candidate work products for review

All interim and final work products are usually candidates for review. Usually, the work products considered to be suitable candidates for review are as follows:

- Requirements specification documents
- User interface specification and design documents
- Architectural, high-level, and detailed design documents
- Test plan and the designed test cases
- Project management plan and configuration management plan

Review roles

In every review meeting, a few key roles need to be assigned to the review team members. These roles are moderator, recorder and the reviewers. The moderator plays a key role in the review process. The principal responsibilities of the moderator include scheduling and convening meetings, distributing review materials, leading and moderating the review sessions, ensuring that the defects are tracked to closure. The main role of the recorder is to record the defects found, the time, and effort data. The review team members review the work product and give specific suggestions to the author about the existing defects and also point out ways to improve the work product.

In the following, we will first discuss a generic review process. Subsequently, we shall discuss the importance of collection of all relevant data to the success of the review process.

Review process

Review of any work product consists of the following four important activities, viz. planning, review preparation and overview, review meeting, rework and follow-up. A review process model is shown in Figure 9.5. The model in Figure 9.5 captures the sequence of the activities that need to be carried out, the input to the activities, and the output produced from the activities. In the following, we briefly discuss these review activities.

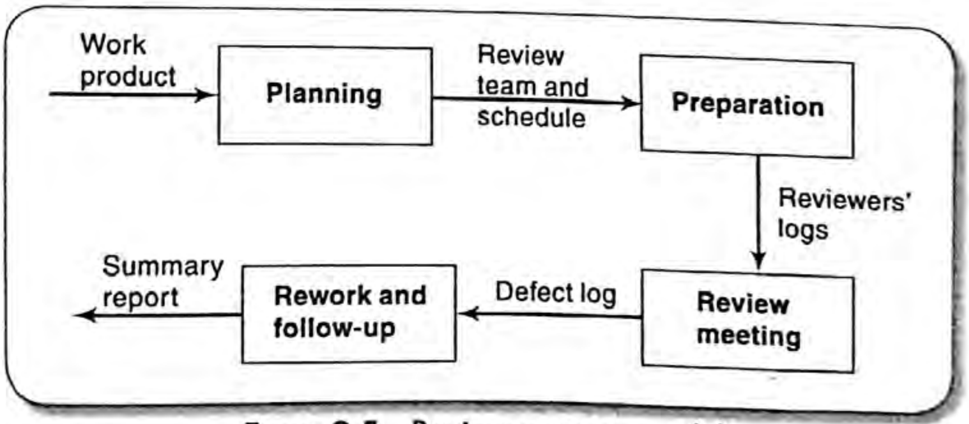


FIGURE 9.5 Review process model

- *Planning* Once the author of a work product is ready for submitting the work for review; the project manager nominates a moderator. A moderator can be someone who is familiar with the work product. In consultation with the moderator, the project manager nominates the other members of the review team. Usually, the review process works best when the number of members is between five and seven.

The effectiveness of review drastically reduces if there are less than three members. The review team is usually selected from the following types of project team members.

- The author of the preceding work product based on which the work product under review was developed
- The member who would use the work product under review
- Peers of the author
- The authors of the work products that would interface with the work product under review

The moderator usually schedules all review meetings.

- *Preparation* To initiate the review process, the moderator convenes a brief preparation meeting. In the preparation meeting, copies of the work product are distributed to the review team members. The author presents a brief overview of the work product. The moderator highlights the objectives of the review. The reviewers then individually carry out review and record their observations in separate documents called review logs.
- *Review Meeting* In the review meeting the reviewer's give their comments based on the logs they have prepared beforehand. The comments may pertain to a defect, work simplification, maintainability, etc. The author responds to the reviewers' comments and in this discussion other reviewers may also take part. The moderator ensures that the discussions remain focused and productive. The recorder scribes all the defects and points that the author agrees to, as well as the review statistics in the form of a review log.
- *Rework* The author addresses all the issues raised by the reviewers by carrying out the necessary modifications to the work product and prepares a rejoinder to all the points scribed in the review log. The rejoinder records the exact ways in which the comments have been taken care of by the author. The corrected work product along with the author's rejoinder is circulated among all the review team members. In a final brief meeting, the review team members check whether all the issues scribed in the review log have been resolved satisfactorily. At the end of this meeting, a final summary report of the review is prepared.

Data collection

Since a review meeting is a completely human endeavour, unless the data representing the results of the meetings is properly recorded, it can get lost. In addition to recording all defects, the data about the time spent by the reviewers in the review activity must also be captured. A record of the defect data is needed for tracking defects in the project.

The different reports in which the review data are captured are as follows:

1. *Review Preparation Log* Each reviewer prepares a review preparation log. The different items recorded in it by the reviewer are the data about defects he observes, their locations, their criticality, and the total time spent in doing the review of the work product.
2. *Review Log* In the review log only those defects that are agreed to by the author are logged. Defect logs are a crucial record since these help in tracking all defects to closure.
3. *Review Summary Report* This report summarizes the review data and presents an overall picture of the review. It contains information regarding the total defects and the amount of time spent on each of the review process activities.

9.5 Visualizing Progress

Having collected data about project progress, a manager needs some way of presenting that data to greatest effect. In this section, we look at some methods of presenting a picture of the project and its future. Some of these methods (such as Gantt charts) provide a static picture, a single snapshot, whereas others (such as timeline charts) try to show how the project has progressed and changed through time.

Gantt chart

One of the simplest and oldest techniques for tracking project progress is the Gantt chart. This is essentially an activity bar chart indicating scheduled activity dates and durations, frequently augmented with activity floats. Reported progress is recorded on the chart (normally by shading activity bars) and a 'today cursor' provides an immediate visual indication of which activities are ahead or behind schedule. Figure 9.6 shows part of Amanda's Gantt chart as at the end of Tuesday of week 17. 'Code and test module D' has been completed ahead of schedule and 'Code and test module A' appears also to be ahead of schedule. The coding and testing of the other two modules are behind schedule.

Henry Gantt (1861–1919) was an industrial engineer interested in the efficient organization of work.

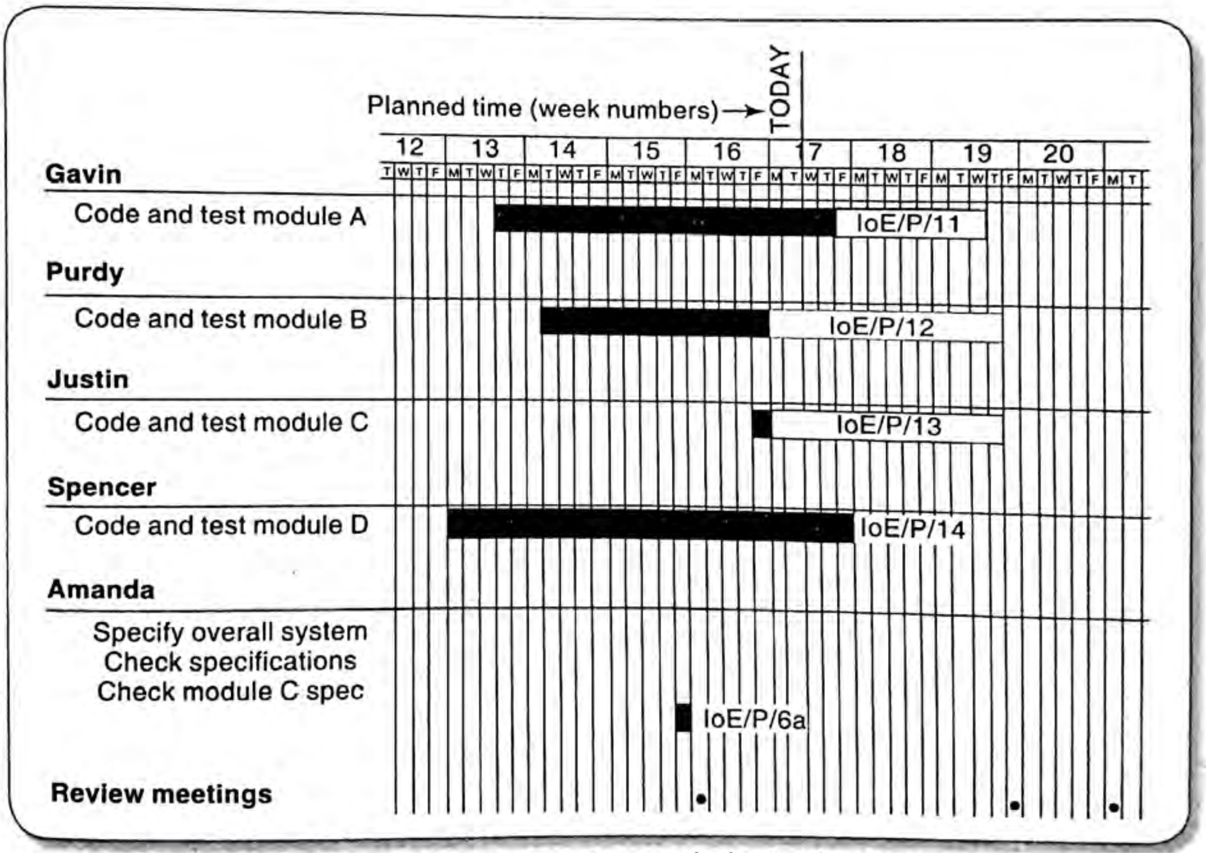


FIGURE 9.6 Part of Amanda's Gantt chart with the 'today cursor' in week 17

Slip chart

A slip chart (Figure 9.7) is a very similar alternative favoured by some project managers who believe it provides a more striking visual indication of those activities that are not progressing to schedule – the more

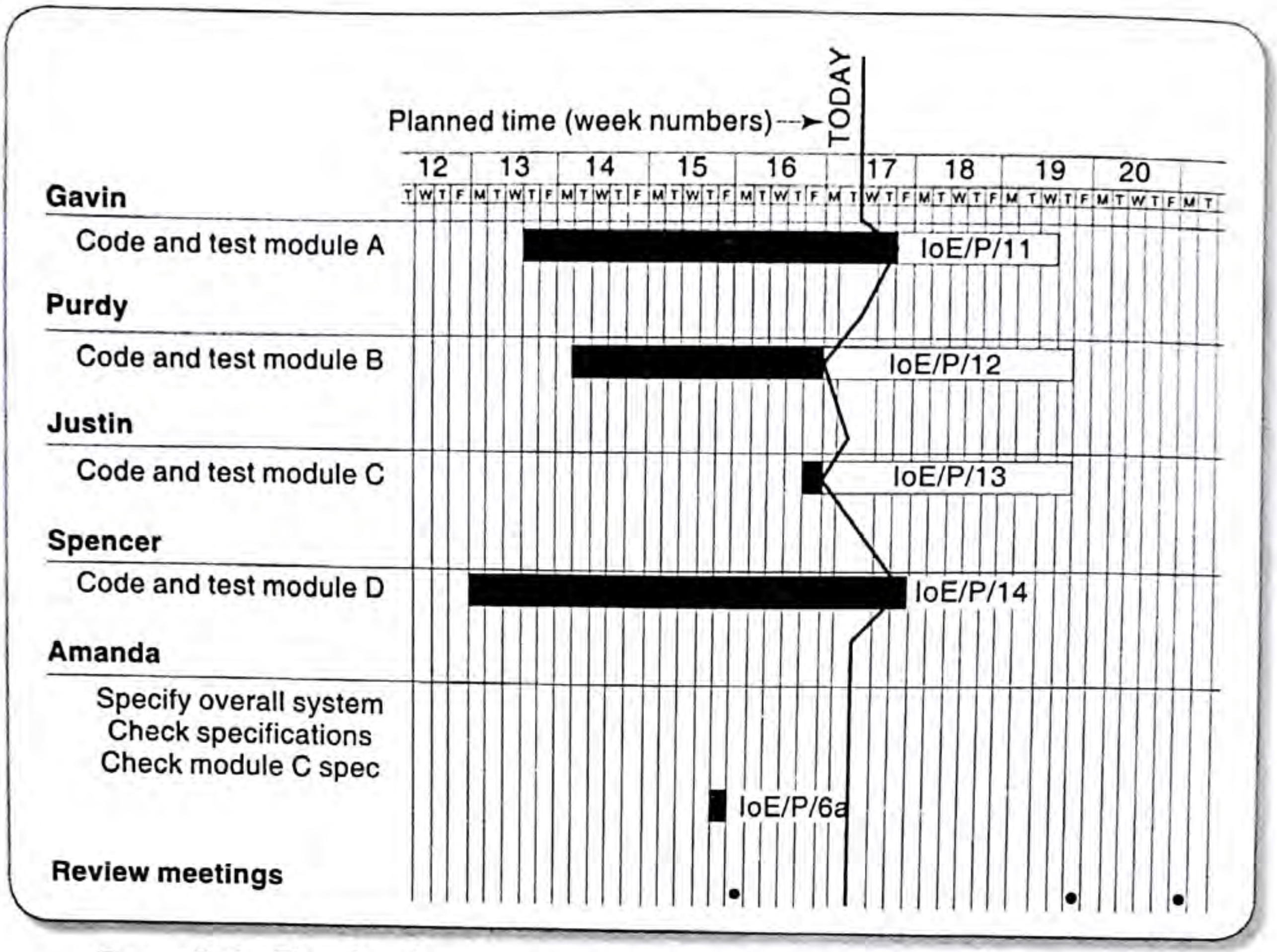


FIGURE 9.7 The slip chart emphasizes the relative position of each activity

the slip line bends, the greater the variation from the plan. Additional slip lines are added at intervals and, as they build up, the project manager will gain an idea as to whether the project is improving (subsequent slip lines bend less) or not. A very jagged slip line indicates a need for rescheduling.

Timeline

One disadvantage of the charts described so far is that they do not show clearly the slippage of the project completion date through the life of the project. Analysing and understanding trends in the project so far allows us to predict the future progress of the project. For example, if a project is behind schedule because so far productivity has not been as high as assumed at the planning stage, it is likely that the scheduled completion date will be pushed back even further unless action is taken to compensate for or improve productivity.

The timeline chart is a method of recording and displaying the way in which targets have changed throughout the duration of the project.

Figure 9.8 shows a timeline chart for Brigette's project at the end of the sixth week. Planned time is plotted along the horizontal axis and elapsed time down the vertical axis. The lines meandering down the chart represent scheduled activity completion dates – at the start of the project 'analyse existing system' is scheduled to be completed by the Tuesday of week 3, 'obtain user requirements' by Thursday of week 5, 'issue tender', the final activity, by Tuesday of week 9, and so on.

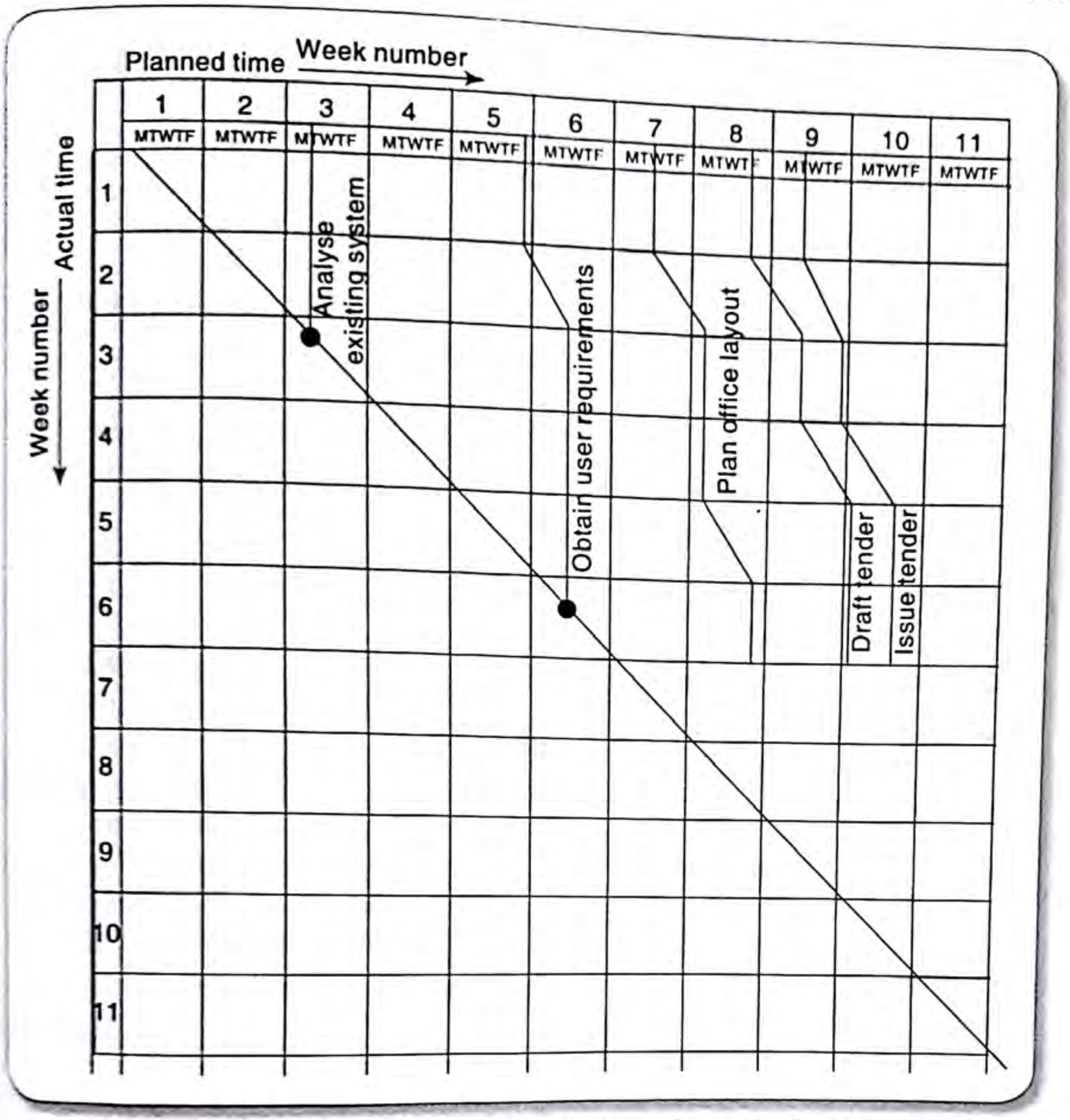


FIGURE 9.8 Brigette's timeline chart at the end of week six

Brigette's timeline chart contains only the critical activities for her project;
● indicates actual completion of an activity.

For the sake of clarity, the number of activities on a timeline chart must be limited. Using colour helps to distinguish activities, particularly where lines cross

At the end of the first week Brigette reviews these target dates and leaves them as they are – lines are therefore drawn vertically downwards from the target dates to the end of week 1 on the actual time axis.

At the end of week 2, Brigette decides that 'obtain user requirements' will not be completed until Tuesday of week 6 – she therefore extends that activity line diagonally to reflect this. The other activity completion targets are also delayed correspondingly.

By the Tuesday of week 3, 'analyse existing system' is completed and Brigette puts a blob on the diagonal timeline to indicate that this has happened. At the end of week 3 she decides to keep to the existing targets.

At the end of week 4 she adds another three days to 'draft tender' and 'issue tender'.

Note that, by the end of week 6, two activities have been completed and three are still unfinished. Up to this point she has revised target dates on three occasions and the project as a whole is running seven days late.

Exercise 9.3

By the end of week 8 Brigette has completed planning the office layout but finds that drafting the tender is going to take one week longer that originally anticipated.

What will Brigette's timeline chart look like at the end of week 8?

If the rest of the project goes according to plan, what will Brigette's timeline chart look like when the project is completed?

The timeline chart is useful both during the execution of a project and as part of the post-implementation review. Analysis of the timeline chart, and the reasons for the changes, can indicate failures in the estimation process or other errors that might, with that knowledge, be avoided in future.

9.6 Cost Monitoring

Project costs may be monitored by a company's accounting system. By themselves, they provide little information about project status.

Expenditure monitoring is an important component of project control, not only in itself, but also because it provides an indication of the effort that has gone into (or at least been charged to) a project. A project might be on time but only because more money has been spent on activities than originally budgeted. A cumulative expenditure chart such as that shown in Figure 9.9 provides a simple method of comparing actual and planned expenditure. By itself it is not particularly meaningful – Figure 9.9 could, for example, illustrate a project that is running late or one that is on time but has shown substantial costs savings. We need to take account of the current status of the project activities before attempting to interpret the meaning of recorded expenditure.

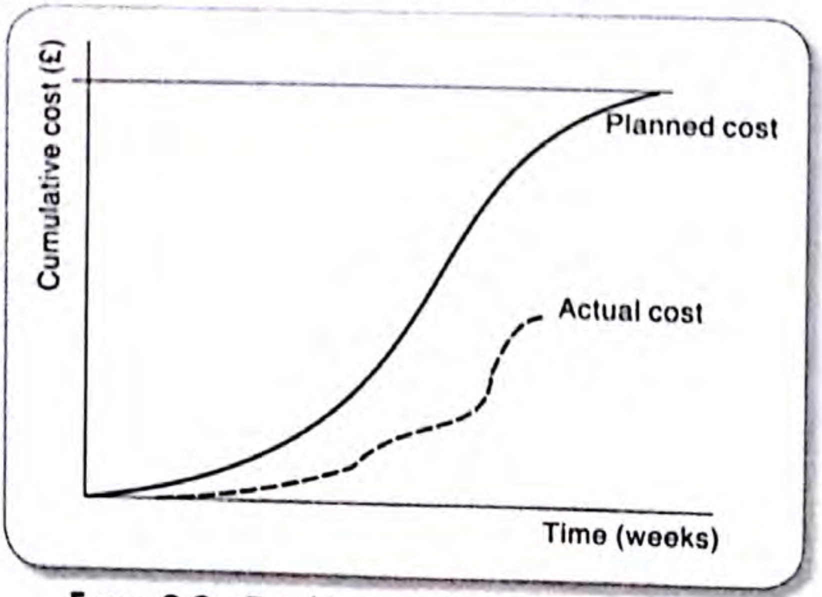


FIGURE 9.9 Tracking cumulative expenditure

Project costs augmented by project monitoring can be used to generate forecasts of future costs.

Cost charts become much more useful if we add projected future costs calculated by adding the estimated costs of uncompleted work to the costs already incurred. Where a computer-based planning tool is used, revision of cost schedules is generally provided automatically once actual expenditure has been recorded. Figure 9.10 illustrates the additional information available once the revised cost schedule is included – in this case it is apparent that the project is behind schedule and over budget.

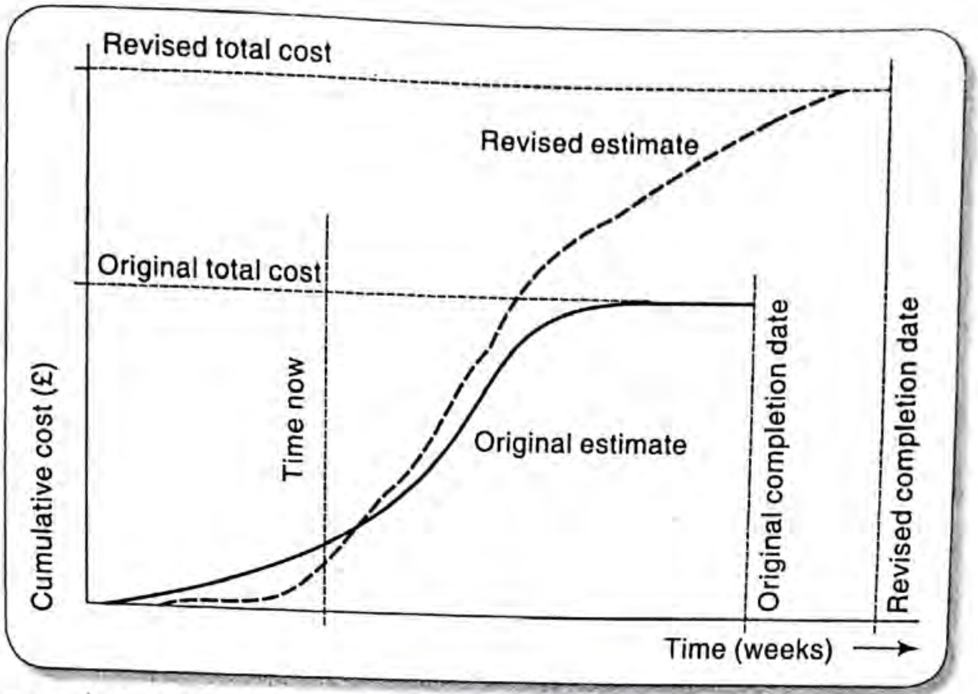


Figure 9.10 The cumulative expenditure chart can also show revised estimates of cost and completion date

9.7 Earned Value Analysis

Earned value analysis has gained in popularity in recent years and may be seen as a refinement of the cost monitoring discussed in the previous section. It originated in the USA's Department of Defence (DOD) as a part of a set of measures to control projects being carried out by contractors for the DOD. Earned value analysis is based on assigning a 'value' to each task or work package (as identified in the WBS) based on the original expenditure forecasts. One way of looking at this is as the equivalent of the price that might be agreed by a contractor to do the unit of work. The assigned value is the original budgeted cost for the item and is known as the *planned value* (PV) or *budgeted cost of work scheduled* (BCWS). A task that has not started is assigned an earned value of zero and when it has been completed, it, and hence the project, is credited with the original planned value of the task. The total value credited to a project at any point is known as the *earned value* (EV) or budgetted cost of work performed (BCWP) and this can be represented as a money value, an amount of staff time or as a percentage of the PV. EV is thus analogous to the agreed price to be paid to the contractor once the work is completed.

Earned value analysis, also known as budgeted cost of work performed, is recommended by a number of agencies including the US and Australian departments of defence. It is also recommended in BS 6079.

Where tasks have been started but are not yet complete, some consistent method of assigning an earned value must be applied. Common methods in software projects are:

- *the 0/100 technique:* where a task is assigned a value of zero until such time that it is completed when it is given a value of 100% of the budgeted value;
- *the 50/50 technique:* where a task is assigned a value of 50% of its value as soon as it is started and then given a value of 100% once it is complete – this matches some contractual arrangements where a contractor is given half the agreed price when starting the work, perhaps to help pay for raw materials, and the remainder on successful completion;

- *the 75/25 technique:* where the task is assigned 75% on starting and 25% on completion – this is often used when a large item of equipment is being bought: 75% is paid when the equipment is actually delivered and the remainder when installation and testing has been satisfactorily completed;
- *the milestone technique:* where a task is given a value based on the achievement of milestones that have been assigned values as part of the original budget plan;
- *percentage complete:* in some cases there may be a way of objectively measuring the amount of work completed – for example, as part of the implementation of an information system, a number of data records have to be manually typed into a database and the actual number so far completed can be objectively counted.

Of these, we prefer the 0/100 technique for software development. The 50/50 technique can give a false sense of security by over-valuing the reporting of activity starts. The milestone technique might be appropriate for activities with a long duration estimate but, in such cases, it is better to break that activity into a number of smaller ones.

Baseline budget

The first stage in setting up an earned value analysis is to create the *baseline budget*. The baseline budget is based on the project plan and shows the forecast growth in earned value through time. Earned value may be measured in monetary values but, in the case of staff-intensive projects such as software development, it is common to measure earned value in person-hours or workdays. Amanda's baseline budget, based on the schedule shown in Figure 8.7, is shown in Table 9.2 and diagrammatically in Figure 9.11. Notice that she has based her baseline budget on workdays and is using the 0/100 technique for crediting earned value to the project.

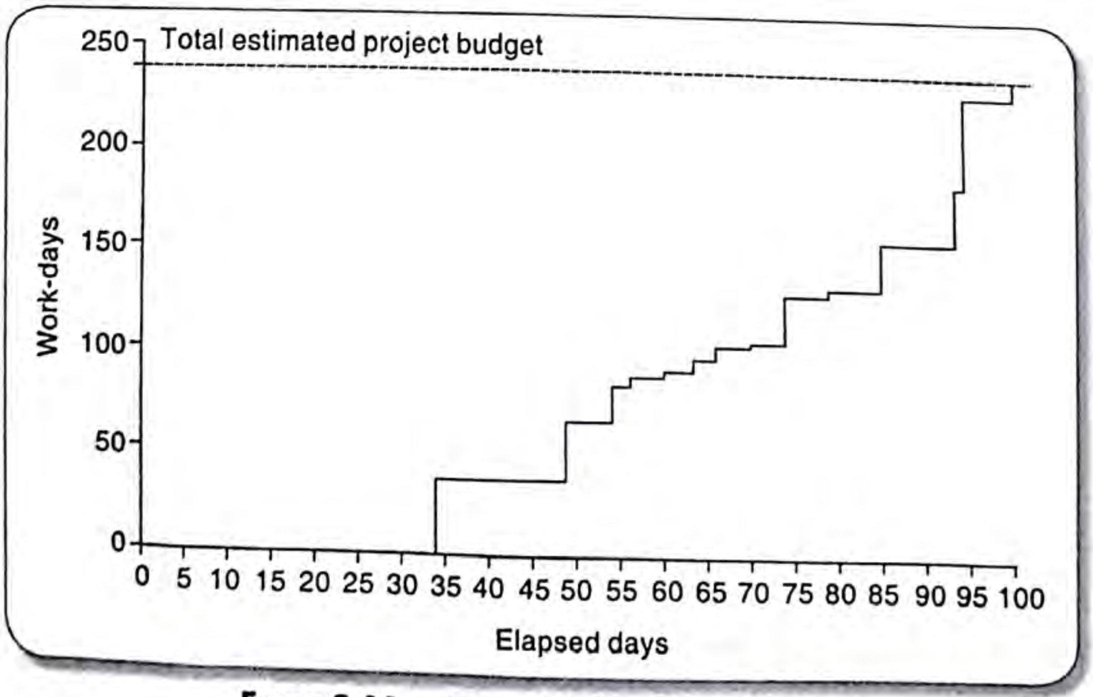


FIGURE 9.11 Amanda's baseline budget

TABLE 9.2 Amanda's baseline budget calculation

Task	Budgeted workdays	Scheduled completion	Cumulative workdays	% cumulative earned value
Specify overall system	34	34	34	14.35
Specify module B	15	49	64	27.00
Specify module D	15	49		
Specify module A	20	54	84	35.44
Check specifications	2	56	86	36.28
Design module D	4	60	90	37.97
Design module A	7	63	97	40.93
Design module B	6	66	103	43.46
Specify module C	25	74	128	54.01
Check module C spec	1	75	129	54.43
Design module C	4	79	133	56.12
Code and test module D	25	85	158	66.67
Code and test module A	30	93	188	79.32
Code and test module B	28	94	231	97.47
Code and test module C	15	94		
System integration	6	100	237	100.00

Amanda's project is not expected to be credited with any earned value until day 34, when the activity 'specify overall system' is to be completed. This activity was forecast to consume 34 person-days and it will therefore be credited with 34 person-days of earned value when it has been completed. The other steps in the baseline budget chart coincide with the scheduled completion dates of other activities.

Monitoring earned value

Having created the baseline budget, the next task is to monitor earned value as the project progresses. This is done by monitoring the completion of tasks (or activity starts and milestone achievements in the case of the other crediting techniques).

Exercise 9.4

Figure 9.12 shows Amanda's earned value analysis at the start of week 12 of the project. Note that here both PV and EV are measured in 'work-days' and that the 0/100 rule is being applied. The earned value (EV) is clearly lagging behind the baseline budget, indicating that the project is behind schedule.

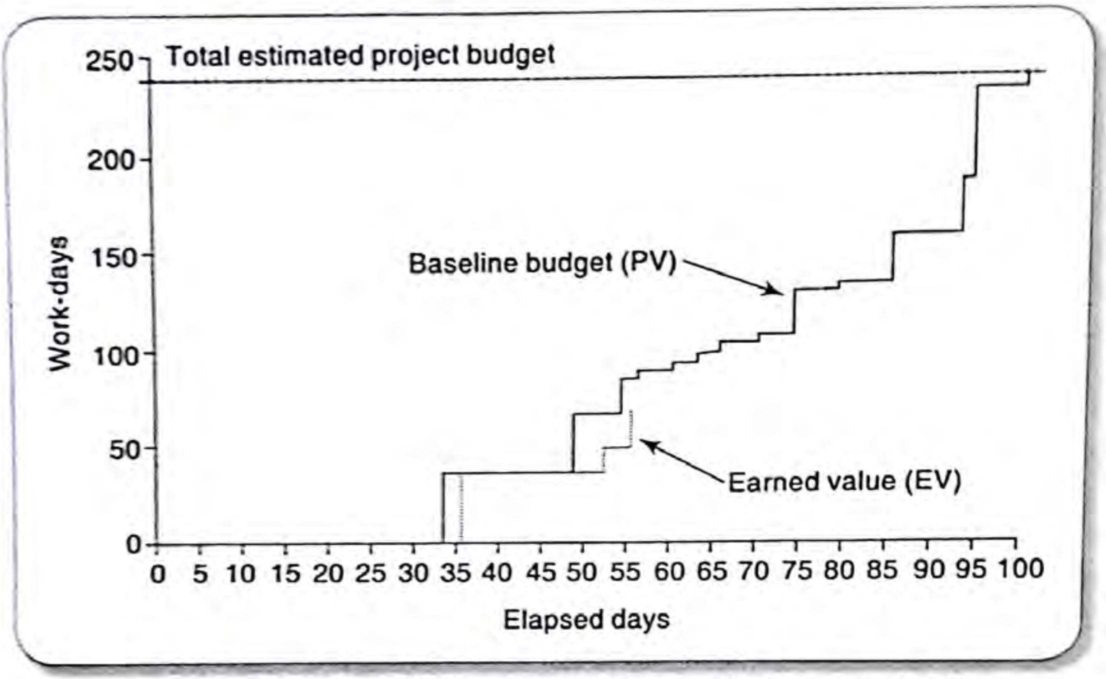


FIGURE 9.12 Amanda's earned value analysis at week 12

By studying Figure 9.13, can you tell exactly what has gone wrong with her project and what the consequences might be?

As well as recording EV, the actual cost of each task can be collected as *actual cost* (AC). This is also known as the *actual cost of work performed* (ACWP). This is shown in Figure 9.12, which, in this case, records the values as percentages of the total budgeted cost.

Figure 9.13 also illustrates the following performance statistics, which can be shown directly or derived from the earned value chart.

Schedule variance (SV)

The schedule variance is measured in cost terms as EV – PV and indicates the degree to which the value of completed work differs from that planned. Say, for example, that work with a PV of £40,000 should have been completed by now. In fact, some of that work has not been done so that the EV is only £35,000. The SV would therefore be £35,000 – £40,000, that is – £5,000. A negative SV means the project is behind schedule.

Time variance (TV)

Figure 9.13 also indicates the *time variance* (TV). This is the difference between the time when the achievement of the current earned value was planned to occur and the time now. In this case, the current EV

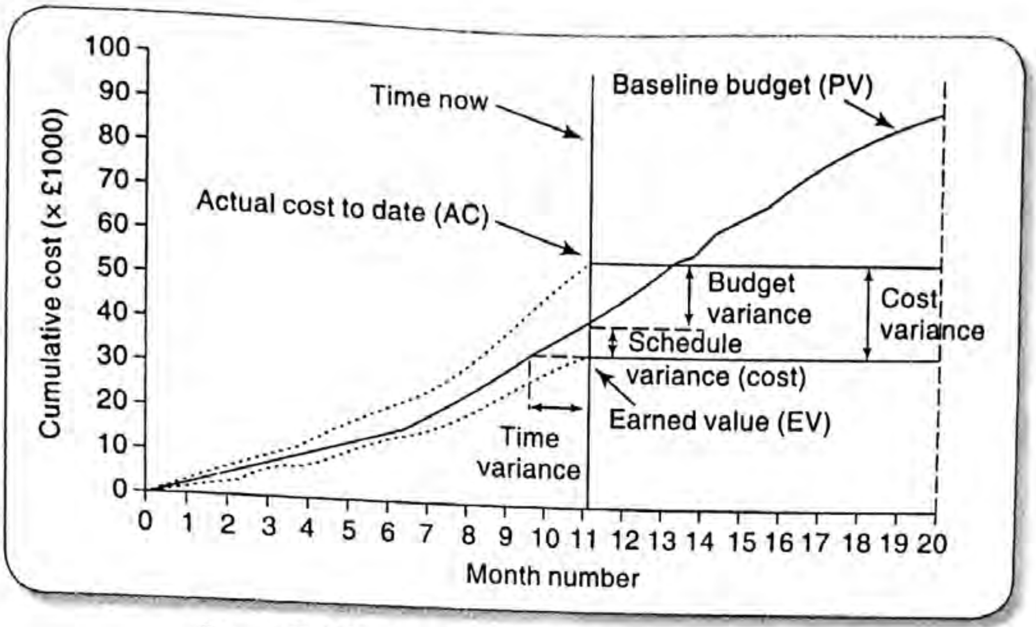


FIGURE 9.13 An earned value tracking chart

should have been achieved in the early part of month 9 and as the time now is the end of month 11, the TV is about –1.75 months.

Cost variance (CV)

This is calculated as EV – AC and indicates the difference between the earned value or budgeted cost and the actual cost of completed work. Say that when the SV above was calculated as –£5,000, £55,000 had actually been spent to get the EV. The CV in this case would have been £35,000 – £55,000 or –£20,000. It can also be an indicator of the accuracy of the original cost estimates. A negative CV means that the project is over cost.

Performance ratios

Two ratios are commonly tracked: the cost performance index (CPI = EV/AC) and the schedule performance index (SPI = EV/PV). Using the examples above, CPI would be £35,000/£55,000, that is, 0.64, and SPI would be £35,000/£40,000, that is, 0.88. The two ratios can be thought of as a 'value-for-money' indices. A value greater than one indicates that work is being completed better than planned, whereas a value of less than one means that work is costing more than and/or proceeding more slowly than planned.

CPI can be used to produce a revised cost estimate for the project (or *estimate at completion* – EAC). EAC is calculated as BAC/CPI where BAC (budget at completion) is the current projected budget for the project. If the BAC was £100,000 then a revised estimate at completion (EAC) would be £100,000/0.64 or £156,250. Similarly, the current SPI can be used to project the possible duration of the project given the current rate of progress. Say the planned total duration for the project is 23 months – in earned value terminology this is the *schedule at completion* (SAC). A time estimate at completion (TEAC) can be calculated as SAC/SPI. In this case it would be 23/0.88, that is, 26.14 months. This is only an approximate guide: where there are several parallel chains of activities being carried out concurrently – as we saw in Chapter 6 – the project duration will depend on the degree to which the activities that have been delayed are on the critical path.

In the same way that the expenditure analysis in Figure 9.9 was augmented to show revised expenditure forecasts, we can augment the simple earned value tracking chart with forecasts as illustrated in Figure 9.14.

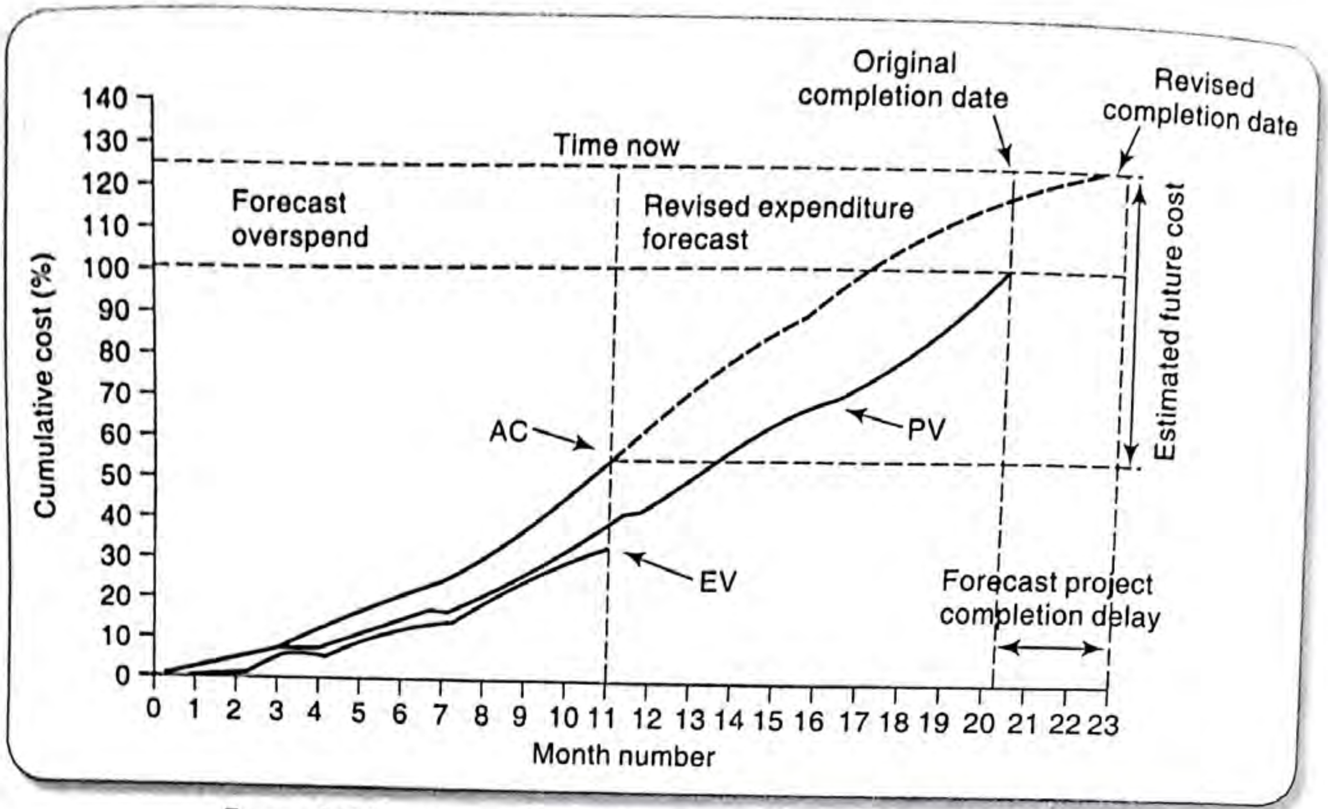


FIGURE 9.14 An earned value chart with revised forecasts

Earned value analysis has not yet gained universal acceptance for use with software development projects, perhaps largely because of the attitude that, whereas a half-built house has a value reflected by the labour and materials that have been used, a half-completed software project has virtually no value at all. This is to misunderstand the purpose of earned value analysis, which, as we have seen, is a method for tracking what has been achieved on a project – measured in terms of the budgeted costs of completed tasks or products.

Exercise 9.5

Suppose a project is to be completed in one year at the cost of £100,000. After three months, you realize that the project is 30% complete at a cost of £40,000. Assess the performance of the project.

9.8 Prioritizing Monitoring

So far we have assumed that all aspects of a project will receive equal treatment in terms of the degree of monitoring applied. We must not forget, however, that monitoring takes time and uses resources that might sometimes be put to better use!

In this section we list the priorities we might apply in deciding levels of monitoring.

- *Critical path activities* Any delay in an activity on the critical path will cause a delay in the completion date for the project. Critical path activities are therefore likely to have a very high priority for close monitoring.

- *Activities with no free float* A delay in any activity with no free float will delay at least some subsequent activities even though, if the delay is less than the total float, it might not delay the project completion date. These subsequent delays can have serious effects on our resource schedule as a delay in a subsequent activity could mean that the resources for that activity will become unavailable before that activity is completed because they are committed elsewhere.

Free float is the amount of time an activity may be delayed without affecting any subsequent activity.

- *Activities with less than a specified float* If any activity has very little float it might use up this float before the regular activity monitoring brings the problem to the project manager's attention. It is common practice to monitor closely those activities with less than, say, one week free float.
- *High-risk activities* A set of high-risk activities should have been identified as part of the initial risk profiling exercise. If we are using the PERT three-estimate approach we will designate as high risk those activities that have a high estimated duration variance. These activities will be given close attention because they are most likely to overrun or overspend.

PERT and the significance of activity duration variance was described in Chapter 7.

- *Activities using critical resources* Activities can be critical because they are very expensive (as in the case of specialized contract programmers). Staff or other resources might be available only for a limited period, especially if they are controlled outside the project team. In any event, an activity that demands a critical resource requires a high level of monitoring.

9.9 Getting the Project Back to Target

Almost any project will, at one time or another, be subject to delays and unexpected events. One of the tasks of the project manager is to recognize when this is happening (or, if possible, about to happen) and, with the minimum delay and disruption to the project team, attempt to mitigate the effects of the problem. In most cases, the project manager, at least initially, tries to ensure that the scheduled project end date remains unaffected. This can be done by shortening remaining activity durations or shortening the overall duration of the remaining project in the ways described in the next section.

A contingency plan should, of course, already exist as a result of the risk analysis methods described in Chapter 7.

It should be remembered, however, that this might not always be the most appropriate response to disruptions to a plan. There is little point in spending considerable sums in overtime payments in order to speed up a project if the customer is not overly concerned with the delivery date and there is no other valuable work for the team members once this project is completed.

The schedule is not sacrosanct – it is a plan that should be adhered to so long as it is relevant and cost-effective.

There are two main strategies to consider when drawing up plans to bring a project back on target – shortening the critical path or altering the activity precedence requirements.

Shorten the critical path

The overall duration of a project is determined by the current critical path, so speeding up non-critical path activities will not bring forward a project completion date. However, there are several ways in which this might be done.

- *Adding resources – especially staff* Exhorting staff to 'work harder' might have some effect, although frequently a more positive form of action is required, such as increasing the resources available for some critical activity. Fact-finding, for example, might be speeded up by allocating an additional

Time/cost trade-off: there is a general rule that timescales can be shortened by buying more (or more expensive) resources; sometimes this is true.

analyst to interviewing users. It is unlikely, however, that the coding of a small module would be shortened by allocating an additional programmer – indeed, it might be counterproductive because of the additional time needed for organizing and allocating tasks and communicating. While adding more staff may be able to speed up progress, this would be at an additional cost. In EV terms, negative schedule variance (SV) may be reduced, but at the price of increasing a negative cost variance (CV).

- *Increase use of current resources* Resource levels can be increased by making them available for longer. Thus, staff might be asked to work overtime for the duration of an activity and computing resources might be made available at times (such as evenings and weekends) when they might otherwise be inaccessible.
- *Reallocate staff to critical activities* The project manager might consider allocating more efficient staff to activities on the critical path or swapping resources between critical and non-critical activities. When a project is actually executed, the critical path may change as the actual durations of activities will vary from the original estimates and staff allocations may be adjusted to reflect this.
- *Reduce scope* The amount of work to be done could be reduced by reducing the scope of the functionality to be delivered. The client may prefer to have a subset of the promised features on time – especially if they are the most useful ones – rather than have the delivery of the whole application delayed.
- *Reduce quality* Some quality-related activities such as system testing could be curtailed. This would probably lead to more corrective work having to be done to the 'live' system once it has been implemented.

By such means we can attempt to shorten the timescale for critical activities until such time as either we have brought the project back to schedule or further efforts prove unproductive or not cost-effective. Remember, however, that shortening a critical path often causes some other path, or paths, to become critical (see Section 6.14).

Reconsider the precedence requirements

If attempting to shorten critical activities proves insufficient, the next step is to consider the constraints by which some activities have to be deferred pending completion of others. The original project network would most probably have been drawn up assuming 'ideal' conditions and 'normal' working practices. It might be that, to avoid the project delivering late, it is now worth questioning whether as yet unstarted activities really do have to await the completion of others. It might, in a particular organization, be 'normal' to complete system testing before commencing user training. In order to avoid late completion of a project it might, however, be considered acceptable to alter 'normal' practice and start training earlier.

One way to overcome precedence constraints is to subdivide an activity into a component that can start immediately and one that is still constrained as before. For example, a user handbook can be drawn up in a draft form from the system specification and then be revised later to take account of subsequent changes.

If we do decide to alter the precedence requirements in such a way, it is clearly important to be aware that quality might be compromised and to make a considered decision to compromise quality where needed. It is equally important to assess the degree to which changes in work practices increase risk. It is possible, for example, to start coding a module before its design has been completed. It would normally, however, be considered foolhardy to do so since, as well as compromising quality, it would increase the risk of having to redo some of the coding once the final design had been completed and thus delay the project even further.

Maintaining the business case

In making decisions about the management of the project, the main concern of the project sponsor, that is, the stakeholder who is putting up the money for the project, is whether the business case for the project has been preserved. You may recall from Chapter 2 that the value of the benefits of a project must be greater than its cost for the project to be viable. If costs increase, then this reduces the value of the benefits at the end of the project. If the project is delayed or the amount of functionality in the deliverables is curtailed, it means that the benefits that the project will generate will be reduced. At some point the costs may exceed the benefits and the project then loses its viability. A decision could then be made to cancel the project.

Exception planning

The project manager will normally be allowed to change the detail of a plan as long as the agreed project outcomes are produced on time and within budget.

In some cases, an operational change may affect other stakeholders. One such case would be where the timing of acceptance testing by users had to be changed. In such a case the project manager would need to gain the acceptance of these stakeholders for the change.

Some changes to the plan might have an impact on the delivery date, project scope or costs. These, in turn, could affect the business case for the project. Here the project manager would need to gain the approval of the business sponsors of the project. We saw above that the interests of the sponsors could be represented through a group variously known as a Project Board (in PRINCE2), project management board or steering committee.

One approach, adopted by PRINCE2, is to require the project manager to write an *exception report* that explains the reasons for the deviation from the existing plan. The consequences of the deviation should be detailed, and if possible a number of options for dealing with the problem. The probable impact of each option on the business case is projected, and a recommendation on a course of action is presented. The Project Board, or equivalent, having considered the report and having approved one of the options, may then task the project manager with producing a more detailed *exception plan*. If this is then approved it replaces the existing plan.

9.10 Change Control

So far in this chapter, we have assumed that the nature of the deliverables has not changed. A project leader like Amanda or Brigette might find, however, that requirements are modified because of changing circumstances or because the users get a clearer idea of what is really needed. The payroll system that Brigette is implementing might, for instance, need to be adjusted if the staffing structure at the college is reorganized.

Other, internal, changes will crop up. Amanda might find that there are inconsistencies in the program specifications that become apparent only when the programs are coded, and these would result in amendments to those specifications.

When a document such as the user requirements is being developed there may be many different versions of the document as it undergoes cycles of development and review. Any change control process at this point would be very informal and flexible. At some point what is assumed to be the final version will be created. This is *baselined*, effectively frozen. Baselined products are the foundation for the development of further products – for instance interface design documents may be developed from baselined user requirements. Thus any changes to the baselined document could have knock-on effects on other parts of the project. The Product

Flow Diagrams (explained in Chapter 3) indicate relationships between the products of a project where this is the case. For this reason subsequent changes to baselined documents need to be stringently controlled.

Exercise 9.6

A change in a program specification will normally be carried through into changes to the program design and then changed code. What other products might need to be modified?

Change control procedures

A simple change control procedure for operational systems might have the following steps:

1. One or more users might perceive a need for a modification to a system and ask for a change request to be passed to the development staff.
2. The user management would consider the change request and, if they approve it, pass it to the development management. It is important that there is a single authorized channel for *requests for change (RFCs)* between the client community and the management of the developers. There would be some filtering within the client community to ensure that the proposed change does genuinely provide a benefit before the RFC is generated.
3. There would be one person within the development area who would receive and process RFCs. They would delegate a member of staff to look at the request and to report on the practicality and cost of carrying out the change. The developer would, as part of this, assess the products that would be affected by the change.
4. The development representative would report back to the user management on the findings and the user management would decide whether, in view of the cost quoted, they wish to go ahead.
5. There would be some individual or group who represented the major stakeholders, both users and developers and also the project sponsor, who would have the authority to prioritize the RFCs for action. Ultimately this should be the Project Board or equivalent. However, the large proportion of RFCs would be relatively small in scope. This could cause a bureaucratic bottleneck if all these changes had to be considered at the highest level. A smaller group of active stakeholder representatives might therefore be delegated the responsibility for considering and approving changes up to a certain level of expenditure. This group would adopt the role of a *change control board*, although they might not actually be called that. A further step is to give the project managers allowances that would allow them accept minor changes (as long as they are documented with an RFC, etc.) as long as they do not exceed planned cost and delivery targets. There is thus a general principle that the larger the amendment the higher in the control hierarchy it would have to be reported. However, this is not simply a matter of size. A very large number of seemingly small changes could have a serious accumulative effect on project progress which may call for the attention of higher management. A very large set of changes might trigger the project manager to produce an exception report – see above.
6. Once an RFC has been approved for action, one or more developers are authorized to take copies of the master products that are to be modified. This would need to be done through the configuration librarian.
7. The copies are modified. In the case of software components this would involve modifying the code and recompiling and testing it.

8. When the development of new versions of the product has been completed the user management will be notified and copies of the software will be released for user acceptance testing.
9. When the user is satisfied that the products are adequate they will authorize their operational release. The master copies of configuration items will be replaced.

Exercise 9.7

The above steps relate to changes to operational systems. How could they be modified to deal with systems under development?

Changes in scope of a system

A common occurrence with IS development projects is for the size of the system gradually to increase. One cause of this is changes to requirements that are requested by users.

This is sometimes called scope creep.

Exercise 9.8

Think of other reasons why there is a tendency for scope creep.

The scope of a project needs to be carefully monitored and controlled. One way is to re-estimate the system size in terms of SLOC or function points at key milestones.

Configuration librarian's role

Control of changes and documentation ought to be the responsibility of someone who may variously be named the configuration librarian, the configuration manager or the project librarian. Among this person's duties would be:

- The identification of all items that are subject to change control
- The establishment and maintenance of a central repository of the master copies of all project documentation and software products
- The setting up and running of a formal set of procedures to deal with changes
- The maintenance of records of who has access to which library items and the status of each library item (e.g. whether under development, under test or released)

BS EN ISO 9001:1994 (formerly BS 5750) requires that a formal change control procedure be in place.

It will be recalled that it was suggested that the setting up of change control procedures might be one of the first things the Brigette would want to do at Brightmouth College.

9.11 Software Configuration Management (SCM)

In the previous section, we examined some of the reasons why changes might occur in Amanda's project. Though the discussion was restricted to changes due to requirements change, the changes can take place in any of the work products and may be due to many reasons such as bug fix, changes on account of work simplification, efficiency considerations, etc. We have discussed how change management can be done manually by a designated configuration librarian. However, the manual change management process gets overwhelmed when we consider changes taking place on all work products and when there are multiple variants of the product. In this situation, a systematic software configuration management (SCM) process with appropriate tool support needs to be deployed.

SCM is concerned with tracking and controlling changes to the software. In any systematic development and maintenance environment, various work products (code, design document, code, etc.) associated with the software continually change during the development as well as the maintenance phase. In a team development environment, each member of the development or maintenance team would be assigned to handle some modification requests. Therefore every work product would have to be accessed and modified by several members. In such a situation, unless a proper configuration management system is deployed, several problems can appear. We first discuss the context in which these problems appear, and subsequently we shall investigate the different problems that a development team might face if it does not deploy an effective configuration management system. Finally, we discuss the configuration management process.

Context in which configuration management is necessary

During the development phase, the work products get modified as development activities are carried out. During the maintenance phase, the work products change due to various types of enhancements and adaptations that are carried out including bug fixes. Thus, the state of the work products continually change both during the development as well as maintenance phase. The state of all work products at any point of time is called the configuration of the software product. Software configuration management deals with effectively tracking and controlling the configuration of a software product during its entire life cycle. For effective configuration management, it is necessary to deploy a configuration management tool. Thus, we can say that the different concepts associated with configuration management are carried out in a project with the help of a tool. There are many configuration management tools available, some are open software that is free of any licensing fees and others are commercial tools. At the end of this section, we review a few open software configuration management tools.

Configuration management practices include version control and the establishment of baselines. Before we discuss configuration management, we must clearly understand terms like version, revision, variant, and baseline.

Few terminologies

In the following section we define terms like configuration, version, revision, variant, and baseline.

Configuration The configuration of software is the state of various work products that are under configuration control. The work products that are under configuration control are usually referred to as the configuration items. It is convenient to think of a configuration as a set of files representing various work products. For example, the configuration of a sample software product shown in Figure 9.15 consists of the configuration items (work products) *W*1, *W*2, ... , *Wn*.

Version As development and maintenance activities are carried out on a software product, its configuration (that is, one or more configuration items) keeps changing. It often becomes necessary to refer to the configuration that existed at certain point of time. For example, we can say that refer to the last week's configuration of the software. Therefore, a version is a configuration that existed at certain point in time. More technically, versioning is a numbering scheme that helps us identify a specific configuration at a certain point in time. This is achieved by a configuration management tool by tagging the files resenting the configuration items with the version name.

Revision A revision system is a numbering scheme that is used to identify the state of a configuration item at any time. Each time a work product is updated its state changes. Thus, we can think of a work product going through a series of updates till it reaches a desired state. The successive states of a work product are its successive revisions. Thus each time a configuration item is updated, a new revision gets formed. It becomes possible to refer to a specific state of a work product by using its revision number.

Baseline A baseline is a software configuration that has been formally reviewed and agreed upon, and serves as a basis for further development.

Variant Variants are versions that are intended to coexist. Different variants may be needed to run the software on different operating systems or on different hardware platforms. For example, one variant of a mathematical computation package might run on Unix-based machines, another on Microsoft Windows machines. Variants may also be required to be created when the software is intended to be used with different levels of sophistication of the functionalities (e.g., novice version, enterprise version, professional version, etc.). Variants are often created during the operation phase during the development phase, and as and when software products with overlapping functionalities are required. Even the initial delivery of software might consist of several versions and more variants may be created later.

In the following, we first discuss the necessity of configuration management and subsequently we discuss the configuration management activities and tools.

Purpose of software configuration management

There are several reasons why proper configuration management of the work products in a project is essential. The following are some of the important problems that can occur if a proper configuration management system is not used.

- *Problems Associated with Concurrent Access* Possibly the most important reason for configuration management is to control the access to the different deliverable objects. Unless strict discipline is enforced regarding update and storage of different work products, several problems can appear. Let us assume that only a single copy of a program module is maintained, and several developers are working on it. Two developers may simultaneously carry out changes to the different functions of the same work product, and while saving overwrite each other.
- *Undoing Changes* It becomes easy to undo some part of a revision or even rollback development to a certain version. Unless proper configuration management system is in place, it becomes very difficult to undo a change.
- *System Accounting* System accounting denotes keeping track of who made a particular change to a configuration item, what change was exactly made, and when the change was made. Knowing the what, who, and when of changes will help in understanding why changes were made and whether some changes are redundant or for comparing the performance of particular versions. It may at times be required to rollback to a previous baseline if a change is not justified or is improper. Users may wish to compare today's version of some software with yesterday's version or last year's version. Since a configuration management system keeps track of every version and revision, this becomes a simple task.

- *Handling Variants* As we have already discussed, it often becomes necessary to create variants. In this situation, without a configuration management system, keeping track of all variants, their versions and revisions is a nontrivial task. Further, existence of variants of a software product causes some peculiar problems. Suppose you have several variants of the same module, and find that a bug exists in one of them. Then it has to be fixed in all versions and revisions. To do it efficiently, you should not have to fix it in each and every version and revision of the software separately. Making a change to one program should be reflected in all relevant versions and revisions.
- *Accurate Determination of Project Status* Normally, a project manager performs the configuration management activity by using a configuration management tool. In addition, a configuration management tool helps to keep track of various deliverable objects so that the project manager can quickly and unambiguously determine the current state of the project. The configuration management tool enables the developer to change the various components in a controlled manner.
- *Preventing Unauthorized Access to the Work Products* Configuration management helps implement a controlled change process. It therefore becomes possible to prevent unauthorized changes to the work products.

Configuration management process

Configuration management is carried out through the following two principal activities:

- *Configuration Identification:* This activity involves deciding which parts of the system should be kept under configuration management.
- *Configuration Control:* This activity is used to ensure that changes to a system occur smoothly.

In the following section, we provide an overview of these two activities.

- *Configuration Identification*

  Project managers normally classify the work products associated with a software development process into three main categories, viz., controlled, pre-controlled, and uncontrolled. Controlled work products are those that are put under configuration control. The team members must follow some formal procedures to change these. Pre-controlled work products are not yet under configuration control, but will eventually be under configuration control. Uncontrolled work products will not be subject to configuration control. Controllable work products include both controlled and pre-controlled work products.

Typical controllable work products include the following:

- Requirements specification document
- Design documents
- Tools used to build the system such as compilers, linkers, lexical analysers, parsers, etc.
- Source code for each module
- Test cases
- Problem reports

Exercise 9.9

What are the advantages and disadvantages of putting all the work products in a project under configuration control?

- *Configuration Control*

Configuration control is part of a configuration management system that most directly affects the day-to-day operations of developers. Configuration control allows only authorized changes to the controlled objects and prevents unauthorized changes. The project manager can give permission to some members to be able to change or access specific work products.

In order to change a controlled work product such as a code module, a developer can get a private copy of the module through a reserve operation (see Figure 9.15). Configuration management tools allow only one team member to reserve a module at any time. Once a work product is reserved, it does not allow anyone else to reserve this module until the reserved module is restored. Thus, by preventing more than one developer to simultaneously reserve a module, the problems associated with concurrent access are taken care of.

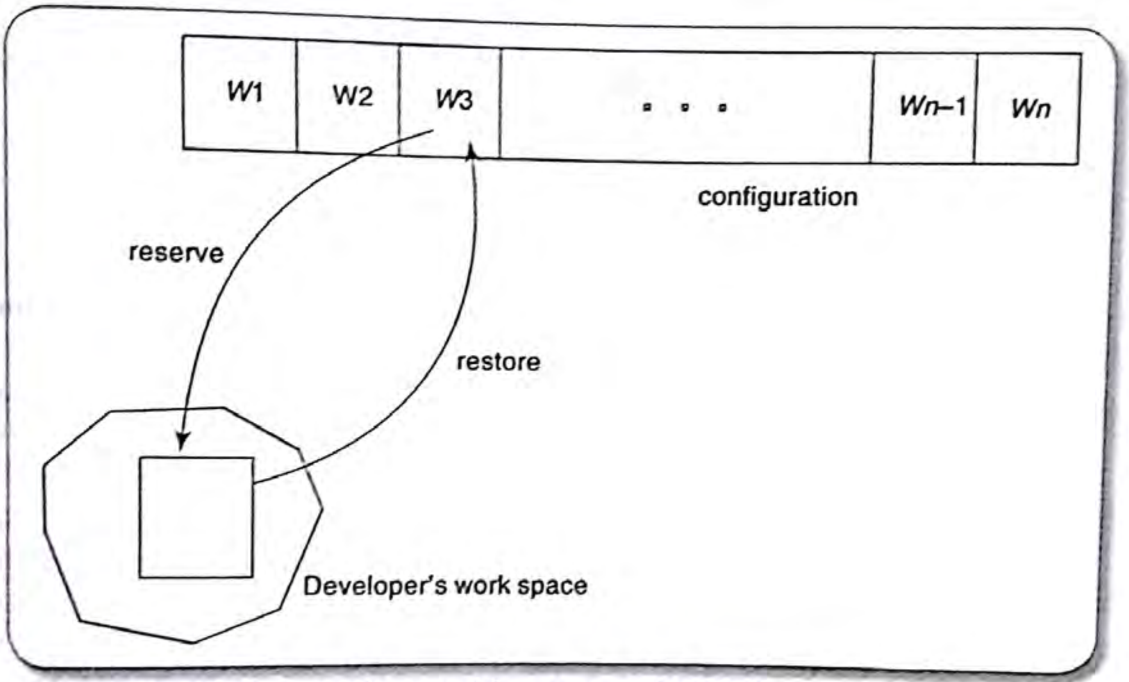


Figure 9.15 Work product modifications under configuration management

Modifications to a work product under configuration control

When developers need to change a work product they first make a reserve request. A reserve request by a team member is honoured only if appropriate authorization has been given by the project manager to that member for the specific work product. After the reserve command successfully executes, a private copy of the work product is created in their local directory. Then, they can carry out all necessary changes to the work product on their private copy. Once they have satisfactorily completed all necessary changes, the changes need to be restored in configuration management repository. However, restoring the changed work product to the system configuration requires the permission of a change control board (CCB).

The CCB is usually constituted from among the development team members. For every change that needs to be carried out, the CCB reviews the changes made to the controlled work product and certifies certain aspects about the change such as

- Change is well-motivated
- Developer has considered and documented the effects of the change

- Changes interact well with the changes made by other developers
- Appropriate people (CCB) have validated the change, e.g., someone has tested the changed code, and has verified that the change is consistent with the need

The change control board (CCB) is seldom a group of people. Except for very large projects, the functions of the change control board are normally discharged solely by the project manager or some senior member of the development team. Once the CCB reviews the changes to the module, the project manager updates the old configuration item through a restore operation (see Figure 9.15). A configuration control tool does not allow a developer to replace a work product in the configuration with his local copy unless he gets an authorization from the CCB. Therefore, incompletely modified or improperly modified work products cannot be updated in the configuration.

Release Management

It is desirable for a software development project to deploy a suitable release management process. A release management process systematizes the work carried out by the developers to provide a new release of a software and on the part of the users to smoothly and effortlessly obtain and use a new release. The release management process has become especially important after it has become possible for the users to instantly and effortlessly download new releases of a software over the Internet. The release process should involve minimal effort on the part of the developer to upload a new release of a software and on the part of the users to effortlessly download and install it. For example, when a new version of a system is to be released, a tool should automatically determine the changed components, the dependencies, and all interdependent components should be retrievable as a group, so that there is no possibility of inconsistency. There would be significant chance for inconsistency and a considerable amount of work to be carried out by the user, if the user would have to decide which specific components need to be downloaded. Further, retrievals of unnecessary and unchanged components should be avoided.

Open source configuration management tools

SCCS and RCS are two popular configuration management tools available on most UNIX systems. SCCS or RCS can be used for controlling and managing different versions of text files. SCCS and RCS do not handle binary files (i.e., executable files, documents, files containing diagrams, etc.). SCCS and RCS provide an efficient way of storing versions that minimize the amount of occupied disk space. Suppose, a module MOD is present in three versions MOD1.1, MOD1:2 and MOD1.3, then SCCS and RCS stores the original module MOD1.1 together with changes needed to transform MOD1.1 into MOD1.2, and MOD1.2 to MOD1.3. The changes needed to transform each baseline file to the next version are stored and are called deltas. The main reason behind storing the deltas rather than storing the full revision files is to save disk space.

The change control facilities provided by SCCS and RCS include the ability to incorporate restrictions on the set of individuals who can create new versions, and facilities for checking components in and out (i.e., reserve and restore operations). Individual developers check out components and modify them. After they have made all the necessary changes to a component, and after these changes have been reviewed, they check in the changed module into SCCS or RCS.

Conclusion

In this chapter we have discussed the requirements for the continual monitoring of projects and the need for making progress visible. Among the important points to emerge were:

- Planning is pointless unless the execution of the plan is monitored
- Activities that are too long need to be subdivided to make them more controllable
- Ideally, progress should be measured through the delivery of project products
- Progress needs to be shown in a visually striking way, such as through bar charts, in order to communicate information effectively
- Costs need to be monitored as well as elapsed time
- Delayed projects can often be brought back on track by shortening activity times on the critical path or by relaxing some of the precedence constraints

Further Exercises

1. Take a look at Amanda's project schedule shown in Figure 8.7. Identify those activities scheduled to last more than three weeks and describe how she might monitor progress on each of them on a fortnightly or weekly basis.
2. Amanda's Gantt chart at the end of week 17 (Figure 9.5) indicates that two activities are running late. What effect might this have on the rest of the project? How might Amanda mitigate the effects of this delay?
3. Table 9.2 illustrates Amanda's earned value calculations based on work-days. Revise the table using monetary values based on the cost figures that you used in Exercise 8.5. Think carefully about how to handle the costs of Amanda as project manager and the recovered overheads and justify your decisions about how you treat them.
4. If you have access to project planning software, investigate the extent to which it offers support for earned value analysis. If it does not do so directly, investigate ways in which it would help you to generate a baseline budget (PV) and track the earned value (EV).
5. Describe a set of change control procedures that would be appropriate for Brigette to implement at Brightmouth College.
6. Give examples of errors that can be identified in a design review.
7. Give examples of how project termination review results can change the development process and the project management process.
8. Suppose a project is budgeted to cost £150,000. The project is to be completed in 18 months. After two months, the project is 10% complete at an expense of £25,000. It was planned that after two months, 15% of the project work should have been completed. Compute the cost performance index and the schedule performance index. Interpret these values to assess the progress of the project.
9. What problems are you likely to face if you are developing several versions of the same software product according to a client's request and are not using any configuration management tools?

10. What do you understand by software configuration? What is meant by software configuration management? How can you manage software configuration (only mention the names of the principal activities involved)? Why is software configuration management crucial to the success of large software product development projects (write only the important reasons)?

11. What is a baseline in the context of software configuration management? How do baselines get updated to form new baselines?

12. How the following can be prevented while using a configuration management tool? Explain.

    (a) Two team members overwriting each other's work

    (b) Accidental deletion of work product

    (c) Unauthorized modifications to a work product

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

    (i) Which one of the following most closely characterizes software configuration management?

    (a) It is used to ensure that all the artefacts associated with the project are correct and complete

    (b) It is used to break down the work parts into manageable chunks

    (c) It is used to ensure that all the project design criteria are met

    (d) It is used to ensure that all the artefacts associated with the project are consistent and up-to-date

    (ii) Which one of the following documents usually contains the change management?

    (a) Scope management plan

    (b) Communications management plan

    (c) Configuration management plan

    (d) Quality management plan

    (iii) At any time during a project execution, Earned Value (EV) helps to provide answer to which one of the following questions?

    (a) What is the value of work that should have been completed to date?

    (b) What is the value of work that has been completed to date?

    (c) How much money has been spent to date?

    (d) How much money should have been spent to date?

    (iv) Which one of the following most accurately describes configuration management?

    (a) Control of changes to project schedules

    (b) Formal review and acceptance of proposed changes to the project deliverables

    (c) Quality control of project deliverables

    (d) Controlling changes to the project deliverables

    (v) Which one of the following is an important purpose of software configuration management?

    (a) Support efficient customer relationship management such as providing technical help and accepting bug reports

    (b) Avoid maintaining multiple copies of the same project files

    (c) Keep track of which team member would perform which task and by when

    (d) Manage the workflow across the team members

(vi) Which one of the following would equal EV/PV?

(a) SPI (b) CPI

(c) SV (d) CV

(vii) Which one of the following scenarios can occur even while a software development organization is impeccably using a configuration management tool?

(a) Two team members overwrite each other's code that are under configuration control

(b) Accidental deletion of a work product that is under configuration control, by a developer and consequent loss of work

(c) A user reporting a software configuration error during installation

(d) Unauthorized modifications to a work product under configuration control by one of the developers

(viii) Which one of the following most closely describes configuration management in a software development project?

(a) Management of the configuration parameter settings in a developed software

(b) Management of objects that control the system configuration parameter settings

(c) Management of the states of various project deliverables

(d) Configuration of the management activities depending on the type of the project

(ix) Preparation of the project baseline budget brings out the financial implications for the project. Which one of the following is the project base line budget?

(a) Actual cost (AC) (b) Earned value (EV)

(c) Planned value (PV) (d) Cost performance index (CPI)

(x) The cost performance index (CPI) is given by which one of the following expressions?

(a) AC/EV (b) EV × AC

(c) EV/AC (d) AC × EV

(xi) During the execution of a project, the project manager determined the schedule performance index (SPI) of the project to be less than 1.0. What does it indicate?

(a) The project is over budget and there can be financial shortfall.

(b) More work is getting completed than what was planned.

(c) The project is running behind the monetary value of work that was planned to be accomplished.

(d) The project is progressing satisfactorily.

(xii) Suppose for a certain project budgeted for £2000, at certain time during the execution of the project, the project manager determined EV = £500 and AC = £400. What is the current estimated cost of the project?

(a) £2500 (b) £1800

(c) £1600 (d) £1200

10 Managing Contracts

Learning Objectives

- Distinguish between the different types of contracts
- Outline the contents of a contract for goods and services
- Plan the evaluation of a proposal or product
- Administer a contract from its signing until the final acceptance of project completion

10.1 Introduction

In the Brightmouth College scenario, the college management have decided to obtain their software externally. Given their limited capability for developing new and reliable software, this seems sensible. At IOE, Amanda has a team of software developers employed by IOE. However, the demand for development effort fluctuates as projects come and go. The IOE management might therefore decide that it is more cost-effective to employ outside software developers for new development while a reduced group of in-house software development staff maintain and support existing systems.

It is not unusual for a major organization to spend 6 to 12 months and 40% of the total acquisition and implementation budget on package evaluation with major customer service and support applications (Demian Martinez, Decision Drivers Inc., *Computing*, 23 July, 1998).

The buying of goods and services, rather than 'doing it yourself', is attractive when money is available but other, less flexible, types of resource, especially staff time, are in short supply. However, there are risks arising from the considerable staff time and attention still needed to manage a contracted-out project successfully. It is essential that customer organizations such as Brightmouth College and IOE find time to clarify their exact requirements at the beginning, and to ensure that the goods and services delivered are satisfactory.

Potential suppliers are likely to be more accommodating before any contract is signed than afterwards – especially if the contract is for a fixed price. Thus, as much forethought and planning is needed with an acquisition project as with internal development.

In the remainder of this chapter, the different types of contract that can be used will be explored. This is followed by the general steps to be followed when placing a contract. The issues to be considered when drafting a contract are then examined. We conclude by describing some of the things done while the contract is executed.

The bargaining position of the customer will be stronger if their business is going to be valuable. If you are buying a cut-price computer game, you are unlikely to be able to negotiate variations on the supplier's standard contract of sale. (In fact, because of the inequality of the parties, such sales are subject to special consumer protection laws.) Potential suppliers will carefully assess the time and money to be spent responding to a customer's requests as there is no guarantee of the final contract.

It was, for example, reported that two consortia led by Sema and EDS, respectively, had spent £4 million over 2 years bidding for a UK government project to renew the ICT infrastructure in the prison service – the final job was estimated as being worth £350 million (*Computing*, 13 August, 1998).

10.2 Types of Contract

The external resources required could be in the form of *services*, for example staff on short-term contracts carrying out some project tasks. At Brightmouth College, Brigette could use temporary staff to input employee details needed for the new payroll system. IOE might carry out application-building in-house but augment the permanent staff with contract developers. The contractor might not only supply the new system but also operate it on the customer's behalf. For example, Brightmouth College might abandon buying a package and instead get a payroll services agency to carry out the payroll work.

On the other hand, a contract for a *completed software package* could be placed. This could be:

- a *bespoke* system created specifically for one customer;
- an *off-the-shelf* package bought 'as is' – this is sometimes referred to as *shrink-wrapped* software;
- *customized off-the-shelf* (COTS) software – where a core system is modified to meet the needs of the client.

David Bainbridge (2007) *Introduction to Computer Law*, Longman, 6th edition, is highly recommended as a guide to the legal aspects of IT contracts.

Where equipment is purchased, in English law, this is normally a contract for the supply of *goods*. With the supply of software this may be regarded as supplying a service (i.e. to write the software) or the granting of a *licence* (i.e. permission) to use the software which remains in the ownership of the supplier. These distinctions will have legal implications.

Exercise 10.1

Which of the three system options (i.e. bespoke, off-the-shelf or COTS) might Amanda consider with regard to the JOE maintenance group accounts system? What factors would she need to take into account?

Another way of classifying contracts is by the way that the payment to suppliers is calculated. We will look

- fixed price contracts;
- time and materials contracts;
- fixed price per delivered unit contracts.

The section on ways of assessing supplier payments draws heavily on material from Paul Radford and Robyn Lawrie of Charismatek Software Metrics, Melbourne, Australia.

Fixed price contracts

In this situation a price is fixed when the contract is signed. The customer knows that, if there are no changes in the contract terms, this is the price they pay on completion. For this to be effective, the customer's requirement has to be fixed at the outset. In other words, when the contract is to construct a software system, the detailed requirements analysis must already have been carried out. Once the development is under way the customer cannot change their requirements without renegotiating the price of the contract.

The advantages of this method are:

- *Known customer expenditure* As long as the requirements are precise and not changed, the customer has a known cost.
- *Supplier motivation* The supplier has a motivation to work in a cost-effective manner.

The disadvantages include:

- *Higher prices to allow for contingency* The supplier absorbs the risk for any errors in the estimates. To reduce the impact of this risk, the supplier will add a margin to the price quoted.
- *Difficulties in modifying requirements* The need to change the scope of the requirements may become apparent during development – this may cause friction between the supplier and customer.
- *Upward pressure on the cost of changes* When competing against other potential suppliers, the supplier will try to quote as low a price as possible. Once the contract is signed, if further requirements are put forward, the supplier is in a strong position to demand a high price for these changes.
- *Threat to system quality* The need to meet a fixed price could mean that the quality of the software suffers.

The cost could still be lower than in-house development because the supplier may be able to exploit economies of scale and also expertise acquired doing similar jobs in the past.

Time and materials contracts

With this type of contract, the customer is charged at a fixed rate per unit of effort, for example per staff-hour. The supplier may provide an initial estimate of the cost based on their current understanding of the customer's requirements, but this is not the basis for the final payment. The supplier usually invoices the customer for work done at regular intervals, say each month.

The advantages of this approach are:

- *Ease of changing requirements* Where a project has a research orientation and the direction of the project may change as options are explored, then this may be an appropriate method of payment.
- *Lack of price pressure* The lack of price pressure may promote better quality deliverables.

The disadvantages of this approach are:

- *Customer liability* The customer absorbs the risks associated with poorly defined or changing requirements.
- *Lack of incentives for supplier* The supplier has no incentive to work in a cost-effective manner or to control the scope of the deliverables.

Because the supplier appears to be given a blank cheque, this approach does not find favour with customers. However, the employment of contract development staff may in effect involve this type of contract.

Fixed price per unit delivered contracts

This is often associated with function point (FP) counting. The size of the system to be delivered is calculated or estimated at the outset of the project. The size could be estimated in lines of code, but FPs can be more easily derived from requirements documents. A price per unit is also quoted. The final price is then the unit price multiplied by the number of units. Table 10.1 shows a typical schedule of prices.

Function point counting was discussed in Chapter 5.

TABLE 10.1 A schedule of charges per function point

Function point count	Function design cost per FP	Implementation cost per FP	Total cost per FP
Up to 2,000	$242	$725	$967
2,001–2,500	$255	$764	$1,019
2,501–3,000	$265	$793	$1,058
3,001–3,500	$274	$820	$1,094
3,501–4,000	$284	$850	$1,134

This table comes from David Garmus and David Herron (1996) *Measuring the software process*, Prentice Hall.

The company that produced this table in fact charge a higher fee per FP for larger systems. For example, a system to be implemented contains 2600 FPs. The overall charge would be 2000 × $967, plus 500 × $1,019, plus 100 × $1,058.

The company in question was RDI Technologies in the USA. These figures are now several years old.

We have already noted that the scope of the application can grow during development. It would be unrealistic for a contractor to be asked to quote a single price for all the stages of a development project: how can they estimate the construction effort needed when the requirements are not yet established? One approach would be to negotiate a series of contracts, each covering a different stage of system development.

Alternatively, the software supplier might first carry out the system design. A charge could then be made for design work based on the figures in the 'Function design cost per FP' column. This, if the designed system was counted at 1000 FPs, would be 1000 × $242, i.e. $242,000. If the design was then implemented, and the actual software delivered, then the additional 1000 × $725 would be charged, i.e. $725,000. If the scope of the system grows because the users find new requirements, these new requirements would be charged at the combined rate for design and implementation, e.g. if new requirements amounting to 100 extra FPs were found, then the charge for this extra work would be $967 × 100, i.e. $96,700.

Exercise 10.2

A system to be designed and implemented is counted as comprising 3200 FPs. What would be the total charge according to the schedule in Table 10.1?

The advantages of this approach are:

- *Customer understanding* The customer can see how the price is calculated and how it will vary with changed requirements.
- *Comparability* Pricing schedules can be compared.
- *Emerging functionality* The supplier does not bear the risk of increasing functionality.
- *Supplier efficiency* The supplier still has an incentive to deliver the required functionality in a cost-effective manner (unlike with time and materials contracts).
- *Life-cycle range* The requirements do not have to be definitively specified at the outset. Thus the development contract can cover both the analysis and design stages of the project.

The disadvantages of this approach are:

- *Difficulties with software size measurement* Lines of code can easily be inflated by adopting a verbose coding style. With FPs, there may be disagreements about what the FP count should really be: in some cases, FP counting rules may be seen as unfairly favouring either the supplier or customer. Users, in particular, will almost certainly not be familiar with the concept of FPs and special training may be needed for them. The solution to these problems may be to employ an independent FP counter.
- *Changing requirements* Some requested changes may affect existing code drastically but not increase the overall FP count. A change made late in the development cycle will usually require more effort to implement than one made earlier.

The impact of late changes will be further discussed in Chapter 13 on software quality.

To reduce the last difficulty, one suggestion from Australia has been to vary the charge depending on the point at which they have been requested – see Table 10.2.

Table 10.2 Examples of additional charges for changed functionality

This table comes from the draft *Acquisition of Customised Software Policy* document, published by the Department of State Development, Victoria, 1996.

	Pre-acceptance testing handover	**Post-acceptance testing handover**
Additional FPs	100%	100%
Changed FPs	130%	150%
Deleted FPs	25%	50%

Exercise 10.3

A contract stipulates that a computer application is to be designed, constructed and delivered at a cost of $600 per FP. After acceptance testing, the customer asks for changes to some of the functions in the system amounting to 500 FPs and some new functions which amount to 200 additional FPs. Using Table 10.2, calculate the additional charge.

There are other options and permutations of options for payments. The implementation of a specification could be at a fixed price, with any additions or changes to the requirements to be charged per FP. Where the contractor has buy in equipment, the price of which may fluctuate, it is possible to negotiate a contract where the final price contains a fixed portion for labour plus an amount that depends on the actual cost of purchased components.

Exercise 10.4

It is easy to see why passing on fluctuations in equipment costs may be advantageous to the contractor. However, is there any advantage to the customer in such an arrangement?

Another way of categorizing contracts, at least initially, is according to the approach that is used in contractor selection, namely

- Open
- Restricted
- Negotiated

This categorization is based on European Union regulations.

Open tendering process

In this case, any supplier can bid to supply the goods and services. All bids compliant with the original conditions in the *invitation to tender* must be considered and evaluated in the same way. With a major project this evaluation process can be time consuming and expensive.

Invitation to tender (ITT) and request for proposal (RFP) are interchangeable terms.

There has been a global movement towards removing barriers to businesses in one country supplying goods and services in another. Examples of this are efforts by the World Trade Organization (WTO) and the European Union to ensure that public bodies do not unfairly favour local businesses. Among the agreements overseen by the WTO is one on government procurement which lays down rules on tendering processes. Where the client is a public body, an open tendering process may be compulsory.

Restricted tendering process

In this case, there are bids only from suppliers who have been invited by the customer. Unlike the open tendering process, the customer may at any point reduce the number of potential suppliers being considered. This is usually the best approach to adopt.

Negotiated procedure

There may, however, be some good reasons why the restricted tendering process may not be the most suitable in some particular sets of circumstances. Say, for example, that there is a fire that destroys some ICT equipment. The key concern here may be to get replacement equipment up and running as quickly as possible and there may simply not be the time to embark on a lengthy tendering process. Another situation might be where a new software application had been successfully built by an outside supplier, but some extensions are required to the system. As the original supplier has staff familiar with the existing system, it might be inconvenient to approach other potential suppliers via a full tendering process. In these cases, an approach to a single supplier may be justified. However, approaching a single supplier could expose the customer to charges of favouritism and should only be done with a clear justification.

10.3 Stages in Contract Placement

Requirements analysis

This discussion assumes that a feasibility study has already provisionally identified the need for the intended software.

Before potential suppliers can be approached, you need to have a clear set of requirements. It is easy for this step to be skimped where the user management have day-to-day pressures and little time to think about future developments. In this situation, an external consultant could draw up a requirements document. Even here, users and their managers need to look carefully at the resulting requirements document to ensure that it accurately reflects their needs. As David Bainbridge has pointed out: '*the lack of, or defects in, the specification are probably the heart of most disputes resulting from the acquisition of computer equipment and software*'.

The requirements document might typically have sections with the headings shown in Table 10.3.

This requirements document is sometimes called an *operational requirement* or OR.

Table 10.3 Main sections in a requirements document

1 Introduction
2 A description of any existing systems and the current environment
3 The customer's future strategy or plans
4 System requirements
— mandatory
— desirable
5 Deadlines
6 Additional information required from potential suppliers

Chapter 13 on software quality discusses how aspects of quality can be measured.

The requirements define carefully the *functions* of the new application and all the necessary *inputs* and *outputs* for these functions. They also state any *standards* that apply, and the existing systems with which the new system should be compatible. There will also need to be operational and quality requirements, concerning such matters as the required response times, reliability, usability and maintainability of the new system.

In general, the requirements document should state *needs* as accurately as possible and avoid technical specifications of possible solutions. The onus should be placed on the potential suppliers to identify the technical solutions judged to meet the customer's needs as they should be technical experts with access to the most up-to-date information about current technology.

Each requirement needs to be identified as being either *mandatory* or *desirable*.

- *Mandatory* If a proposal does not meet this requirement then the proposal is to be immediately rejected.
- *Desirable* A proposal may be deficient in this respect, but other features of the proposal could compensate for this.

For example, in the case of the Brightmouth College payroll package acquisition project, Brigette might identify a mandatory requirement that any new system carry out all the processes carried out by the old system. However, a desirable feature might be that the new payroll package should be able to produce staff costing details in a format accessible to the college's accounting computer system.

The requirements document issued to potential suppliers would also contain requests for information needed to judge the standing of the organization itself. This could include financial reports, references from past customers and the CVs of key development staff.

One suggestion is that the weighting between product criteria and supplier criteria when selecting software ought to be 50:50 (Demian Martinez, Decision Drivers Inc., *Computing*, 23 July, 1998).

Evaluation plan

Having drawn up a list of requirements, we now need a plan of how the proposals are to be evaluated. The situation will be different if the contract is for a system that is to be specially written rather than an off-the-shelf package. In the latter case, it is the *application* itself that is being evaluated while in the former situation it is a *proposal* for an application.

Ways of checking that the mandatory requirements are met need to be identified. The next consideration is how the desirable requirements can be evaluated. The problem here is weighing the value of one quality against another. The ISO 9126 standard, which is discussed in Chapter 13 on software quality, can assist in deciding whether one system has more of some quality than another, but if there is a difference in price between the two, we need to estimate if the increase in quality is worth the additional price. Hence 'value for money' is often the key criterion. For example, a financial value could be placed on a link between the payroll and accounting applications. If we were to cost clerical effort at £20 an hour and knew that four hours of clerical effort a month went into inputting staffing costs into the accounting computer system, we could conclude that over a four-year period (£20 an hour × 4 hours a month × 48 months), or £3,840, would be saved. If system A has this feature and costs only £1,000 more than system B which does not, this would give system A an advantage.

The costs to be taken into account are those for the whole of the lifetime of the proposed system, not just the costs of acquiring the system. Also, where the relationship with the supplier is likely to be ongoing, the supplier organization needs to be assessed as well as its products.

Exercise 10.5

One desirable feature sought in the Brightmouth College payroll is the ability to raise staff automatically to the next point in their salary scale at the beginning of each payroll year. At present, the new scale points are entered clerically and then checked. This takes about 20 hours of staff effort each year, which costs £20 an hour. System X has this feature, but system Y does not. System X also has a feature which can automatically produce bar charts showing payroll expenditure per department. Such a report currently is produced twice a year by hand and on each occasion takes about 12 hours' effort. With system Y, changes to department names can be carried out without any coding effort whereas in the case of system X, the supplier would charge a minimum of £300 to do this. The college authorities estimate there is a 50% chance that this could occur during the expected four-year lifetime of the system. System X costs £500 more than system Y. Given this information, which system appears to give better value for money?

Invitation to tender

Having produced the requirements and the evaluation plan, it is now possible to issue the invitation to tender to prospective suppliers. Essentially, this will be the requirement document with a supporting letter containing information about how responses to the invitation are to be lodged. A deadline will be specified and it is hoped that by then a number of proposals with price quotations will have been received.

In English law, with certain exceptions, a contract does not have to be in writing. Clearly it is desirable that it should be.

In English law, for a contract to exist there must be an offer on one side which is accepted by the other. The invitation to tender is not an offer itself, but an invitation for prospective suppliers to make an offer.

Certain problems might now emerge. The requirements specified could be satisfied in a various ways. The customer not only needs to know a potential supplier's price but also how they intend to satisfy the requirements – this will be particularly important where the contract is to build a completely new system.

In relatively straightforward cases, it would be enough to have post-tender clarification and negotiation to resolve issues in the supplier's proposal. With more complex projects a more sophisticated approach may be needed. One way of getting the detail of the suppliers' proposals elaborated is to have a two-stage tendering process.

In the first stage, technical proposals are requested from potential suppliers who do not necessarily quote any prices. Some of these proposals can be dismissed as not meeting mandatory requirements. The remaining ones could be discussed with representatives of the suppliers in order to clarify and validate the technical proposals. The suppliers might be asked to demonstrate certain aspects of their proposals. Where shortcomings in the proposal are detected, the supplier could be given the opportunity to remedy these.

This approach has been recommended for government ICT contracts in the United Kingdom.

These discussions could result in a *Memorandum of Agreement* (MoA) with each prospective supplier. This is an acceptance by the customer that the proposed solution (which might have been modified during discussions) offered by the supplier satisfactorily meets the customer's requirement.

Tenders are then invited from the suppliers who have signed individual Memoranda of Agreement. The tender would incorporate the MoA and would be concerned with the financial terms of a potential contract.

If a design has to be produced as part of the proposal made by a supplier in response to an invitation to tender then the supplier would have to do a considerable amount of work with only a limited prospect of being paid for it. One way of reducing this burden is for the customer to choose a small number of likely candidates who will be paid a fee to produce design proposals. These can then be compared and the final contract for construction awarded to the most attractive proposal.

Evaluation of proposals

We have already mentioned the need to produce an evaluation plan describing how each proposal will be checked against the selection criteria. This reduces risks of requirements being missed and ensures that all proposals are treated consistently. It would be unfair to favour a proposal because of the presence of a feature not requested in the original requirement.

We noted earlier that an application could be bespoke, off-the-shelf, or customized. In the case of off-the-shelf packages the software itself could be evaluated and it might be possible to combine some of the evaluation with acceptance testing. With bespoke development it would be a proposal that is evaluated, while COTS may involve elements of both. Thus different approaches would be needed.

The process of evaluation may include:

- Scrutiny of the proposal documents
- Interviewing suppliers' representatives
- Demonstrations
- Site visits
- Practical tests

The proposal documents provided by the suppliers can be scrutinized to see if they contain features satisfying all the original requirements. Clarification might be sought over certain points. Factual statements made by a supplier have a legal commitment if they influence the customer to offer the contract to that supplier. It is therefore important to get a written, agreed, record of these clarifications. The customer might take the initiative here by taking minutes of meetings and then writing afterwards to the suppliers to get them to confirm their accuracy. A supplier could, in the final contract document, attempt to exclude any commitment to any representations made in pre-contract negotiations – the terms of the contract need to be scrutinized for this.

Where there is an existing product there could be a demonstration. A danger is that demonstrations can be controlled by the supplier and as a passive observer it may be difficult to maintain full attention for more than, say, half an hour. Because of this, the customer organization should have their own schedule of what needs to be demonstrated, ensuring that all the important features are seen in operation.

With off-the-shelf software, the customer could actually try out the package. For example, a demonstration version could be made available which closes itself down after 30 days. Once again a test plan is needed to ensure that all the important features are evaluated in a complete and consistent manner. Once a package is identified as the most likely candidate, it needs to be examined for any previously unforeseen factors that might invalidate this choice.

A frequent problem is that while an existing application works well on one platform with a certain level of transactions, it does not work satisfactorily with the customer's ICT configuration or level of throughput. Demonstrations might not reveal this problem. Visits to operational sites already using the system could be more informative. In the last resort a special volume test could be conducted.

Exercise 10.6

How would you evaluate the following aspects of a proposal?

(i) The usability of an existing software application.

(ii) The usability of a software application which is yet to be designed and constructed.

(iii) The maintenance costs of hardware to be supplied.

(iv) The time taken to respond to requests for software support.

(v) Training.

Where substantial sums of money are involved, legal advice on the terms of the contract is essential.

A decision is made to award the contract to a supplier. One reason for a structured and, as far as possible, objective approach to evaluation is to demonstrate that the decision has been made impartially. In most large organizations, placing a contract involves the participation of a second party within the organization, such as a contracts department, who can check that the correct procedures have been carried out. Also, the final legal format of a contract will almost certainly require some legal expertise. Not only should the successful candidate be notified but the unsuccessful candidates should also be told of the decision. This might not be simply a matter of courtesy: under WTO or EU rules, there is a legal requirement to do this in certain circumstances. It makes dealing with unsuccessful bidders easier if they can be given clear and objective reasons why their proposals did not find favour.

10.4 Typical Terms of a Contract

In a textbook such as this, it is not possible to describe the all necessary content of contracts for ICT goods or services. It is possible, however, to outline some of the major areas of concern.

Definitions

The terminology used in the contract document may need to be defined, e.g. who is meant by the words 'client' and 'supplier'.

Form of agreement

For example, is it a contact of sale, a lease, or a licence? Also, can the subject of the contract, such as a licence to use a software package, be transferred to another party?

Goods and services to be supplied

Equipment and software to be supplied This should include an actual list of the individual pieces of equipment to be delivered, complete with the specific model numbers.

Services to be provided This would cover such things as:

- Training
- Documentation
- Installation

- Conversion of existing files
- Maintenance agreements
- Transitional insurance arrangements

Ownership of the software

Who has ownership of the software? There may be two key issues here: first, whether the customer can sell the software to others and, second, whether the supplier can sell the software to others. Where an off-the-shelf package is concerned, the supplier often simply grants a licence for the customer to use the software. Where the software is written for a specific customer then that customer may want exclusive use of the software – they might object to software which they hoped would provide a competitive edge being sold to rivals. They could ensure this by acquiring the copyright to the software outright or by specifying in a contract that they should have *exclusive use* of the software. Where a core system has been customized by a supplier then there is less scope for the customer to insist on exclusive use.

Where software is written by an employee as part of their normal job, it is assumed that the copyright belongs to the employer. Where the customer organization has contracted an external supplier to write software for them, the contract needs to make clear who is going to retain the copyright – it cannot, in this case, be automatically assumed that it is the customer. The customer may decide to take responsibility for maintenance and development once the software is delivered and would need the source code. In other cases, where the customer does not have an adequate in-house maintenance function, the supplier may retain the source code, and the customer may have to approach the supplier for any further changes. There are dangers with this, for example that the supplier could go out of business. An *escrow* agreement can be included in the contract so that up-to-date copies of the source code are deposited with a third party. In the United Kingdom, the NCC Group provides an escrow service.

Any assignment of copyright would need to be in writing.

Environment

Where physical equipment is to be installed, the demarcation line between the supplier's and customer's responsibilities with regard to such matters as accommodation and electrical supply needs to be specified. Where software is being supplied, the compatibility of the software with the existing hardware and operating system platforms would need to be confirmed.

Customer commitments

Even when work is carried out by external contractors, a development project still needs the participation of the customer. The customer may have to provide accommodation for the suppliers and perhaps other facilities such as telephone lines.

Acceptance procedures

Good practice is to accept a delivered system only after user acceptance tests. Part of the contract would specify such details as the time that the customer will have to conduct the tests, deliverables upon which the acceptance tests depend and the procedure for signing off the testing as completed.

Some customers find that specially written or modified software is not thoroughly tested by the supplier before delivery. Some suppliers seem to think that it is cheaper to get the customer to do the testing for them!

Standards

This covers the standards with which the goods and services should comply. For example, a customer could require the supplier to conform to the ISO 12207 standard relating to the software life cycle and its documentation (or, more likely, a customized sub-set of the standard). Within the European Union, government customers with contracts for projects above a certain threshold value must, by law, ensure that the work conforms to certain standards.

Project and quality management

The arrangements for the management of the project must be agreed. These include the frequency and nature of progress meetings and the progress information to be supplied to the customer. The contract could require that appropriate ISO 9001 standards are followed.

Timetable

This provides a schedule of when the key parts of the project should be completed. This timetable will commit both the supplier and the customer. For example, the supplier may only be able to install the software on the agreed date if the customer makes the hardware platform available at that time.

Price and payment method

Obviously the price is very important. What also needs to be agreed is when the payments are to be made. The supplier's desire to be able to meet costs as they are incurred needs to be balanced by the customer's requirement to ensure that goods and services are satisfactory before parting with their money.

Miscellaneous legal requirements

This is the legal small print. A contract may require clauses which deal with such matters as the definition of terms used in the contract, the legal jurisdiction that will apply to the contract, what conditions would apply to the subcontracting of the work, liability for damage to third parties, and liquidated damages. *Liquidated damages* are estimates of the financial losses that the customer would suffer if the supplier were to fall short of their obligations. It is worth noting that under English law, the penalties laid down in penalty clauses must reflect the actual losses the customer would suffer and cannot be unrealistic and merely punitive. Even this limitation may not be enough in some cases as far as the supplier is concerned. As computer systems assume increasingly critical roles and in safety-critical applications can even be life-threatening in the case of malfunction, consequential damage could be astronomical. Suppliers will try to limit this liability. The courts (in England and Wales) have tended to look critically at such attempts at limiting liability, so that suppliers may, in the case of major contracts, take out insurance to cover such liabilities.

If there is a dispute, resorting to litigation, while being lucrative for the lawyers involved, is likely to be time-consuming and expensive. An alternative is to agree that disputes be settled by *arbitration*. This requires disputes to be referred to an expert third party whose decision on the facts of the case is binding. Even this procedure might not be quick and inexpensive and another option is *alternative dispute resolution* where a mediator acts in an advisory capacity only and attempts to broker an agreement between the two sides.

10.5 Contract Management

ISPL Euromethod offers guidance about how decision points may be planned.

We have already noted that forms of communication between the supplier and customer during the project could be specified in the contract. It would probably suit all concerned if the contractor is left to get on with the work. However, at certain *decision points* (or *milestones*) the customer might wish to examine work already done and make decisions about the future direction of the project. The project could require representatives of the supplier and customer to interact at key points in the development cycle – for example, users may need to provide information to assist interface design.

Chapter 4 discusses incremental delivery.

One way of identifying the decision points is to divide a large project into increments. For each increment there could be an interface design phase, and the customer might need to approve the designs before the increment is built. There could also be decision points between increments.

For each decision point, the deliverables from the suppliers, the decisions to be made by the customer and the possible outcomes need to be defined. These decision points have added significance if they are the basis for payment to the contractor. The customer also has responsibilities at these decision points – for example, the contractor should not be delayed unnecessarily awaiting customer approval of interim deliverables.

There will be concerns about the quality of contracted work. The ISO 12207 standard envisages the possibility of there being agents, independent of both the supplier and customer, who will carry out verification, validation and quality assurance. It also allows for joint reviews of project processes and products to be agreed when the contract is negotiated.

We saw earlier that changes to requirements will vary the contract terms. Oral evidence is not normally admissible to contradict, add to, or vary the terms of a written contract, so that agreed changes need to be documented. A change control procedure must record requests for changes, the supplier's agreement to them and the cost for additional work.

The supplier might not meet a legal obligation. This might not be their fault, if, for example, the customer causes the delay by lateness in giving the necessary approvals for intermediate products. If no action is taken when the default occurs, this might imply that the customer in fact condones the failure and could lead to the loss of legal rights. The customer should protect their legal rights by officially notifying the supplier that the failure has been recognized. It will be recalled that under English law any claim for liquidated damages should be based on actual losses, so the customer needs to keep an accurate record of the actual losses incurred as a result of the default.

10.6 Acceptance

When the work has been completed, the customer needs to arrange acceptance testing. The contract may limit how long acceptance testing can take, so the customer must be organized to carry out this testing before the time limit for requesting corrections expires.

We have already noted that some software suppliers are rather cursory with their pre-acceptance testing. It seems that they would rather the users spent their time on testing than them. This imposition can be reduced by asking to approve the supplier's internal test plans. An associated pitfall is that once the main development work is completed, the supplier not unnaturally wants to reallocate their most productive staff to other projects. The customer could find that all their problem reports are being dealt with by relatively junior members of the supplier's staff, who may not be familiar with all aspects of the delivered system.

Part or all of the payment to the supplier should depend on this acceptance testing. Sometimes part of the final payment is retained for a period of operational running and is paid if the levels of performance are as contracted for. There may also be a period of warranty during which the supplier should fix any errors found for no charge. The supplier might suggest a very short warranty period of, say, 30 days. It may be in the customer's interests to negotiate a more realistic period of, say, at least 120 days.

Conclusion

Some of the key points in this chapter have been:

- The successful contracting out of work requires considerable amounts of management time
- It is easier to gain concessions from a supplier before a contract is signed rather than afterwards
- Alternative proposals need to be evaluated as far as possible by comparing costs over the whole lifetime of the system rather than just the acquisition costs
- A contract will place obligations on the customer as well as the supplier
- Contract negotiation should include reaching agreement on the management of the supplier–customer relationship during the execution of the project

Further Exercises

1. At IOE, the management are considering 'outsourcing' the maintenance accounting system, i.e. getting an outside specialist organization to take over the operation, maintenance and support activities associated with the system. Write a short memorandum to management outlining the advantages and disadvantages of such a reorganization.
2. Further exercise 4 at the end of Chapter 1 concerned a software house that needed a training course developed to introduce new users to an order processing application that they had developed. Assume that you are an independent training consultant who has been approached by the software house to develop the training package. You have agreed in principle and now a contract is being negotiated for the work.
   (a) List the points that you would want clarified and included in the contract.
   (b) Having produced the list of points requiring clarification, examine it from the point of view of the software house. Are there any additional points that they would want clarified?
3. In each of the following cases, discuss whether the type of application package to be adopted would be most likely to be bespoke, off-the-shelf or COTS.
   (a) A college requires a student fees application. It is suggested that the processes required in the application are similar to those of any billing system, with some requirements that are peculiar to the administration of higher education.
   (b) A computer-based application is needed at IOE to hold personnel details of staff employed.
   (c) A system is required by a national government that calculates, records and notifies individual taxpayers about income tax charges.
   (d) An expert system for use in a hospital to diagnose the causes of eye complaints.

4. The schedule of charges per function point shown in Table 10.1 has higher rates for larger systems. Give arguments explaining why this might be justified and also arguments against.
5. Table 10.2 has a charge of 25% and 50% of the normal rate for deleting transactions from an application. This may seem to be rather high for simply removing code. What work would be involved in deleting functionality that could justify this cost?
6. Assume that IOE has decided on a COTS solution that will replace the whole of the existing maintenance accounting system rather than simply plugging in additional modules to deal with annual contracts. Write a memorandum that Amanda could send to IOE's legal department outlining the important provisions that a contract to supply this system should have.
7. For each of the following questions, exactly one option is correct. Select the appropriate option.
   (i) Which one of the following is typically not expected in a fixed price contract?
      (a) Vendors tend to overprice the bids.
      (b) The selected vendor may demand higher price to accommodate new requirements.
      (c) Better quality of software is realized compared to time and material contracts.
      (d) Best model to follow when the bidder has stringent budget restrictions.
   (ii) Which one of the following contractor selection procedure is likely to result in the lowest price bid?
      (a) Open tendering
      (b) Restricted tendering including nonlocal vendors
      (c) Negotiated contract
      (d) Restricted tendering among local vendors
   (iii) Which one of the following contractor selection procedure for a certain item can result in the fastest deployment?
      (a) Open tendering
      (b) Restricted tendering including nonlocal vendors
      (c) Negotiated contract
      (d) Restricted tendering among local vendors

11 Managing People in Software Environments

Learning Objectives

- Identify some of the factors that influence people's behaviour in a project environment
- Select and induct new staff into a project
- Increase staff motivation
- Take steps to reduce unnecessary stress and threats to health and safety

11.1 Introduction

We are going to examine some of the problems that Amanda and Brigette could meet when dealing with members of their teams. Where possible, we want to base any advice on the findings of writers on organizational behaviour (OB). We will pay special attention where the sources refer to software development environments. Some of these human considerations affect staff as individuals. These will be the subject of this chapter. Others arise from the need for people involved in ICT system development and implementation to work in cooperation with others. These team and organizational issues are the topics of the following chapter. A group is, of course, made up of individuals so despite this division of concerns, the two chapters will have some overlaps.

There will be four main concerns in the current chapter: staff selection, staff development, staff motivation and the continued well-being of staff during the course of a project.

The issues raised in this chapter have impacts at all stages of project planning and execution but in particular at the following points (see also Figure 11.1).

- Some objectives can address health and safety during the project (Step 1).
- Although project leaders might have little control over organizational structure, they need to be aware of its implications (Step 2).

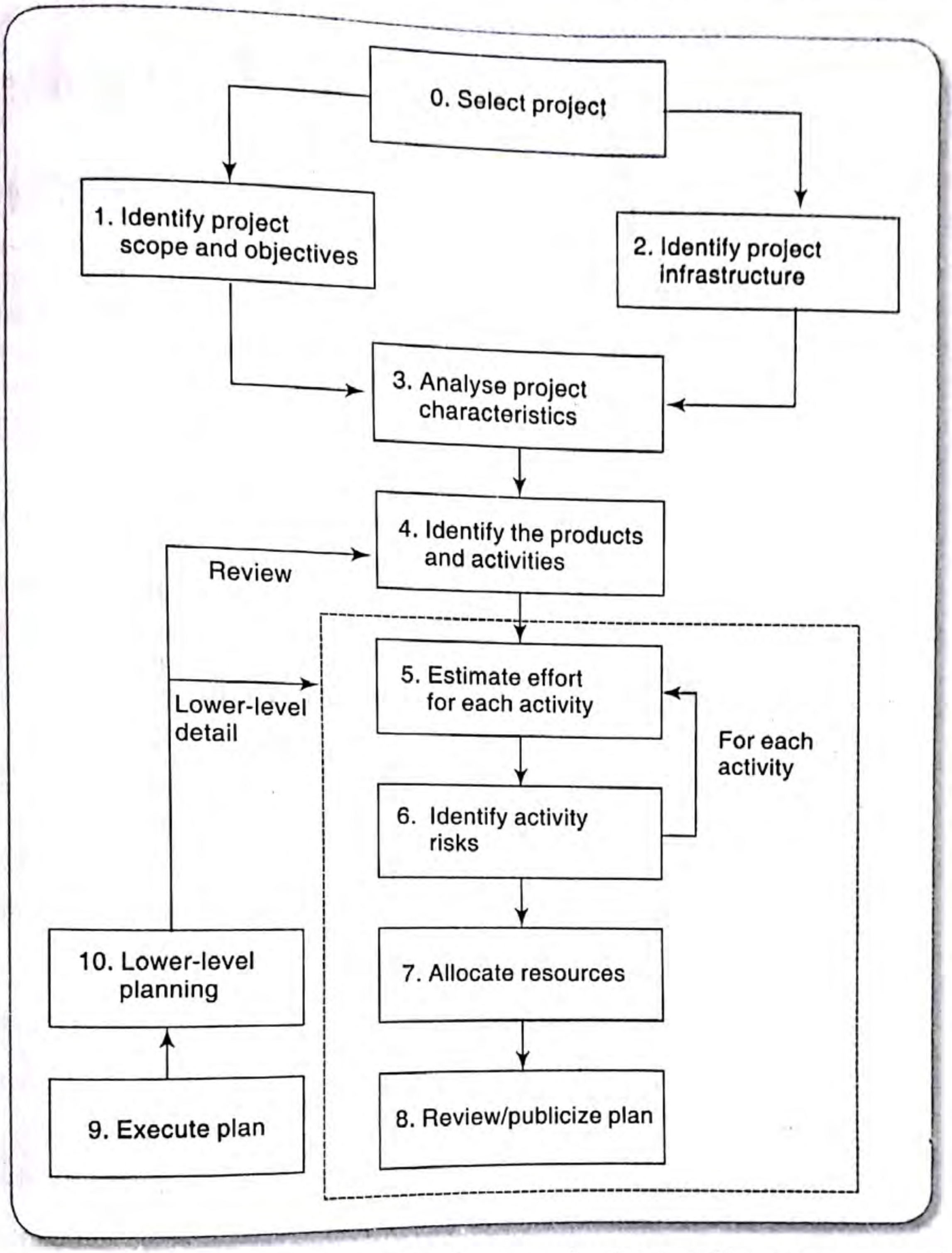

0. Select project
1. Identify project scope and objectives
2. Identify project infrastructure
3. Analyse project characteristics
4. Identify the products and activities
Review
5. Estimate effort for each activity
Lower-level detail
For each activity
6. Identify activity risks
7. Allocate resources
8. Review/publicize plan
9. Execute plan
10. Lower-level planning

FIGURE 11.1 Some places in the Step Wise framework where staffing concerns are important

- The scope and nature of activities can be set in a way that will enhance staff motivation (Step 4).
- Many risks to project success relate to staffing (Step 6).
- The qualities of individual members of staff should be taken into account when allocating staff to activities (Step 7).

11.2 Understanding Behaviour

People with practical experience of projects invariably identify the handling of people as an important aspect of project management. People like Amanda and Brigette would want to know whether the effective and sensitive management of staff comes only from experience or whether expert advice can help. Such advice may be more convincing if it is based on evidence that has been gathered through some kind of research.

This research into individual and group behaviour in software and ICT development environments needs to adopt social science research methods. This type of research requires a different mindset to that usually needed by software developers. Although the development of systems is usually based on user requirements that can be interpreted in more than one way, the end result is a system that works in a perfectly consistent way. The developers who produce such systems will inevitably have a tendency to see things in terms of deterministic systems where once a sequence of inputs is known, the outputs can be forecast with some certainty.

Such systems are perceived as being governed by mechanistic laws, just as there are in the physical sciences such as chemistry. This mindset tends to favour experimentation as the means of establishing the relationships between inputs and outputs and is sometimes referred to as a *positivist* approach. Attempts have been made to extend this model to social systems. However, because social systems, including business organizations, are so complex, it is not possible to predict their outcomes with any certainty. What can be done is to detect statistical relationships within such systems that can be expressed as generalized models or theories.

The discipline of *organizational behaviour* has evolved theories that try to explain people's behaviour. These theories are often structured as '*If A is the situation then B is likely to result*'. Attempts are made to observe behaviour where variables for A and B are measured and a statistical relationship between the two variables sought. Unlike physical science it is rarely, if ever, that it can be said that B *must* always follow A.

An *interpretivist* school of thought can be contrasted with the positivist one, particularly in relation to the extension of the quantitative and experimental methods from the physical sciences to people and organizations. Interpretivists point out that many concepts are not objective but are inter-subjective ones created by human beings. For example, later in this chapter we will examine whether there are particular personal characteristics that are associated with successful software developers. Some studies have found personal characteristics that seem to be strongly associated with 'software engineers' while other studies have found none. One question here would be how 'software engineer' is defined. Would someone who customizes and installs off-the-shelf packaged software count as a 'software engineer'? Would the description 'software engineer' cover the role of the ICT business analyst? Furthermore, how would you define 'successful'? Is it someone who can write lots of code very quickly? Or someone who knows where to find the right existing software to do a job? One way of resolving such questions would be to look closely at specific ICT environments and observe the different types of role that people undertake and the tasks and skills associated with such roles. The typical way of doing this is an in-depth study of a small number (perhaps only one) of instances of a particular type of organization which produces a description of how things are done in that context.

The two viewpoints labelled positivist and interpretivist can both be valid and useful. In the types of research that underpin the material in the current chapter on individuals in work environments the quantitative (or 'positivist') type predominates. In the following chapter on working in teams the research drawn upon tends to be more qualitative and based on case studies in the interpretivist tradition.

In the real world there will be a wide range of influences on a situation, many invisible to the observer. It is therefore difficult to decide which set of research findings is relevant. A danger is that we end up with a set of maxims which are little better than superstitions. However, by examining these issues people can at least become more sensitive and thoughtful about them.

Work Psychology by J. Arnold, C. L. Cooper and I. T. Robertson (2004) 4th edition, FT Prentice Hall, is a good general text on these topics.

In what follows we will be making references to workers in the OB field such as Taylor, McGregor and Herzberg. Rather than overwhelming the reader with references, we recommend the reader who is interested in exploring this topic further to look at some of the books in the Further Reading section at the back of the book. Where we have given references these tend to be for works related specifically to an ICT environment.

11.3 Organizational Behaviour: A Background

The roots of studies in OB can be traced back to work done in the late 19th and early 20th centuries by Frederick Taylor. Taylor attempted to analyse the most productive way of doing manual tasks. The workers were then trained to do the work in this way.

Frederick Winslow Taylor, 1856–1915, is regarded as the father of 'scientific management' of which OB is a part.

Taylor had three basic objectives:

- To select the best people for the job
- To instruct them in the best methods
- To give incentives in the form of higher wages to the best workers

'Taylorism' is often represented as crude and mechanistic. However, a concern for identifying best practice is valid. In the more mundane world of software development, the growth of both structured and agile methods is an example of an emphasis on best practice. Both Amanda and Brigette will be concerned that tasks are carried out in the proper way. More contentious is Taylor's emphasis on the exclusively financial basis of staff motivation, although Amanda and Brigette will find many colleagues who hold Taylor's view on the importance of 'performance-related pay'. Unfortunately, Amanda and Brigette are likely to have very little control over the financial rewards of their staff. However, they should be encouraged by findings that motivation rests not just on such rewards.

The research that obtained these findings was done at the Hawthorne Works of Western Electric in Chicago, hence the 'Hawthorne Effect'.

During the 1920s, OB researchers discovered, while carrying out a now famous set of tests on the conditions under which staff worked best, that not only did a group of workers for whom conditions were improved increase their work-rates, but also a control group for whom conditions were unchanged. Simply showing a concern for what workers did increased productivity. This illustrated how the state of mind of workers influenced their productivity.

The cash-oriented, or *instrumental*, view of work of some managers can thus be contrasted with a more rounded vision of people in their place of work. The two attitudes were labelled Theory X and Theory Y by Donald McGregor.

Theory X holds that:

- The average human has an innate dislike of work
- There is a need therefore for coercion, direction and control
- People tend to avoid responsibility

Theory Y, on the other hand, holds that:

- Work is as natural as rest or play
- External control and coercion are not the only ways of bringing about effort directed towards an organization's ends
- Commitment to objectives is a function of the rewards associated with their achievement
- The average human can learn to accept and further seek responsibility
- The capacity to exercise imagination and other creative qualities is widely distributed

A 'reward' does not have to be a financial reward – it could be something like a sense of achievement.

One way of judging whether a manager espouses Theory *X* or Theory *Y* is to observe how staff react when the boss is absent: if there is no discernible change then this is a Theory *Y* environment; if everyone visibly relaxes, it is a Theory *X* environment. McGregor's distinction between the two theories also draws attention to the way that expectations influence behaviour. If a manager (or teacher) assumes that you are going to work diligently and create products of good quality then you are likely to try to meet their expectations.

11.4 Selecting the Right Person for the Job

Taylor stressed the need for the right person for the job. Many factors, such as the use of software tools and methodologies, affect programming productivity. However, one of the biggest differences in software development performance is between individuals. As early as 1968 a comparison of experienced professional programmers working on the same programming task found a ratio, in one case, of 1:25 between the shortest and longest time to code the program and, more significantly perhaps, of 1:28 for the time taken to debug it. Amanda and Brigette would therefore be rightly concerned to get the best possible people working for them.

B. W. Boehm considered the quality of staff the most important influence on productivity when constructing the COCOMO software cost model (Chapter 5).

What sort of characteristics should they be looking for? Is an experienced programmer better than a new graduate with a first-class mathematics degree? It is dangerous to generalize but, looking at behavioural characteristics, the American researcher Cheney found that the most important influence on programmer productivity seemed to be experience. This is not surprising as the impact of experience is the most important factor in software productivity in Boehm's COCOMO models – see Chapter 5. Cheney found that mathematical aptitude had quite a weak influence in comparison.

P. M. Cheney (1984) 'Effects of individual characteristics, organizational factors and task characteristics on computer programmer productivity and job satisfaction' Information and Management, 7.

Amanda and Brigette will want staff who can communicate well with each other and with users. Unfortunately, the American researchers Couger and Zawacki found that information systems (IS) professionals seemed to have much weaker 'social needs' than people in other professions. They quote Gerald Weinberg: '*If asked, most programmers probably say they prefer to work alone where they wouldn't be disturbed by other people.*' We see many who are attracted to writing software, and are good at it, but do not make good managers later in their careers.

J. D. Couger and R. A. Zawacki (1978) 'What motivates DP Professionals?' Datamation, 24.

Later surveys, however, have *not* found significant differences between IS and other staff. An explanation of this could be that IS has become broader and less purely technical in recent years.

Recruitment process

It must be stressed that often project leaders have little choice about the people who will make up their team – they have to make do with the 'materials that are to hand'. Recruitment is often an organizational responsibility: the person recruited might, over a period of time, work in many different parts of the organization.

Meredith Belbin usefully distinguishes between *eligible* and *suitable* candidates. *Eligible* candidates have a curriculum vitae (CV) which shows, for example, the 'right' number of years in some previous post and the 'right' paper qualifications. *Suitable* candidates can actually do the job well. A mistake is to select an eligible candidate who is not in fact suitable. Suitable candidates who are not officially eligible can, on the other hand, be ideal candidates as once in post they are more likely to remain loyal. Belbin suggests we should try to assess actual skills rather than past experience and provide training to make good minor gaps in expertise. It seems to us to show that policies that avoid discrimination on the grounds of race, gender, age or irrelevant disabilities can be not just socially responsible but also a shrewd recruitment policy.

R. Meredith Belbin (1996) *Team Roles at Work*, 2nd edition, Butterworth-Heinemann.

A general approach might be the following.

- *Create a job specification* Advice is often needed as there could be legal implications in an official document. However, formally or informally, the requirements of the job, including the types of task to be carried out, should be documented and agreed.
- *Create a job holder profile* The job specification is used to construct a profile of the person needed to carry out the job. The qualities, qualifications, education and experience required would be listed.
- *Obtain applicants* Typically, an advertisement would be placed, either within the organization or outside in the trade or local press. The job holder profile would be examined carefully to identify the medium most likely to reach the largest number of potential applicants at least cost. For example, if a specialist is needed it would make sense to advertise in the relevant specialist journal. The other principle is to give enough information in the advertisement to allow an element of self-elimination. By giving the salary, location, job scope and any essential qualifications, the applicants will be limited to the more realistic candidates.
- *Examine CVs* These should be read carefully and compared to the job holder profile – nothing is more annoying for all concerned than when people have CVs which indicate clearly that they are not eligible for the job and yet are called for interview.
- *Interviews, etc.* Selection techniques include aptitude tests, personality tests and the examination of samples of previous work. Any method must test specific qualities detailed in the job holder profile. Interviews are the most commonly used method. It is better if there is more than one interview session with an applicant and within each session there should not be more than two interviewers as a greater number reduces the possibility of follow-up questions and discussion. Some formal scoring system for the qualities being judged should be devised and interviewers should then individually decide scores which are then compared. An interview might be of a technical nature where the practical expertise of the candidate is assessed, or of a more general nature. In the latter case, a major part of the interview could be evaluating and confirming statements in the CV – for example, time gaps in the education and employment history would be investigated, and the precise nature of previous jobs would need to be explored.

A standard form which lists each selection criterion and the degree to which the candidate meets it should be used to ensure a consistent and fair approach.

- *Other procedures* References will need to be taken up where necessary, and a medical examination might be needed.

Exercise 11.1

A new analyst/programmer is to be recruited to work in Amanda's team at JOE. The intention is to recruit someone who already has some experience. Make a list of the types of activities that the analyst/programmer should be capable of carrying out that can be used as the basis for a job specification.

11.5 Instruction in the Best Methods

Decisions will need to be made about whether a newcomer can more effectively pick up technical expertise on the job or on formal training courses.

This is the second concern that we have taken from Taylor. When new members of th team are recruited, the team leader will need to plan their induction into the team ver carefully. Where a project is already well under way, this might not be easy. Howeve the effort should be made – it should pay off as the new recruit will become a full effective member of the team more quickly.

The team leader should be aware of the need to assess continually the training need of their team members. Just as you formulate a user requirement before considering a new system, and a jol holder profile before recruiting a member of staff, so a training needs profile ought to be drawn up for each staff member when considering specific courses. Some training might be provided by commercial training companies. Where money is tight, alternative sources of training should be considered but training should no be abandoned. It could just be a team member finding out about a new software tool and then demonstrating it to colleagues. Of course, the nice thing about external courses is talking to colleagues from other organizations – but attending meetings of your local branch of a computer-related professional association, such as the British Computer Society (BCS) in the United Kingdom, can serve the same purpose.

The methods learnt need, of course, to be actually applied. Reviews and inspections help to ensure this.

In the next chapter we will return to this topic from the point of view of integrating outsiders into a new group environment.

11.6 Motivation

The third of Taylor's concerns was that of motivating people to work. We are going to look at some models of motivation.

Taylorist model

Piece-rates are where workers are paid a fixed sum for each item they produce. Day-rates refer to payment for time worked.

Taylor's viewpoint is reflected in the use of piece-rates in manufacturing industries and sales bonuses amongst sales forces. Piece-rates can cause difficulties if a new system will change work practices. If new technology improves productivity, adjusting piece-rates to reflect this will be a sensitive issue. Usually, radical changes in work practices have to be preceded by a move from piece-rates to day-rates. As will be seen later, the tendency towards dispersed or 'virtual projects' where staff work on their own premises at some distance from the sponsoring organization's site has seen a movement away from payment based on time worked.

Even where work practices are stable and output can be easily related to reward, people paid by the amount they produce will not automatically maximize their output in order to maximize their income. The amount of output will often by constrained by 'group norms': informal, even unspoken, agreements among colleagues about the amount to be produced.

Group norms are discussed further under group decision making.

Rewards based on piece-rates need to relate directly to work produced. Where a computer application is being developed, it is difficult to isolate and quantify work done by an individual, as system development and support is usually a team effort. As one member of staff in a study of software support work said: '*This support department does well because we're a team, not because we're all individuals. I think it's the only way the support team can work successfully.*'

Quoted by Wanda J. Orlikowski in *Groupware & Teamwork*, edited by Claudio U. Ciborra, Wiley and Sons, 1996.

In this kind of environment, a reward system that makes excessive distinctions between co-workers could damage morale and productivity. Organizations sometimes get around this problem by giving bonuses to project team members at the end of a successful project, especially if staff have 'volunteered' considerable unpaid overtime to get the project completed.

Exercise 11.2

A software development department want to improve productivity by encouraging the reuse of existing software components. It has been suggested that this could be encouraged through financial rewards. To what extent do you think this could be done?

Maslow's hierarchy of needs

The motivation of individuals varies. Money is a strong motivator when you are broke. However, as the basic need for cash is satisfied, other motivators are likely to emerge. Abraham Maslow, an American psychologist, suggested a hierarchy of needs. As a lower level of needs is satisfied then gradually a higher level of needs emerges. If these are then satisfied then another level will emerge. Basic needs include food, shelter and personal safety. The highest-level need, according to Maslow, is the need for 'self-actualization', the feeling that you are completely fulfilling your potential.

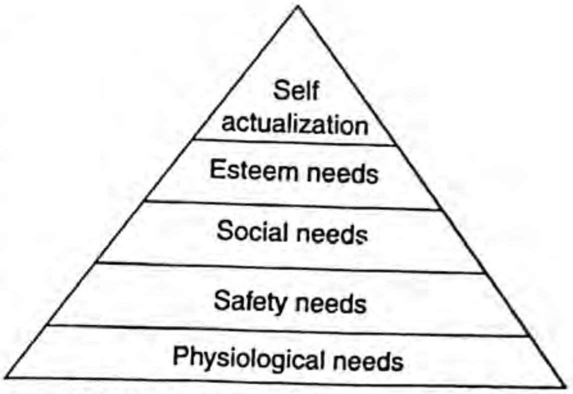


FIGURE 11.2 Maslow's hierarchy of needs.

The hierarchy of needs according to Maslow is shown pictorially in Figure 11.2.

In practice, people are likely to be motivated by different things at different stages of their life. For example, salary increases, while always welcome, probably have less impact on the more mature employee who is already relatively well paid than on a lowly paid trainee. Older team-members might place more value on qualities of the job, such as being given autonomy, which show respect for their judgement and sense of responsibility.

However, salary level can be important to staff approaching retirement because the amount of pension paid can depend on it.

Some individual differences in motivation relate simply to personality differences. Some staff have 'growth needs' – they are interested in their work and want to develop their work roles – while others simply see the job as a way of earning a living.

Exercise 11.3

Newspapers often report on the vast sums of money that are paid to the top executives of many companies. Does this mean that these people are at a low level in the Maslow hierarchy of motivation? Do they really need all this money to be motivated? What do you think the significance of these salaries really is?

Herzberg's two-factor theory

Some things about a job can make you dissatisfied. If the causes of this dissatisfaction are removed, this does not necessarily make the job more exciting. Research into job satisfaction by Herzberg and his associates found two sets of factors about a job:

- *hygiene or maintenance factors*, which can make you dissatisfied if they are not right, for example the level of pay or the working conditions;
- *motivators*, which make you feel that the job is worthwhile, like a sense of achievement or the challenge of the work itself.

Brigette, at Brightmouth College, might be in an environment where it is difficult to compete with the high level of maintenance factors that can be provided by a large organization like IOE, but the smaller organization with its closer contact with the users might be able to provide better motivators.

Exercise 11.4

Identify three incidents or times when you felt particularly pleased or happy about something to do with your work or study. Identify three occasions when you were particularly dissatisfied with your work or study. Compare your findings with those of your colleagues and try to identify any patterns.

Expectancy theory of motivation

Amanda and Brigette need to be aware of how the day-to-day ups and downs of system development affect motivation. A model of motivation developed by Vroom and his colleagues illustrates this. It identifies three influences on motivation:

- *expectancy:* the belief that working harder will lead to a better performance;
- *instrumentality:* the belief that better performance will be rewarded;
- *perceived value:* of the resulting reward.

Motivation will be high when all three factors are high. A zero level for any one of the factors can remove motivation.

In fact, Vroom's expectancy theory can be given by the following expression:

$$\text{Motivation} = \text{Expectancy} \times \text{Instrumentality} \times \text{Perceived value}$$

Imagine trying to get a software package supplied by a third party to work. You realize that you will never get it to work because of a bug, and you give up. No matter how hard you work you will not be able to succeed (*zero expectancy*).

You are working on a package for a user and, although you think you can get it to work, you discover that the user has started employing an alternative package and no longer needs this one. You will probably feel you are wasting your time and give up (*zero instrumentality*).

Given that the users really do want the package, your reward might simply be the warm feeling of helping your colleagues and their gratitude. If in fact, when the users employ the package, all they do is complain and hold you responsible for shortcomings, then you might avoid getting involved if they later ask for help implementing a different package (*low perceived value of reward*).

11.7 The Oldham–Hackman Job Characteristics Model

Managers should group together the elements of tasks to be carried out so that they form meaningful and satisfying assignments. Oldham and Hackman suggest that the satisfaction that a job gives is based on five factors. The first three factors make the job 'meaningful' to the person who is doing it:

- *Skill variety:* the number of different skills that the job holder has the opportunity to exercise
- *Task identity:* the degree to which your work and its results are identifiable as belonging to you
- *Task significance:* the degree to which your job has an influence on others

The other two factors are:

- *Autonomy:* the discretion you have about the way that you do the job
- *Feedback:* the information you get back about the results of your work

Oldham and Hackman also noted that both the job holders' personal growth needs and their working environment influenced their perception of the job. Some writers have pointed out that if people are happy with their work for other reasons, they are likely to rate it higher on the Oldham–Hackman dimensions anyway. Thus it might be that cause and effect are reversed.

In practical terms, activities should be designed so that, where possible, staff follow the progress of a particular product and feel personally associated with it.

Methods of improving motivation

To improve motivation the manager might therefore do the following.

- *Set specific goals* These goals need to be demanding and yet acceptable to staff. Involving staff in the setting of goals helps to gain acceptance for them.
- *Provide feedback* Not only do goals have to be set but staff need regular feedback about how they are progressing.
- *Consider job design* Jobs can be altered to make them more interesting and give staff more feeling of responsibility.

Two measures are often used to enhance job design – job enlargement and job enrichment.

Job enlargement and job enrichment are based on the work of F. Herzberg.

Sarah Beecham *et al.* (2008) 'Motivation in software engineering' *Information and software technology* 50 860–78.

- *Job enlargement* The person doing the job carries out a wider variety of activities. It is the opposite of increasing specialization. For example, a software developer in a maintenance group might be given responsibility for specifying minor amendments as well as carrying out the actual code changes. Couger and Zawacki found that programmer/analysts had higher job satisfaction than programmers.
- *Job enrichment* The job holder carries out tasks that are normally done at a managerial or supervisory level. With programmers in a maintenance team, they might be given authority to accept requests for changes that involve less than five days' work without the need for their manager's approval.

A comprehensive survey of research into the motivation of software developers can be found in paper published by Sarah Beecham and colleagues in 2008.

11.8 Stress

Quoted in *Death March* by Edward Yourdon, 2nd edition, Prentice-Hall, 2003.

Projects are about overcoming obstacles and achieving objectives. Almost by definition, both the project manager and team members will be under pressure. An American project manager is quoted as saying: '*Once a project gets rolling, you should expect members to be putting in at least 60 hours a week. . . . The project leader must expect to put in as many hours as possible. . . .*'

Kent Beck advocates a maximum 40-hour working week as an extreme programming practice – see Chapter 4.

Some pressure is actually healthy. Boredom can make many jobs soul-destroying. Beyond a certain level of pressure, however, the quality of work decreases and health can be affected. There is good evidence that productivity and the quality of output go down when more than about 40 hours a week are worked. As long ago as 1960 it was found in a US study that people under 45 years of age who worked more than 48 hours a week had twice the risk of death from coronary heart disease.

Many software developers are expected to work overtime on projects for no additional payment. In these cases, a fall in productivity is more than compensated for by the fact that the work is effectively free to the employer.

Clearly, it is sometimes necessary to put in extra effort to overcome some temporary obstacle or to deal with an emergency, but if overtime working becomes a way of life then there will be longer-term problems.

Good project management can reduce the reliance on overtime by the more realistic assessment of effort and elapsed time needed, based on careful recording and analysis of the performance of previous projects. Good planning and control will also help to reduce 'unexpected' problems generating unnecessary crises.

Stress can be caused by *role ambiguity* when staff do not have a clear idea of the objectives that their work is supposed to be fulfilling, what is expected of them by others and the precise scope of their responsibilities. The project manager could clearly be at fault in these instances.

Role conflict can also heighten stress. This is where the person is torn between the demands of two different roles. The parent of young children might be torn between the need to look after a sick child and the need to attend an important meeting to win new business.

Some managers claim to be successful through the use of essentially bullying tactics to push projects through. They need to create crises in order to justify the use of such tactics. This, however, is the antithesis of professional project management which aims at a rational, orderly and careful approach to the creation of complex products.

11.9 Stress Management

As already mentioned, stress is a routine part of almost every body's life, and it is usually agreed that some amount of stress can be beneficial by making an individual focused and more productive. Low stress is usually associated with boredom and leads to drop in performance. However, when the level of stress becomes burdensome, there is a drop in performance due to cognitive (associated with thoughts), emotional and physical strains. Cognitive strain may manifest in many forms such as worrying, forgetting and lacking concentration. Emotional strains can lead to anxiety, restlessness, panic, interpersonal problems, losing touch with friends, irritability and anger. The associated physical strains may manifest itself in the form of shallow breathing, nausea, fatigue, headache, shoulder and back pain, sleep disturbances and hypertension. High stress is sometimes present among software developers and project managers. These roles involve intellectual work, meeting customer expectations and team work. Each of these can be source of stress and when the stress level of an individual exceeds some threshold, suitable stress management technique should be deployed. In the following, we discuss three important categories of stress management techniques.

Imagery, relaxation and meditation

These techniques rely on deep breathing, relaxation, physical exercise, guided imagery, yoga, progressive muscle relaxation and massage therapy. An example of a simple relaxation technique can be rolling the head from side to side. Guided imagery refers to a wide variety of techniques such as simple visualization, metaphor and story-telling to instil positive feeling.

Cognitive behavioural approaches

These techniques involve developing emotion-focused cognitive coping skills, such as, self-monitoring of stress intensity, thought record-keeping and rewriting, time management, assertiveness training and increased social interactions.

Systemic approaches

Systemic approaches focus on altering the factors which contribute to stress. For example, if a team member finds it stressful to work with certain tools and techniques, a switch of job role may be suggested, so that the team member does not have to deal with those tools and techniques which are causing stress.

11.10 Health and Safety

Health and safety issues are more prominent in construction and other heavy engineering projects than in ICT development. Sometimes, however, the implementation of office systems requires the creation of physical infrastructure which can have inherent physical dangers. ICT infrastructure could, for example, be installed in a building where construction work is still going on.

In this section we are not addressing general concerns relating to the safety of ICT equipment of which any organization using such equipment would need to be aware. Nor are we discussing the safety of products created by the software development process. We are focusing briefly on the health and safety issues that relate to the conduct of a project.

Various pieces of legislation govern safety policy and the details of these can be consulted in the appropriate literature. In the United Kingdom, legislation requires organizations employing more than five employees to have a written *safety policy* document. A project manager should be aware of the contents of the document that applies to the environment in which the project is to be undertaken.

Professional Issues in Software Engineering (3rd edition) by M. F. Bott *et al.*, Taylor and Francis, 2001, explores these issues in greater depth.

As far as the project manager is concerned, safety objectives, where appropriate, should be treated like any other project objectives, such as the level of reliability of the completed application or the overall cost of the project. The management of safety should therefore be embedded in the general management of the project.

Responsibility for safety must be clearly defined at all levels. Some points that will need to be considered include:

- Top management must be committed to the safety policy
- The delegation of responsibilities for safety must be clear
- Job descriptions should include definitions of duties related to safety
- Those to whom responsibilities are delegated must understand the responsibilities and agree to them
- Deployment of a safety officer and the support of experts in particular technical areas
- Consultation on safety
- An adequate budgeting for safety costs

Safety procedures must be brought to the attention of employees and appropriate training be given where needed.

This is a very cursory glimpse at some of the issues in this area. For a fuller treatment, the specialized literature should be consulted.

11.11 Some Ethical and Professional Concerns

As we saw above, there is now a legal requirement to act to reduce the threats to the health and safety of employees at work. Yet even if there were no such law, there would be very few who would not at least pay lip service to the moral obligation to prevent foreseeable injury to those at work. This would be an *ethical* judgement. There are bound to be cases where we would agree that people are, unethically, acting in a way potentially harmful to others even though laws have not – yet – been passed to prohibit that precise behaviour.

See Milton Friedman (1970) 'The social responsibility of business is to increase profits' *The New York Times Magazine* 13 September. Available at: www.umich edu/~thecore/doc/ Friedman.doc

Some ethical responsibilities are shared by all members of the community, regardless of their position – for example, to alert the emergency services when a serious motor accident has taken place. Other ethical responsibilities affect particular organizations and the people who belong to them. Further responsibilities relate to a person's professional expertise, such as that of the software engineer or IT practitioner.

It might be thought that organizations have greater ethical responsibilities given their greater power to inflict damage than individuals, particular when they implement large development projects of various kinds. However, there is an argument – associated particularly with the economist Milton Friedman – that those working for commercial organizations have a contract to safeguard and enhance the assets of the stockholders of the company. These stockholders are those who have invested money in the company and are legally its owners – they could include ordinary people who have invested their retirement savings in the company. It was argued that pursuing other goals that might benefit the community as a whole at the expense of the stockholders would be dishonest behaviour by the company's employees.

Exercise 11.5

Identify some of the possible objections and criticisms that can be made of the stockholder business ethics model described above.

Another argument for the reduced – or at least peculiar – ethical responsibilities of commercial organizations is that they are competing with other businesses. If my business wins some aspect of this game, then my competitors must lose: investors might lose money and employees their jobs. But, it is argued, that is the way the market works, and as a result consumers benefit from reduced prices. However, in the longer term competition which destroys competitors leads to the domination of monopolies and increased prices.

A rather extreme argument that normal ethical rules do not apply in business can be found in Alfred Carr (1968) 'Is business bluffing ethical?' *Harvard Business Review*, 46(1) 143–53.

Most organizations will, however, recognize that they do have ethical responsibilities. This could be purely out of self-interest. You may, as a potential customer, be wary of entrusting your custom to organizations which are transparently motivated by pure greed. Organizations often express their objectives and aspirations – perhaps in the form of a mission statement – and these tend to include some objectives that relate to matters of the general public good such as concern for the environment.

Despite removing levels of management (delayering) and creating flatter reporting structures, large organizations will always have some sort of hierarchy. As we saw in Chapter 1, the people at the top will specify a general strategy, hopefully consistent with the aspirations of the mission statement. Managers at the next level will take the strategy and devise programmes of work to achieve the strategic goals in their areas of responsibility. When doing this they are making decisions within their designated areas of responsibility. This process will be repeated at successively lower levels in the company until we get to the people who actually implement the decisions.

Any decision that is made will have to satisfy a number of organizational requirements which could appear to conflict. For example, a new ICT application may be needed to meet a legal requirement with a fixed deadline. A high-quality system where reliability and correctness can be guaranteed would require a large team to develop it. This would be very costly and require the normal service to customers to be degraded. Some kind of balance would need to be struck between the need for reliability in the new system and the current quality of customer service. Whatever the final decision, there would be some risk about the final outcomes.

Among the decisions involving risks will be those allocated to technical experts such as engineers and ICT practitioners. These will have special ethical responsibilities as they have knowledge and expertise that others may not fully understand but upon which they depend. These experts are likely to be entrusted with decisions about the deployment of new technologies.

An excellent detailed exploration on these issues is Rosa Lynn B. Pinkus *et al.* (1997) *Engineering Ethics*, Cambridge University Press, which uses the Challenger space shuttle disaster as a case study

ICT practitioners are unlikely to be expert in all areas of ICT and its development, so identifying a person's area of expertise is crucial. It would clearly be unethical for an ICT practitioner to pretend to be knowledgeable about some area where they are not. It also follows that if an ICT practitioner has expertise that would prevent a colleague from doing something harmful, it would be unethical for them to remain silent.

The decisions entrusted to these specialists would not only have to be technically justifiable but be unbiased. Accepting what amounts to bribes is clearly an example of unacceptable behaviour. However, recommending a particular technology because it happens to be one that the practitioner is expert in and its adoption would enhance his or her career might not immediately appear to be unethical to an individual.

As noted above, all decisions involve risks and true professionals would need to identify and warn about these risks. We also saw above that organizational actions tend to be implemented in a top-down manner, with the big decisions about strategy being decided first, and then the different elements of the overall plan being examined and more detailed decisions being made. Sometimes these high-level decisions have technical flaws and it would be the responsibility of the software engineer or ICT practitioner to point out such deficiencies.

This responsibility for emerging technical risks is not a matter solely for the practitioner. The organization must have a mechanism whereby such concerns can be communicated to a responsible manager who is competent to evaluate the issue and to take necessary actions. This might include escalating the issue to a higher level of management.

Long-established professions, such as medicine, have ways of certifying the competence of practitioners and enforcing ethical codes of conduct. In the United Kingdom, the British Computer Society (BCS) is a body which has produced *Codes of Conduct* and *Good Practice* (www.bcs.org/upload/pdf/conduct.pdf and www.bcs.org/upload/pdf/cop.pdf) – as has the IEEE (www.ieee.org/web/aboutus/ethics) and ACM (www.acm.org/about/se_code) in the United States – and various schemes for certifying the competence of different ICT specialists. However, BCS membership is still held by only a small minority of ICT practitioners so there is a long way to go in establishing ICT as a true profession.

Conclusion

Some of the important points that have been made in this chapter are:

- People may be motivated by money, but they are motivated by other things as well
- Both staff selection and the identification of training needs should be done in an orderly, structured way where requirements are clearly defined first
- Thoughtful job design can increase staff motivation
- Undue pressure on staff can have short-term gains, but is harmful to both productivity and personal health in the longer term
- Project objectives should include, where appropriate, those relating health and safety

Further Exercises

1. An organization has detected low job satisfaction in the following departments:
   - The system testing group

- The computer applications help desk
- Computer batch input

How could these jobs be redesigned to give more job satisfaction?

2. In Exercise 11.1, a job specification was requested.
   (a) Write a job holder profile of the sort of person who would be able to fulfil the specification in terms of qualities, qualifications, previous education and experience.
   (b) For each element in the job holder profile that you have produced in (a) above, describe ways of finding out whether an applicant has met the requirement.
3. Section 11.8 focuses on the responsibilities of management in relation to staff stress. Evaluate an alternative view that individual staff members need themselves to be responsible for reducing their own stress levels, perhaps through changes in personal working practices.
4. Job enlargement sounds like a good thing. Explore what the possible disadvantages of job enlargement might be for both employers and staff.
5. For each of the following questions, exactly one of the options is correct. Select the appropriate option.
   (i) Which one of the following may be the highest motivator for a senior manager of a software development organization?
      (a) Lunch allowance
      (b) House rent allowance
      (c) Company-provided car
      (d) More interesting job assignment at the same pay
   (ii) Which one of the following is the most accurate ranking of human needs as per Maslow?
      (a) Self-actualization; self-promotion; social; security and physiological needs
      (b) Self-esteem; self-actualization; social; security and physiological
      (c) Self-actualization; self-esteem; social; security and physiological
      (d) Self-fulfilment; self-esteem; social; security and physiological
   (iii) Which one of the following has been identified by Herzberg as factor, which, if present, will lead to increased motivation?
      (a) Good supervision
      (b) Job security
      (c) Regular promotions
      (d) Good salary
   (iv) If a team member is finding it extremely stressful, which one of the following stress management techniques would be suggested by a systemic approach?
      (a) Rolling head from side to side
      (b) Change of job role
      (c) Deep breathing
      (d) Increased social interactions

(v) Which one is not a factor in job satisfaction according to Oldham–Hackman job characteristics model?

(a) Skill variety

(b) Task identity

(c) Task complexity

(d) Task significance

(vi) Which one of the following is a 'hygiene factor' under Herzberg's Motivation-Hygiene Theory?

(a) Recognition for excellent work

(b) Self-actualization

(c) Good relations with co-workers and managers

(d) Clean work environment

12 Working in Teams

Learning Objectives

- Improve group working
- Analyse the coordination needs of a project
- Select the best communication genres to support the coordination needs of a project
- Draw up a communication plan
- Evaluate the characteristics of the various team structures
- Use the most appropriate leadership styles

12.1 Introduction

We associate software development with advanced technologies yet it is a task requiring intense human mental activity. Software-based systems can be huge – the software to control a telephone switching system can contain five million lines of code – so that this human effort has to be shared between individual software developers within teams and between groups of developers. Amanda at IOE wants to get the best out of her team, but also needs to coordinate the work of her group with other parts of IOE, including the users. At Brightmouth College, Brigette does not have a big team to manage, but the need to coordinate her efforts with those of other project stakeholders is probably greater.

This chapter will look enhancing communication between individual developers within teams and across teams. It will also look at how the efforts of individuals and teams can be coordinated through communication.

By 'teams' we usually mean groups of people who are working together. Typically the individuals work in the same office, that is, are *co-located* – although we will see that this is not always so. However, the term 'project team' is sometimes used to refer to *all* the people working on a project. These people may sit in different work groups at some distance from each other. These groups can also change over time. Thus individual software developers are likely to transfer between teams as projects start and finish.

We will start by looking at the small group environment where the term 'team' is perhaps most justified. We will look at how true teams come to be formed. We will see how, apart from their technical roles, team members take on social roles that help team effectiveness.

A team is created to carry out a joint assignment. We will see how some tasks contributing to project objectives are best done by an individual. Other tasks, usually those that involve judgement or decision-making, may be better done by groups.

We will look at how teams can be coordinated. An organization needs to control the allocation of staff to work assignments. This is one form of coordination needed between groups and individuals within a project and other types will be outlined.

Communication genres refer to methods of communication. This goes beyond technologies used and includes the organizational conventions involved in the communication. Communication genres can be selected and developed to deal with particular need for project coordination. We will see how arrangements for communication between project stakeholders can be documented in a *communication plan*.

As well as coordination which reacts to day-to-day problems, but there needs to be proactive central direction. This introduces issues related to leadership.

The collaborative nature of project work will have an influence on nearly all stages of the Step Wise project planning framework (Figure 12.1).

1. *Identify project scope and objectives*. Here stakeholders in the project are identified and communications channels are established.
2. *Identify project infrastructure*. The organization structure within which the project team will exist is identified.
3. *Analyse project characteristics*. Decisions made about how the project is to be executed – for example buying versus building software functionality – will affect the team structure needed.
4. *Estimate effort for each activity*. Individual and group experience will have a key influence on developer productivity.
5. *Identify activity risks*. Risks will include those that relate to staff such as continued availability.
6. *Allocate resources*.
7. *Review/publicize plan*. A communication plan could be produced at this point.

12.2 Becoming a Team

First we look at how small work groups – where the description 'team' is perhaps most apt – are formed. Simply throwing people together will not immediately enable them to work together as a team. It is suggested that teams go through five basic stages of development:

- *Forming* The members of the group get to know each other and try to set up some ground rules about behaviour.
- *Storming* Conflicts arise as various members of the group try to exert leadership and the group's methods of operation are being established.
- *Norming* Conflicts are largely settled and a feeling of group identity emerges.
- *Performing* The emphasis is now on the tasks at hand.
- *Adjourning* The group disbands.

This classification is associated with B. W. Tuckman and M. A. Jensen.

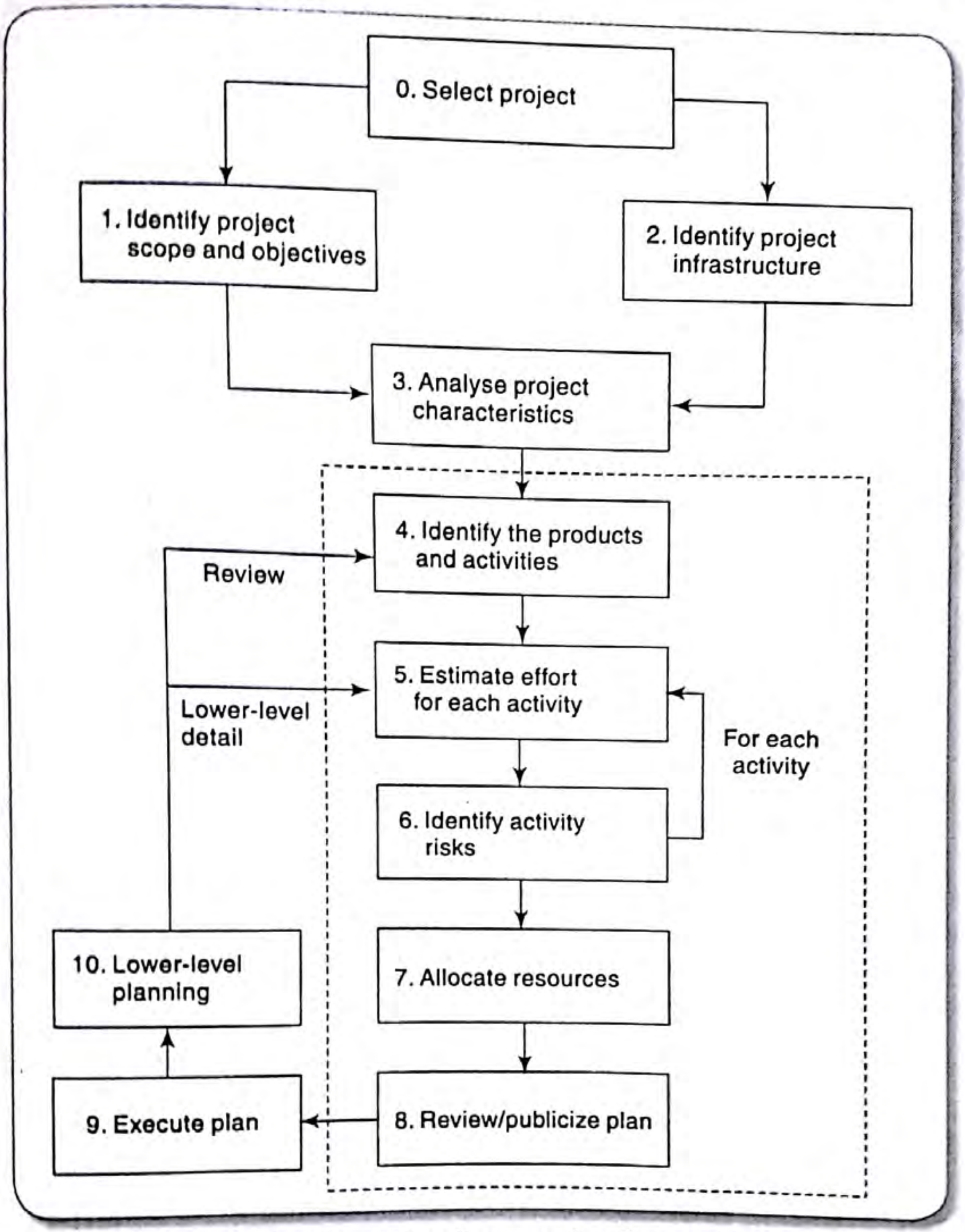

0. Select project
1. Identify project scope and objectives
2. Identify project infrastructure
3. Analyse project characteristics
4. Identify the products and activities
Review
5. Estimate effort for each activity
Lower-level detail
For each activity
6. Identify activity risks
7. Allocate resources
10. Lower-level planning
9. Execute plan
8. Review/publicize plan

Figure 12.1 Some places in the Step Wise framework influenced by collaborative working

Sometimes specific team-building exercises can be undertaken. Some organizations, for example, send their management teams off on outdoor activities. Without going to these lengths, Amanda and Brigette might devise some training activities which promote team building.

Valuable research has examined the best mix of personalities in a project team. Belbin studied teams working together on management games. He initially tried putting the most able people into one group. Surprisingly, these élite teams tended to do very badly – they argued a lot and as a result important tasks were often neglected.

Belbin came to the conclusion that teams needed a balance of different types of people.

R. Meredith Belbin (2003) *Management Teams: Why They Succeed or Fail*, 2nd edition, Elsevier, contains a self-assessment questionnaire which identifies the role a person is best suited to.

In *Team roles at work*, 1996, Belbin suggests that 'coordinator' and 'implementer' are better descriptions than 'chair' and 'team worker'. A new role is added: the 'specialist', the 'techie' who likes to acquire knowledge for its own sake.

- *The chair:* not necessarily brilliant leaders but they must be good at running meetings, being calm, strong but tolerant.
- *The plant:* someone who is essentially very good at generating ideas and potential solutions to problems.
- *The monitor–evaluator:* good at evaluating ideas and potential solutions and helping to select the best one.
- *The shaper:* rather a worrier, who helps to direct the team's attention to the important issues.
- *The team worker:* skilled at creating a good working environment, for example, by 'jollying people along'.
- *The resource investigator:* adept at finding resources in terms of both physical resources and information.
- *The completer–finisher:* concerned with completing tasks.
- *The company worker:* a good team player who is willing to undertake less attractive tasks if they are needed for team success.

A person can have elements of more than one type. On the other hand, about 30% of the people examined by Belbin could not be classified at all.

Problems can occur when there is an imbalance between the role types of people in a group. For example, if there are two or more shapers within a group and nobody who takes a chair role to moderate conflicting views, there is likely to be a stormy atmosphere. On the other hand, if a group mainly consists of plants and specialists with no shapers or completer–finishers, the team is likely to have interesting discussions but may not get around to actually implementing anything. When putting together a team Belbin recommends selecting the essential technical specialists first. The group roles of these individuals can then be assessed and any remaining team members can then be allocated with an eye on making the group roles more balanced.

Group performance

The IBM manager was quoted by Angelo Failla in 'Technologies for co-ordination in a software factory' in *Groupware & Teamwork*, edited by C. U. Ciborra, Wiley & Sons, 1996.

Are groups more effective than individuals working alone? Given the preference of many people attracted to software development for working on their own, this is an important question. In many projects, judgements are needed about which tasks are best carried out collectively and which are best delegated to individuals. As one manager at IBM said: '*Some work yields better results if carried out as a team while some things are slowed down if the work is not compartmentalized on an individual basis.*' Part of the answer lies in the type of task being undertaken.

One way of categorizing group tasks is into:

- Additive tasks
- Compensatory tasks
- Disjunctive tasks
- Conjunctive tasks

Additive tasks mean that the efforts of each participant are added to get the final result, e.g. a gang clearing snow. The people involved are interchangeable.

With *compensatory tasks* the judgements of individual group members are pooled so that the errors of some are compensated for by the inputs from others. For example, individual members of a group are asked to provide estimates of the effort needed to produce a piece of software and the results are then averaged. In these circumstances group work is generally more effective than the efforts of individuals.

Code reviews could be seen as an example of a compensatory task.

With *disjunctive tasks* there is only one correct answer. The effectiveness of the group depends on:

- Someone coming up with the right answer
- The others recognizing it as being correct

Here the group can only be as good as its best member – and could be worse!

Conjunctive tasks are where progress is governed by the rate of the slowest performer. Software production where different staff are responsible for different modules is a good example of this. The overall task is not completed until all participants have completed their part of the work. In this case cooperative attitudes are productive: the team members who are ahead can help the meeting of group objectives by assisting those who are behind. As we will see in a moment, this is an example of *group heedfulness*.

With all types of collective task, but particularly with additive ones, there is a danger of *social loafing*, where some individuals do not make their proper contribution. This can certainly occur with student group activities, but is not unknown in 'real' work environments. As one software developer has commented: '*[The contribution made to others] is not always recognized. Nor is the lack of any contributions... nobody points out those who fail to make any contributions. Like when there's somebody with vital skills and you ask him for help, but he doesn't provide it.*'

The source of the quotation is the paper by Failla that is cited above.

Exercise 12.1

Social loafing is a problem that students often encounter when carrying out group assignments. What steps can participants in a group take to encourage team members to 'pull their weight' properly?

12.3 Decision Making

Before we can look more closely at the effectiveness with which groups can make decisions, we need to look in general terms at the decision-making process.

Many of the evaluation techniques in Chapter 2 are attempts to make decision making more structured.

Decisions can be categorized as being:

- *Structured:* generally relatively simple, routine decisions where rules can be applied in a fairly straightforward way
- *Unstructured:* more complex and often requiring a degree of creativity

Another way of categorizing decisions is by the amount of *risk* and *uncertainty* that is involved.

Some mental obstacles to good decision making

Many of the techniques in Chapter 2 on project selection are based on the rational-economic model.

So far we have rightly stressed a structured, rational, approach to decision makin Many management decisions in the real world, however, are made under pressure a based on incomplete information. We have to accept the role of intuition in such case but be aware of some mental obstacles to effective intuitive thinking, for example:

- *Faulty heuristics* Heuristics or 'rules of thumb' can be useful but there are dangers:
- they are based only on information that is to hand, which might be misleading;
- they are based on stereotypes, such as accepting a Welshman into a male voice choir without an auditio because of the 'well-known' fact that the Welsh are a great singing nation.
- *Escalation of commitment* This refers to the way that once you have made a decision it is increasingl difficult to alter it even in the face of evidence that it is wrong.
- *Information overload* It is possible to have too much information so that you 'cannot see the wood fo the trees'.

Group decision making

A different type of participatory decision making might occur when end-users are consulted about the way a projected computer system is to operate.

There might be occasions where Amanda at IOE, for instance, might want to consul with her whole project team. With a project team different specialists and points o view can be brought together. Decisions made by the team as a whole are more likel to be accepted than those that are imposed.

Assuming that the meetings are genuinely collectively responsible and have beer properly briefed, research would seem to show that groups are better at solving complex problems when the members of the group have complementary skills and expertise. The meeting allows them to communicate freely and to get ideas accepted.

Joint Application Development (JAD) was discussed in Chapter 4.

Groups deal less effectively with poorly structured problems needing creative solutions. Brainstorming techniques can help groups in this situation but research shows that people often come up with more ideas individually than in a group. Where the aim is to get the involvement of end-users of a computer system, then prototyping and participatory approaches such as JAD might be adopted.

Obstacles to good group decision making

Once established, group norms can survive many changes of membership in the group.

Amanda could find that group decision making has disadvantages: it is time-consuming; it can stir up conflicts within the group; and decisions can be unduly influenced by dominant personalities.

Conflict can, in fact, be less than might be expected. Experiments have shown that people will modify their personal judgements to conform to *group norms*, common attitudes developed by a group over time.

You might think that this would moderate the more extreme views that some in the group might hold. In fact, people in groups sometimes make decisions that carry more risk than where they make the decision on their own. This is known as the *risky shift*.

Measures to reduce the disadvantages of group decision making

One method of making group decision making more efficient and effective is by training members to follow a set procedure. The *Delphi technique* endeavours to collate the judgements of a number of experts without actually bringing them face to face. Given a problem, the following procedure is carried out:

- Cooperation of a number of experts is enlisted
- Problem is presented to the experts
- Experts record their recommendations
- These recommendations are collated and reproduced
- Collected responses are recirculated
- Experts comment on the ideas of others and modify their recommendations if so moved
- If the leader detects a consensus then the process is stopped, otherwise the comments are recirculated to the experts

An advantage of this approach is that the experts could be geographically dispersed. However, this means that the process can be time-consuming.

Exercise 12.2

What developments in information technology would be of particular assistance to use of the Delphi technique?

Team heedfulness

Sometimes, despite all these problems, teams work well together. To use the inevitable sporting analogy, a football team does not play at its best when individual players simply display their skills as individuals but do not support one another. A successful move can be triggered where one player sees that another is in a position to score a goal if provided with a ball. This is an example of team heedfulness, where group members are aware of the activities of others that contribute to overall group success and can identify ways of supporting that contribution. In these cases there almost seems to be a 'collective mind'. Clearly there is no such physical entity in reality, and the appearance of a 'collective mind' comes from shared understanding, familiarity and good communications. Some attempts have been made actively to promote this in a software development environment, such as the concept of egoless programming, chief programmer teams and Scrum.

These ideas are explored further in K. Crowston and E. E. Kammerer (1998) 'Coordination and collective mind in software requirements development' *IBM Systems Journal*, 37(2) 227–45.

Egoless programming

In the early days of computer development managers tended to think of the software developer as communing mysteriously with the machine. The tendency was for programmers to see programs as being an extension of themselves and to feel over-protective towards them. The effects of this on the maintainability of programs can be imagined. Gerald Weinberg made the then revolutionary suggestion that programmers and programming team leaders should read each others' programs. Programs would

G. M. Weinberg (1998) *The Psychology of Computer Programming*, Silver Anniversary Edition, Dorset House.

become in effect the common property of the programming group and programming would become 'egoless'. Peer code reviews are based on this idea where items produced by individual team members are checked by selected colleagues – see Chapter 13.

Chief programmer teams

Brooks' *Mythical Man-Month* has already been referred to. He was in charge of the huge team that created the operating system for the IBM 360 range.

The larger the development group the slower it becomes because of the increased communication. Thus large time-critical projects tend to have a more formalized, centralized structure. Brooks stressed the need for design consistency when producing a large complex system and how this is difficult where large numbers of people are involved in development. He suggested reducing this number but making the remaining programmers as productive as possible by giving them more support.

The result was the *chief programmer team*. The chief programmer defines the specification, and designs, codes, tests and documents the software. He or she is assisted by a *co-pilot*, with whom the chief programmer can discuss problems and who writes some code. They are supported by an *editor* to write up the documentation drafted by the chief programmer, a *program clerk* to maintain the actual code, and a *tester*. The general idea is that this team is under the control of a single unifying intellect.

The chief programmer concept was used on the influential *New York Times* data bank project where many aspects of structured programming were tried out. In this case each chief programmer managed a senior-level programmer and a program librarian. Additional members could be added to the team on a temporary basis to deal with particular problems or tasks.

The problem with this kind of organization is getting hold of really outstanding programmers to carry out the chief programmer role. There is also the danger of information overload on the chief programmer. There is in addition the potential for staff dissatisfaction among those who are there simply to minister to the needs of the superstar chief programmers.

Extreme programming (XP)

Extreme programming was discussed in Chapter 4.

The new *extreme programming* (XP) concepts have inherited some of these ideas. Most XP practices can be seen as ways of promoting a 'collective mind'. In conventional software development projects, a typical approach to improving communication and coordination is to introduce more documentation. The advocates of XP argue that this is self-defeating. They suggest other, less formal, methods of communication and coordination. Rather than creating separate documents, the key software products, software code and test data, are enhanced. For example, coding is constantly *refactored* (that is, rewritten) and coding standards are followed to make the code clearly convey how the system works. Test cases and expected results are produced before the code, and act effectively as a form of specification. A user representative should be on hand to clarify user needs. The fit between software components is ensured by continual integration testing. Software development by pairs of developers is advocated – this seems to be a new version of the chief programmer/co-pilot relationship.

We will see that while internal group coordination is enhanced, the problem of coordination between teams remains.

Scrum

It would be self-defeating if the practices advocated by agile approaches should themselves become codified, structured and rigid in application. Promoters of agile methods, such as Kent Beck, are the first to stress that different types of project will need different approaches.

Linda Rising and Norman S. Janoff (2000) 'The Scrum software development process for small teams' *IEEE Software* July/August 26–32 provides a good overview of Scrum in practice.

The *Scrum* software development process illustrates some of these points as it has many elements found in agile methods but also has an element of the chief programmer philosophy. The name 'Scrum' comes from rugby scrums and the image of everyone pushing together in a common undertaking. The process was originally designed for new software product development for a competitive market rather than as a commission for a single client. Here, getting something to market before your competitors may be more important than having a comprehensive range of non-essential features. There is no precise specification of the requirements of a particular client, while having a product that is attractive to a number of customers is important. Proposals for features are likely to evolve as ideas are tried out during development.

The Scrum process starts with a systems architecture and planning phase. This has something of the chief programmer approach as a chief architect defines the overall architecture of the product. The required release date for the product and a set of the desired features of the product, each with a priority, would be defined at this stage.

This phase is now followed by a number of *sprints*, each of which typically lasts between one and four weeks. The features that it is hoped can be developed during a sprint are selected. The tasks needed to implement the features are lised. Sprints are carried out by groups, ideally with about seven developers and at a maximum ten. It is possible for Scrum teams to work in parallel on different sprints, but all teams must finish their sprint on the same day.

The progress of a sprint is marked by short (typically 15 minute) meetings each day. During the meeting, team members report on progress with their current task, describing any obstacles they are experiencing. The meeting allows any colleagues who can assist with a problem to come forward. This might be because the co-worker had a similar problem in the past for which they found a solution. Any resulting problem-solving discussions take place after the meeting. These Scrum meetings should promote shared understanding in the group but also help motivate the team as each person's progress is visible to the whole group.

Sprints are time-boxed and at the end of the sprint period some uncompleted, lower-priority features may be held over. Unlike XP, external requirements are frozen during the sprint – it will be recalled that with XP, changes can be requested at any point. However, at the end of the sprint, all sprint teams meet with the other project stakeholders to review the products created. It is at this point that new features could be added, and previous ones deleted or modified. The priority of desired features could be modified. The features to be built in the next sprint are then chosen, and the tasks needed to deliver those features are planned. The sprint process described above is then repeated.

When all the sprints have been completed, there is a final closure phase where tasks like regression and integration testing and the writing of user and training guides take place to create a final package for delivery to market.

Linda Rising and Norman S. Janoff (2000) have described the implementation of Scrum at AG Communications in the USA. Of interest in their account is the evidence of flexibility in implementing the process. One team, for example, decided to have Scrum meetings three times a week, rather than each day. In another case, a team decided to break the rule that externally imposed changes should be ignored during a sprint, when an unusually severe externally imposed change was clearly unavoidable.

12.4 Organization and Team Structures

Large software development companies are usually organized into departments. Departmentalization of a company may be based on several criteria such as staff specialization, product lines, categories of customers, or geographical location. For example, a certain company at a high-level may be divided into departments such as banking, embedded application, and telecom software development. Such departments are also called verticals. Small companies do not have high-level departmentalization. Therefore, we can view a small company as having only a single department.

Every department usually handles several projects at any time, and each project is assigned to a separate team of developers. The effectiveness of the developers in achieving the project objectives is significantly affected by how a department is organized into teams and how the individual teams are structured. In this context, two important issues that are critical to the effective functioning of every organization are

- *Department Structure:* How is a department organized into teams?
- *Team Structure:* How are project teams structured?

We discuss these issues in the following section.

Department structure

There are essentially three broad ways in which a software development department can be structured, viz., functional, project, and matrix formats.

Functional format

As will be seen later, a functional division could facilitate outsourcing.

In the functional format, the developers are divided into functional groups based on their specialization or experience. In other words, each functional group comprises developers having expertise in some specific task or functional area. For example, the different functional groups of an organization might specialize in areas such as database, networking, requirements analysis, design, testing, and so on. The functional organizational structure is shown in Figure 12.2(b).

Programme management can facilitate better sharing of staff between projects.

Every developer in an organization would belong to some functional group depending on his/her specialization. For carrying out specific activities, different projects borrow developers from the corresponding functional groups (shown using arrows in Figure 12.2). Upon the completion of their activities, the developers are returned to their respective functional groups. The partially completed product passes from one team to another and evolves due to the work done on it by several teams. A functional team working on a project does not physically meet the members of other functional teams who have carried out other parts of the project. Consequently, a team understands the work carried out by the other functional teams solely by studying the documents produced by them. Unless good quality documents are produced by each team, teams working subsequently on the project will find it hard to understand the work already completed. We can therefore say that a functional organization mandates production of good quality documentation.

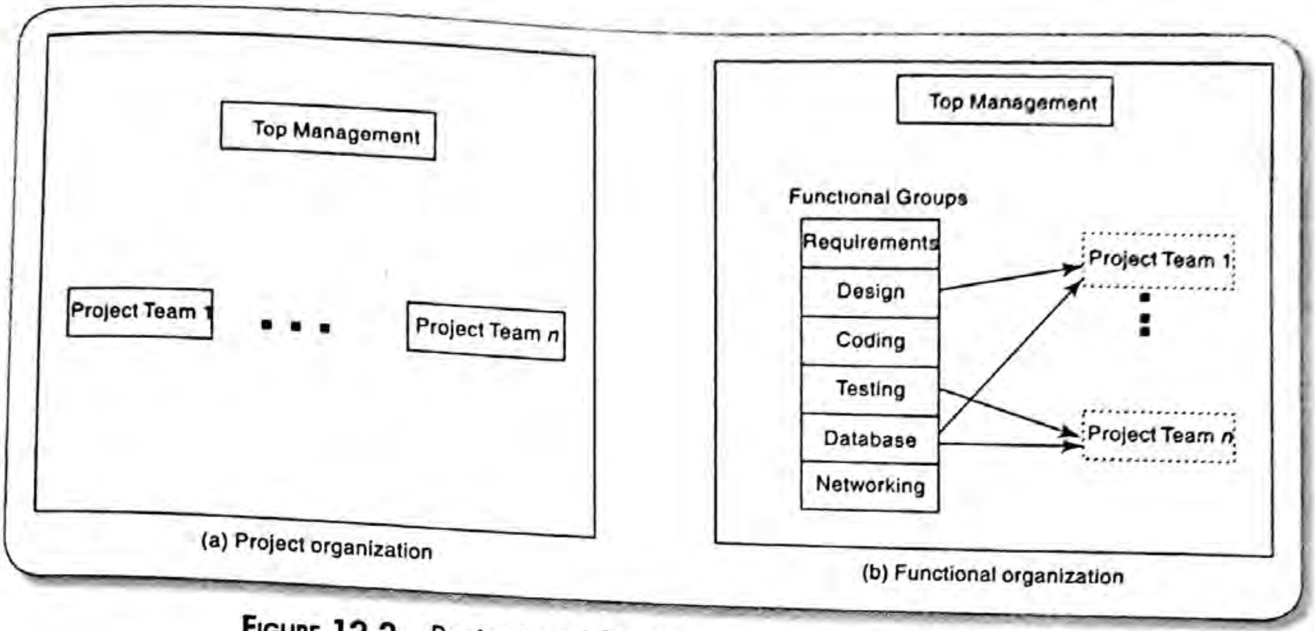


FIGURE 12.2 Project and functional organization structures

Project format

The project format is designed for realizing task-oriented teams. In the project format, at the start of every project, a set of developers are assigned to it (See Figure 12.2(a)). It is assumed that, among them the assigned members can carry out various activities required for project completion. The developers remain with the project till the completion of the project. Thus, the same team carries out all the project activities. This is in contrast to a functional organization, where each developer belongs to a functional group and for completing a project activity, members of the corresponding functional area are assigned to the project temporarily, who are returned back to their respective functional area after completion of the activity.

Functional versus project formats

As we have already pointed out, in a functional organization, the team members carrying out the different activities of a project do not meet each other. The consequent communication gap is a weak point of this format. Also, users often prefer the project team approach because they will have a group dedicated to their needs and they need not deal with members of a large number of functional groups. Further, the project team members build up familiarity with the software over a relatively long period of time and can efficiently carry out maintenance activities. Therefore, the project team approach is advantageous for carrying out the software maintenance activities. On the other hand, the functional format offers several other types of advantages. The main advantages that the functional team format offers are the following.

- *Ease of staffing* The functional organization structure provides an efficient solution to the staffing problem. Usually different numbers of developers are needed to carry out different project activities. The project staffing problem is eased significantly because any number of required personnel can be brought into a project as needed, and they can be returned to the functional group when they complete their work. This possibly is the most important advantage of the functional organization. A project organization structure, on the other hand, mandates the manager to accept a fixed number of developers at the start of the project. These developers work for the entire duration of the project. This results in many team members idling in the initial phases of software development and the entire team comes under tremendous pressure in the later phases of development.

- *Production of good quality documents* A functional organization mandates production of good quality documents, since the team members working on some part of a project do not meet the developers who have completed other parts of the project and gone back to their functional teams.
- *Job specialization* The functional organization structure facilitates developers to become to specialize in particular tasks such as database, networking, compilers, requirements analysis, design, coding, testing, maintenance, etc. They perform these activities again and again for different projects, and thereby gain experience and insights into their respective areas of specialization.
- *Efficient handling of the problems associated with manpower turnover* Functional organizations help to effectively handle the problem of manpower turnover compared to a democratic organization. First, developers are brought in from the functional pool when needed. Also, good documentation produced in this organization structure helps any new member to quickly get familiarized with the work already completed.
- *Career planning* A functional organization makes it easier for a developer to have a career that is technically oriented, called the technical ladder. On the other hand, a project organization tends to facilitate a more general form of career progression, where the developers become business analysts and managers.

Exercise 12.3

In spite of several important advantages of the functional organization, it is rarely adopted by the industry. Explain the apparent paradox.

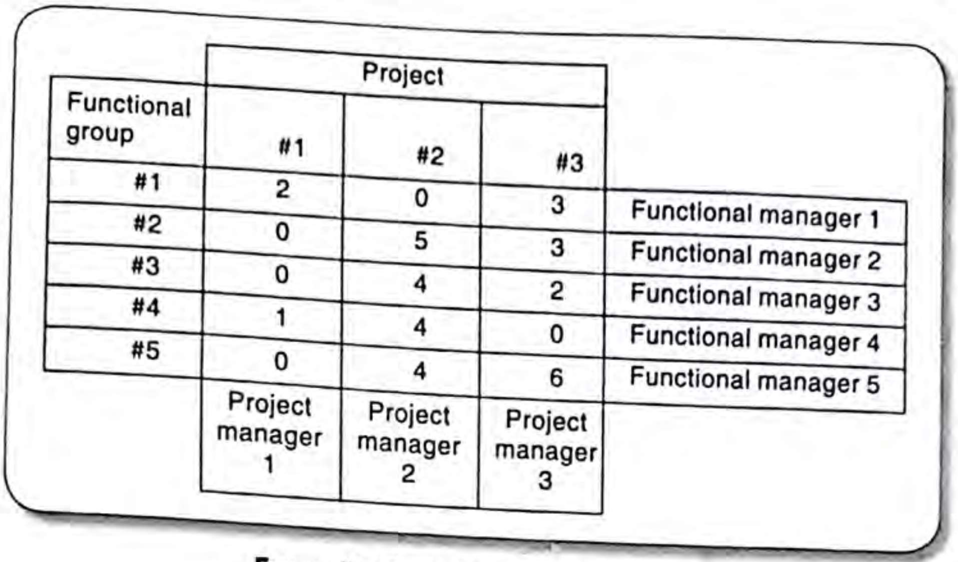
Matrix format

Matrix format is an extension of a functional format, and is intended to provide the advantages of both the functional and project structures. In a matrix organization, the pool of functional specialists is assigned to different projects as needed. Thus, the deployment of the different functional specialists in different projects can be represented in a matrix (see Figure 12.3). Observe that a member assigned to a project reports to both the manager of his functional group as well as the manager of the project to which he has been assigned. Thus, in a matrix organization, the project manager needs to share the project responsibility with a number of individual functional managers.

Matrix organizations can be characterized as weak or strong, depending upon the relative authority of the functional managers and the project managers. In a strong functional matrix, the functional managers have authority to assign workers to projects and project managers have to accept the assigned personnel. In a weak matrix, the project manager completely controls the project budget, can reject workers from functional groups, and can even decide to hire outside workers.

Though a matrix team organization offers several advantages, two important problems that such an organization may suffer from are the following.

- Due to the multiplicity of authority, conflicts can occur between functional and project managers over allocation of workers.
- In a strong matrix organization, frequent shifting of workers may take place as the functional managers adopt a firefighting mode to tackle the crises in different projects.



Functional group	Project #1	Project #2	Project #3	
#1	2	0	3	Functional manager 1
#2	0	5	3	Functional manager 2
#3	0	4	2	Functional manager 3
#4	1	4	0	Functional manager 4
#5	0	4	6	Functional manager 5
	Project manager 1	Project manager 2	Project manager 3	

FIGURE 12.3 Matrix organization

Team structure

Team structure denotes the reporting, responsibility, and communication structures in individual project teams. We consider only three team structures: democratic, chief programmer and the mixed team organizations, although several other variations to these structures are possible. Please note that it is not necessary that all project teams in an organization are structured the same way. In fact, it is usually the case that within the same organization, different projects adopt different team structures due to differences to their complexities and sizes.

Chief Programmer team

A schematic representation of the chief programmer team structure has been shown in Figure 12.4. In this team structure, a senior member provides the technical leadership and is designated as the chief programmer. The structure of the chief programmer team is the philosophy behind the chief programmer team is in keeping with the suggestions of Brooks, who suggested that the design activity should be carried out by a small team to maintain design consistency. He argued in favour of making the designers as productive as possible through support from the other team members. The chief programmer defines the specification and constructs the high-level design; and then partitions the remaining tasks of detailed design, viz., coding, testing, documentation, etc., into many smaller tasks; and assigns them to the team members. He/she also verifies and integrates the work completed by different team members.

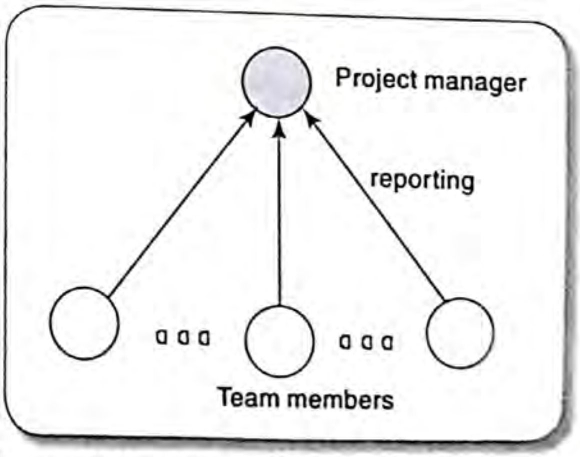


FIGURE 12.4 Chief programmer team structure

Advantages of the chief programmer team

A chief programmer team is more efficient than a democratic team for completing simple and small projects since the chief programmer can quickly work out a satisfactory design and assign work to the team members to code and test different modules of his design solution.

Disadvantages of the chief programmer team

- The chief programmer is provided with an authority to assign work to the team members and to monitor their work. This however leads to lower team morale, as the team members work under the constant supervision of the chief programmer.
- The chief programmer team structure inhibits collective and original thinking by the team members and the chief programmer typically takes all important decisions by himself/herself.
- The chief programmer team is subject to single point failure since too much responsibility and authority is assigned to the chief programmer. That is, a project might get severely affected if the chief programmer either leaves the organization or becomes unavailable for some other reasons.
- A major problem with the chief programmer structure is getting hold of a really outstanding programmer for the role of the chief programmer. Since the chief programmer carries out many tasks individually, there is a danger of information overload on the chief programmer. This is especially true for large projects.

Let us now try to understand the types of projects for which the chief programmer team structure would be appropriate. Suppose an organization has successfully completed many simple MIS projects. Then, for a similar MIS project, chief programmer team structure can be adopted. The chief programmer team structure works well when the task is within the intellectual grasp of a single individual. However, even for small projects the chief programmer team structure should not be used unless the importance of early completion of the project outweighs other factors such as team morale, personal developments, etc.

Democratic team

The democratic team structure, as the name implies, does not enforce any formal team hierarchy. Decisions are taken based on discussions, where any member is free to discuss with any other member as shown in Figure 12.5. Typically, a manager provides the administrative leadership. At different times, different

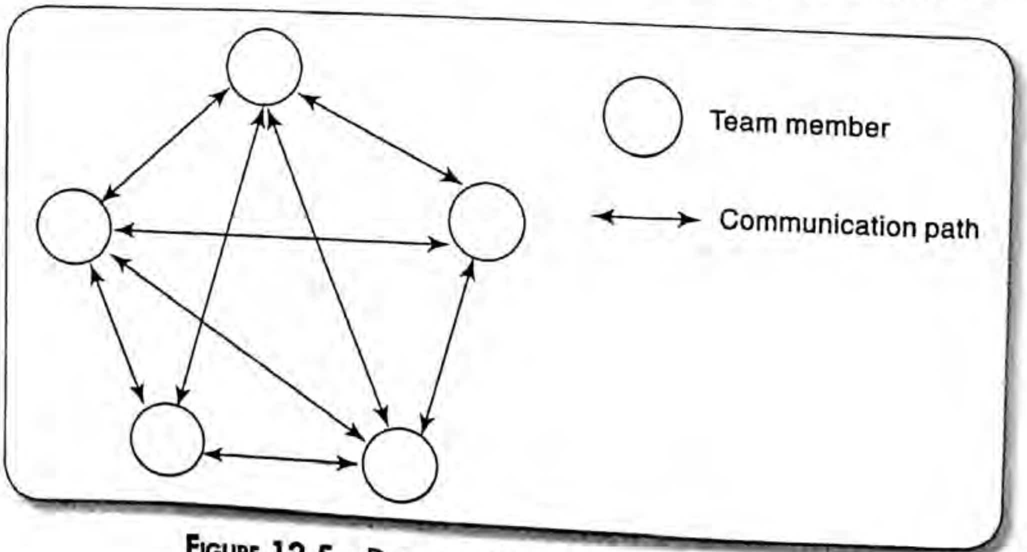


FIGURE 12.5 Democratic team structure

members of the team provide technical leadership. Since a lot of debate and discussions among the team members takes place, for large team sizes significant overhead is incurred on this count.

It is generally accepted that a democratic structure offers higher moral and job satisfaction to the team members. Consequently, a democratic team usually suffers from lower manpower turnover compared to the chief programmer team. Though democratic teams are less productive compared to the chief programmer team for small and simple projects, the democratic team structure is appropriate for less understood problems, since a group of developers can invent better solutions than a single individual as in a chief programmer team. A democratic team structure is suitable for research-oriented projects requiring less than five or six developers. For large sized projects, a pure democratic organization tends to become chaotic. The democratic team organization encourages egoless programming as programmers can share and review one another's work. We have already discussed egoless programming in this section.

Mixed control team structure

The mixed team structure, as the name implies, draws ideas from both the democratic and chief-programmer team structures. The mixed control team structure is shown pictorially in Figure 12.6. In Figure 12.6, the communication paths are shown as dashed lines and the reporting structure is shown using solid arrows. Observe that this team structure incorporates both hierarchical reporting and democratic set up. The democratic arrangement at the level of senior developers is used to decompose the problem into small parts. Democratic setup at the programmer level facilitates working out at effective solution to a single part. This team structure is extremely popular and is being used in many software development companies. The mixed control team organization is suitable for large team sizes.

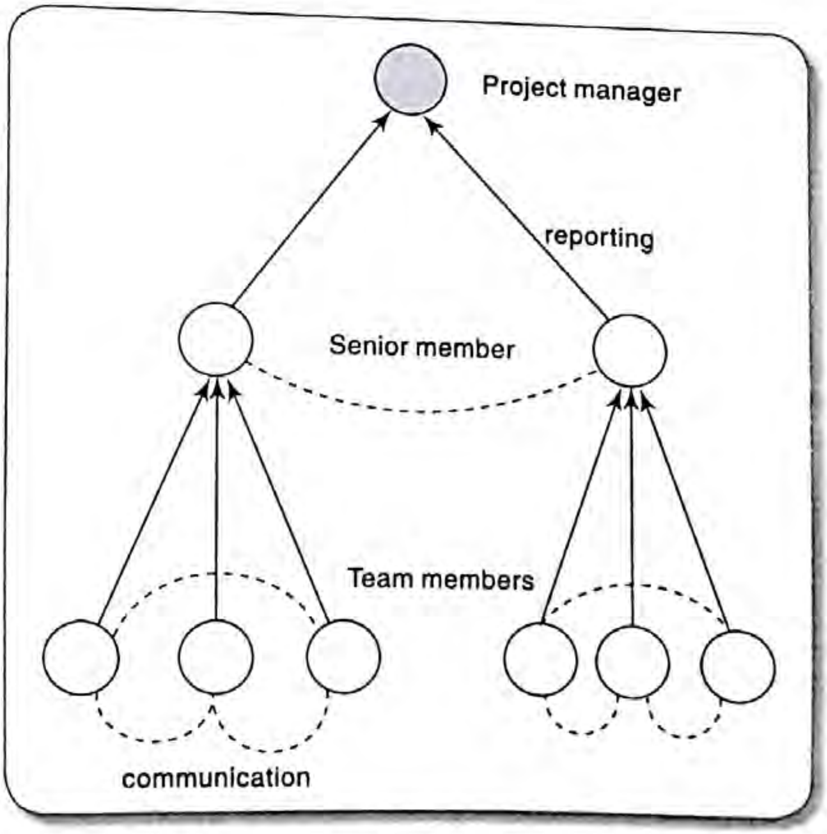


FIGURE 12.6 Mixed control team structure

12.5 Coordination Dependencies

Ian R. McChesney and Séamus Gallagher (2004) 'Communication and co-ordination practices in software engineering projects' *Information and Software Technology* 46 473–89 gives a good introduction to these concepts and insights into their application.

Why and to what extent do the different units within an overall organizational structure really need to communicate? Researchers and innovators in the area of *computer-supported cooperative work* (CSCW) have been interested in identifying the types of coordination where computer tools could be of assistance. A *coordination theory* has been developed which provides a useful classification of coordination dependencies that are likely to exist in any substantial organizational undertaking. These are listed below.

- *Shared resources*. An example in software development projects is where several projects need the services of particular types of scarce technical experts for certain parts of the project. The unavailability of these experts because of commitments elsewhere could delay a project. We noted in Chapter 2 that programme management may be established at a higher level than individual projects to reduce these resources clashes.
- *Producer–customer ('right time') relationships*. A project activity may depend on a product being delivered first. For example, a business analyst may need to produce an agreed requirements document before the development of software components can begin. The Product Flow Diagram (PFD) promoted by the PRINCE2 methodology and described in Chapter 3 can help identify some of these dependencies, but the key point is that some other organizational unit, which could in fact be outside the business, is involved.
- *Task–subtask dependencies*. In order to complete a task a sequence of subtasks have to be carried out. Like the producer–customer relationships described above, this could be reflected in the PFD. Unlike the producer–customer relationship, this sequencing is forced by the technical nature of the thing being created, or the method that is being adopted, rather than by decisions about who is to do what.
- *Accessibility ('right place') dependencies*. This type of dependency is of more relevance to activities that require movement over a large geographical area. The problems of getting an available ambulance to the site of a medical emergency as quickly as possible would a prime example of this. In ICT and software development the examples are less obvious, but arranging the delivery and installation of ICT equipment might be identified as such.
- *Usability ('right thing') dependencies*. In this context, this is a broader concern than the design of user interfaces more usually associated with the term 'usability'. It relates to the general question of *fitness for purpose*, which includes the satisfaction of business requirements. In software development this could lead to activities, such as prototyping, which ensure that the system being created will meet the users' operational needs. It could also involve change management activities when users need to change requirements because of, for example, events in the business environment such as legislative changes.
- *Fit requirements*. This is ensuring that different system components work together effectively. Integration testing is one mechanism that ensures that these requirements are met. One concern of configuration management (as described in Chapter 9) is assessing whether changes made to one component will have knock-on effects on other components.

In many cases, information systems tools can support these coordination tasks. For example, project planning tools, such as Microsoft Project, can be used to help decision making about the allocation of resources both within projects and across a portfolio of concurrent projects. Such tools, through the support they give to the development, analysis and manipulation of activity networks (as we have seen in Chapters 6 and 8), can help the control of producer–customer and task–subtask dependencies. Another example of software tool support is the use of change management and configuration management databases to keep track of changes to the system under development and thus support usability and fit dependencies.

Ian McChesney and Séamus Gallagher have published a research report which analyses two real-world project environments in terms of the way coordination activities were carried out. Among some quite detailed findings, they noted the use of software tools to support some coordination activities, but also noted how a single person in the project team could have a key coordination role. This person could act as a go-between for staff who need to communicate, for example directing user enquiries to the developer best able to provide information.

E-mail was noted as a principal means of communication. The practice had been developed of copying emails to third parties who might need to be 'kept in the loop', that is, made aware of developments. It is interesting that this development was seen as invaluable – there are reports of other environments where email has become less effective as a means of communication as staff become overwhelmed by the sheer volume of emails.

12.6 Dispersed and Virtual Teams

We have seen how projects require a team of people to carry them out, and the members of this team could each be a specialist in a particular field. Thus, the heart of many projects is *collaborative problem solving*. The Second World War underlined the importance of cooperation between individuals and groups to execute major global operations, and encouraged research after the conflict into effective team working. At that time, group working meant, almost by definition, that the team members worked in close physical proximity. However, in recent years the concept and practice of having *dispersed* or '*virtual teams*' have emerged.

See Tom DeMarco and Timothy Lister (1999) *PeopleWare: Productive Projects and Teams*, 2nd edition, Dorset House.

We have also to see how projects work, especially the development of large software products, needs coordination which in turn means that team members need to communicate. Being located in the same physical space clearly assists this. However, offices can be noisy places and while software development needs communication it also needs periods of solitary concentrated effort. DeMarco and Lister describe the condition of deep concentration needed for effective creative work as 'flow', and suggest that about 15 minutes of uninterrupted effort is needed to achieve this state. Every interruption destroys flow and requires another 15 minutes for its recovery.

It was noted earlier that project managers often have little control over who will be allocated to their team. They are even less likely to have control over the physical environment in which the team will work. Many years ago, research at IBM suggested that ideally each software developer should have:

- 100 square feet of dedicated space
- 30 square feet of work surface
- Noise protection in the form of enclosed offices or partitions at least six feet high

For various reasons it is often difficult for software developers to be provided with this kind of accommodation, yet DeMarco and Lister found clear links between reported noise levels in the workplace and the number of defects found in the resulting software.

The survey was carried out by the Economist Intelligence Unit and was reported on in 'Remote working boosts productivity' in *Computing*, 25 November, 2004, p. 6.

One answer is to send the software developers home. One recent (2004) survey found that 77% of businesses allowed at least some of their staff to work at home. Most of those working at home reported that they were more productive. The development of cheap internet-based communications, supported by broadband channels, has reduced the coordination problems that were the drawback of home working.

Modern communication technologies also mean that organizations can more easily form temporary teams to carry out specific projects from amongst their employees without having to relocate them. The nature of the work carried out in some projects means that the demand for certain specialist skills is intermittent. Ideally the project manager would like to have access to these skills for a short time but then be able to release them and thus avoid further costs. An example of this might be the passing need for a graphic designer to produce aesthetically pleasing designs for a web application project. This desire for flexible labour means that contract workers are often used. The internet allows these contractors to carry out well-defined tasks at their own premises without necessarily having to travel to their clients' site.

It is then only a short step to use 'off-shore' staff who live and work in a different part of the world. Hence we arrive at the dispersed or virtual team.

To recap the possible advantages of such an arrangement:

- A reduction in staff costs by using labour from developing countries where salaries are lower.
- A reduction in the overheads that arise from having your own employees on site, including costs of accommodation, social security payments, training.
- The flexible use of staff – they are not employed when they are not needed.
- Productivity might be higher.
- Use of specialist staff for specific jobs, rather than more general project workers, might improve quality.
- Advantage can be taken of people working in different time zones to reduce task durations – for example, software developers can deliver new versions of code to testers in a different time zone who can test it and deliver the results back at the start of the next working day.

Some of the challenges of dispersed working are:

One estimate was that 24,000 IT and software development jobs would be moved off-shore from the UK between 2003 and 2005, according to a British Computer Society working party report, *Offshoring – a challenge or opportunity for IT Professionals*, (British Computer Society 2004).

- The requirements for work that is distributed to contractors have to be carefully specified.
- The procedures to be followed will need to be formally expressed, where previously practices might have been picked up through observation and imitation of co-workers on site.
- Coordination of dispersed workers can be difficult.
- Payment methods may need to be modified to make them fixed price or piece-rate.
- There may be a lack of trust of co-workers who are remote and never seen.
- Assessment of the quality of delivered products will need to be thorough.
- Different time zones can cause communication and coordination problems.

12.7 Communication Genres

So far we have focused on some of the reasons why men and women engaged on a common project would need to communicate, not only within work groups but with colleagues in other parts of the organization, or in some cases in partner organizations. We have also mentioned various methods of communication but have not examined communications media in a structured way.

Some work has been done to study the characteristics of various methods of communication. One approach has been to try to identify *communication genres*. These refer to something more than just the technical means of communicating. They are types of communication that people are in the habit of making and where there are some 'ground rules' about when and how such communications should be carried out. For some types of communication, such as official meetings, these rules might be quite formal. Within the general heading of 'management meetings' there could be a range of types of meeting each with their own conventions. These could be seen as genres in their own right.

Within the general heading of the email communication genre, advanced email-based applications can be developed where the content of the email is structured by preset proformas designed to fulfil a standard process, such as requesting a change to a software specification. These applications can be seen as communication genres in their own right.

A major influence on the nature of communication genres is the constraints of time and place. Modes of communication can be categorized as combinations of two opposites: same time/different time and same place/different place – see Table 12.1.

TABLE 12.1 Time/place constraints on some communication methods

	Same place	Different place
Same time	Meetings	Telephone
	Interviews etc.	Instant messaging
Different times	Noticeboards	E-mail
	Pigeon-holes	Voicemail
		Documents

The nature of the information to be conveyed also needs to be considered.

- What is the extent and complexity of the information to be conveyed? A telephone conversation may be a very quick way of conveying simple messages – but has disadvantages as a medium for large amounts of information.
- Is it easy to understand? For example, is the context well known to both the sender and the recipient? If it is likely that the recipient will need clarification of aspects of the information, then a mode of communication that is two-way would be best.
- Where the communication is personally sensitive, then face-to-face contact is the most effective form of communication, even if it can be uncomfortable or inconvenient for those concerned.

Exercise 12.4

What would be the best mode of communication for the following?

(a) A developer needs clarification of what is meant by a particular term used in a specification.

(b) The users of a system have found what appears to be a fault in a software application that they use.

(c) A finance director needs to ensure that a software application is changed to conform with new legal requirements.

(d) A software developer can only complete her software component if another developer finishes his component first, but he has not. The first developer is under a lot of pressure from the client to complete the work.

At different stages of a project it is likely that different communication genres will be preferred.

Early stages of a project

Charles Handy (1995) 'Trust and the virtual organization' *Harvard Business Review*, May/June 45–50.

At the start of the project, team members will need to build up their trust and confidence in their co-workers. For this same time/same place communication, actually meeting is probably best. It is argued that this is especially the case with dispersed projects: as Charles Handy has written: '*paradoxically, the more virtual an organization becomes, the more its people need to meet in person*'.

Julian Baggini (2005) 'Touched by your absence' *The Guardian* 6 January.

However, not everyone might agree with this. Julian Baggini, describing his experience of writing a textbook on philosophy with someone he had never met, argues: '*It is simply not necessary to know the whole person in order to have a good relationship with them.... If you get to know and dislike the way that someone behaves outside the office, that can make you uncomfortable with them in it.*'

The early stages of a project are when at least some of the team will be involved in making decisions about the overall design of the product to be delivered and the method by which it is to be created. In the preliminary stages at least, same time/same place meetings are the most effective means of progressing.

Intermediate design stages of the project

Once the overall architecture of the product has been established, detailed design on different components could well be carried out in parallel in different locations. However, some points will need to be clarified and for this, same time/different place communication could well be best, such as the use of teleconferencing.

'mplementation stages of the project

M. L. Mazneski and K. M. Chudoba (2000) 'Bridging space over time global virtual team dynamics and effectiveness' *Organization Science*, 11 (5).

Once the design is clarified and everyone knows his or her role, work can progress. Where there is a need to exchange information at this point, different time/different place communication media such as e-mail are likely to be sufficient.

Even at this stage some recommend regular face-to-face meetings of at least some staff as this supplies a rhythm to the project which helps coordination of the project and maintains motivation. Martha Maznevski and Katherine Chudoba observed the workings of a dispersed project and have noted '*interaction between coordination meetings was mainly in response to the previous meeting or in anticipation of the next one. The coordination meeting served as a heartbeat, rhythmically pumping new life into the team's processes*. . .'.

12.8 Communication Plans

Communication is important in all projects but a vital matter in the case of dispersed projects. Because of this, consideration of the way that project stakeholders will communicate ought to be a part of the project planning process. Some have gone as far as to suggest that a specific planning document ought to address communication issues affecting the project, not just for dispersed projects but for any project with a substantial number of important stakeholders.

The first step in producing such a plan is to list the main stakeholders, with special attention to those who are participating in the development and implementation of the project – it may be recalled that the identification of stakeholders and their concerns was stressed in Chapter 1 as being fundamental to project success. Once the overall project plan has been created using a process such as that described in Chapter 3, each of the main activities and milestones is examined to see which channels and methods would be best for effective communication with these stakeholders. We have already carried out such a process in our discussion of the communication needs of the different phases of a dispersed project. Consultation with the representatives of the various groups of stakeholders would be an essential part of this process.

The results of this process could be documented in a table with the following column headings.

This table is based on that in the Princeton Project Methodology.

- *What* This contains the name of a particular communication event, for example 'kick-off meeting', or a communication channel, for example 'project intranet site'.
- *Who/target* The target audience for the communication. 'Target audience' may not convey quite the right idea as this implies that there are passive recipients of information from a central authority. In fact the communication event or channel could be a means of eliciting information from the 'audience'.
- *Purpose* What the communication is to achieve.
- *When/frequency* If the communication by means of a single event, then a specific date can be supplied. If the event is a recurring one, such as a progress meeting, then the frequency should be indicated.
- *Type/method* The nature of the communication, for example a meeting or a distributed document.
- *Responsibility* The person who initiates the communication.

12.9 Leadership

When Amanda and Brigette first took on project management responsibilities, one of their private anxieties might well have been that staff would not take them seriously. Leadership is generally taken to mean the ability to influence others in a group to act in a particular way to achieve group goals. A leader is not necessarily a good manager or vice versa, as managers have other roles such as organizing, planning and controlling.

See Robert Johansen *et al.* (1991) *Leading Business Teams*, Addison-Wesley.

Authorities on this subject have found it difficult to agree a list of the common characteristics of good leaders. It would, however, seem safe to say that they seem to have a greater need for power and achievement and have more self-control and more self-confidence than others.

Leadership is based on the idea of authority or power, although leaders do not necessarily have much formal authority. Power may come either from the person's position (*position* power), from the person's individual qualities (*personal* power) or may be a mixture of the two. Position power has been further analysed into:

- *coercive* power, the ability to force someone to do something by threatening punishment;

These ideas are associated with the work of J. R. P. French and B. H. Raven.

- *connection* power, which is based on having access to those who have power;
- *legitimate* power, which is based on a person's title conferring a special status;
- *reward* power, where the holder can give rewards to those who carry out tasks to his or her satisfaction.

Personal power, on the other hand, can be further analysed into:

- *expert* power, which comes from being the person who is able to do a specialized task;
- *information* power, where the holder has exclusive access to information;
- *referent* power, which is based on the personal attractiveness of the leader.

Exercise 12.5

What kinds of power (as defined above) would the following people have?

(a) An internal auditor looking at the payroll system at Brightmouth College.

(b) A consultant who is called in to advise International Office Equipment about ways of improving software development productivity.

(c) The principal of Brightmouth College who has told staff that they must accept a new contract or face the sack.

(d) Brigette in respect to the users of the college payroll system.

(e) Amanda in respect of the people in the project team developing the annual maintenance contract application.

Leadership styles

Amanda and Brigette might be initially concerned about establishing their personal authority. Balanced against this is the need to involve the staff in decision making in order to make the best use of expertise and to gain commitment. Amanda and Brigette will need to judge when they must be authoritative and insist on things and when they must be more flexible and tolerant. Amanda, for example, may decide to be very democratic when formulating plans, but once the plans have been agreed, to insist on a very disciplined execution of the plan. Brigette, on the other hand, may find at Brightmouth College that she alone has the technical expertise to make some decisions, but, once she has briefed staff, they expect to be left alone to get on with the job as they see fit.

This approach is associated with Rensis Likert.

Attempts have been made to measure leadership styles on two axes: directive vs. permissive and autocratic vs. democratic:

- *directive autocrat:* makes decisions alone, close supervision of implementation;
- *permissive autocrat:* makes decisions alone, subordinates have latitude in implementation;

- *directive democrat:* makes decisions participatively, close supervision of implementation;
- *permissive democrat:* makes decisions participatively, subordinates have latitude in implementation.

Another axis used to measure management styles has been on the degree to which a manager is *task-oriented*, that is, the extent to which the execution of the task at hand is paramount, and the degree to which the manager is concerned about the people around them (*people orientation*). It is perhaps not surprising that subordinates appear to perform best with managers who score highly in *both* respects.

It should be emphasized that there is no one best style of management – it depends on the situation.

Work environments vary with amount of control exerted over work. Some jobs are routine and predictable (e.g. dealing with batched computer output). Others are driven by outside factors (e.g. a help desk) or are situations where future direction is uncertain (e.g. at the early stages of a feasibility study). With a high degree of uncertainty subordinates will seek guidance from above and welcome a task-oriented management style. As uncertainty is reduced, the task-oriented manager is likely to relax, becoming more people-oriented, and this will have good results. People-oriented managers are better where staff can control the work they do, without referring matters to their line managers. It is then argued that if control becomes even easier the people-oriented manager will be tempted to get involved in more task-centred questions, with undesirable results.

Research also shows that where team members are relatively inexperienced, a task-oriented approach is most effective. As group members mature, consideration for their personal needs and aspirations becomes more valued. Where maturity is very high, there is no need for a strong emphasis on either of these approaches.

Exercise 12.6

What in your view would be the most appropriate management style when dealing with the following subordinates?

(a) At Brightmouth College, a former member of the local authority who has dealt with the college payroll for several years and who has been employed by the college to set up and manage the new payroll section.

(b) At IOE, a new trainee analyst/programmer who has just joined Amanda's group.

(c) At IOE, a very experienced analyst/programmer in their 40s, who was recruited into the software development department some time ago from the accounts department and who has been dealing with system support for the old maintenance accounts system that is now being revised.

Conclusion

Some of the important points that have been made in this chapter are:

- Consideration should be given, when forming a new project team, to getting the right mix of people and to planning activities which will promote team building
- Group working is more effective with some types of activity than others
- The people who need to communicate most with each other should be grouped together organizationally

- Different styles of leadership are needed in different situations
- Care should be taken to identify the most effective way of communicating with project participants at key points in the project

Further Exercises

1. To what extent is the Belbin approach to balanced teams compatible with having chief programmer teams?
2. If you have been involved recently in a group activity or project, try to categorize each participant according to the Belbin classification. Were there any duplications or gaps in any of the roles? Did this seem to have any impact on progress?
3. Three different mental obstacles to good decision making were identified in the text: faulty heuristics, escalation of commitment and information overload. What steps do you think can be taken to reduce the danger of each of these?
4. Exercise 12.5 asked you to identity the management style most appropriate for each of three different situations. Go back and consider how you as a manager would respond to each of these three situations in terms of practical things to do or avoid.
5. Do you agree with the following statement? 'Few, if any, organization in the real world is purely functional, project, or matrix in nature'. Justify your answer.
6. Explain the advantages of a functional organization over a project organization. Also explain why software development houses prefer to use project organization over functional organization.
7. As a project manager, identify the characteristics that you would look for in a software developer while trying to select personnel for your team.
8. For each of the following questions, exactly one of the options is correct. Select the appropriate option.

   (i) Which one of the following types of team organization would be most suitable for a small yet complex project?

   (a) Chief programmer (b) Democratic

   (c) Hybrid (d) Squat

   (ii) In which one of the following types of organization is team building likely to be most difficult?

   (a) Functional (b) Projectized

   (c) Matrix (d) Hybrid

   (iii) Joy is a software engineer who works for a software development company. The company accepts outsourcing projects from overseas clients. Each time it accepts a project, it sets up a team to handle the project. When the project completes, the team is dissolved and the engineers are assigned to other projects. Which one of the following is the organization structure of Joy's company?

   (a) Matrix (b) Projectized

   (c) Functional (d) Hybrid

13 Software Quality

Learning Objectives

- Explain the importance of software quality to software users and developers
- Define the qualities of good software
- Design methods of measuring the required qualities of software
- Monitor the quality of the processes in a software project
- Use external quality standards to ensure the quality of software acquired from an outside supplier
- Develop systems using procedures that will increase their quality

13.1 Introduction

While quality is generally agreed to be 'a good thing', in practice what is meant by the 'quality' of a system can be vague. We need to define precisely what qualities we require of a system. However, we need to go further – we need to judge objectively whether a system meets our quality requirements and this needs measurement. This would be of particular concern to someone like Brigette at Brightmouth College in the process of selecting a package.

For someone – like Amanda at IOE – who is developing software, waiting until the system exists before measuring it would be leaving things rather late. Amanda might want to assess the likely quality of the final system while it was still under development, and also to make sure that the development methods used would produce that quality. This leads to a different emphasis – rather than concentrating on the quality of the final system, a potential customer for software might check that the suppliers were using the best development methods.

This chapter examines these issues.

13.2 The Place of Software Quality in Project Planning

Quality will be of concern at all stages of project planning and execution, but will be of particular interest at the following points in the Step Wise framework (Figure 13.1).

- *Step 1: Identify project scope and objectives* Some objectives could relate to the qualities of the application to be delivered.
- *Step 2: Identify project infrastructure* Within this step, activity 2.2 identifies installation standards and procedures. Some of these will almost certainly be about quality.
- *Step 3: Analyze project characteristics* In activity 3.2 ('Analyze other project characteristics – including quality based ones') the application to be implemented is examined to see if it has any special quality requirements. If, for example, it is safety critical then a range of activities could be added, such as *n*-version development where a number of teams develop versions of the same software which are then run in parallel with the outputs being cross-checked for discrepancies.

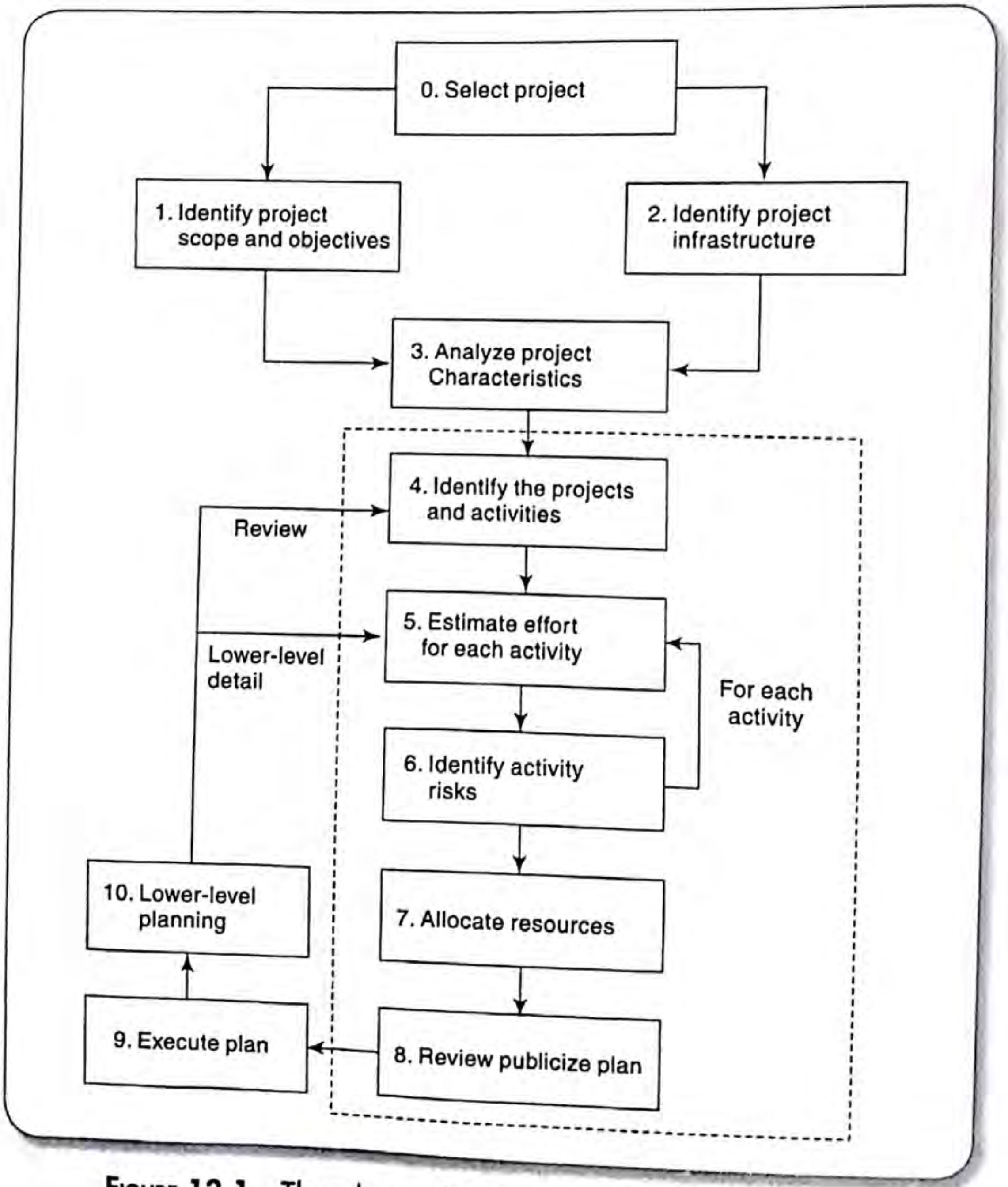

0. Select project
1. Identify project scope and objectives
2. Identify project infrastructure
3. Analyze project Characteristics
4. Identify the projects and activities
Review
5. Estimate effort for each activity
Lower-level detail
For each activity
6. Identify activity risks
7. Allocate resources
10. Lower-level planning
9. Execute plan
8. Review publicize plan

FIGURE 13.1 The place of software quality in Step Wise

- *Step 4: Identify the products and activities of the project* It is at this point that the entry, exit and process requirements are identified for each activity. This is described later in this chapter.
- *Step 8: Review and publicize plan* At this stage the overall quality aspects of the project plan are reviewed.

13.3 Importance of Software Quality

We would expect quality to be a concern of all producers of goods and services. However, the special characteristics of software create special demands.

- *Increasing criticality of software* The final customer or user is naturally anxious about the general quality of software, especially its reliability. This is increasingly so as organizations rely more on their computer systems and software is used in more safety-critical applications, for example to control aircraft.
- *The intangibility of software* can make it difficult to know that a project task was completed satisfactorily. Task outcomes can be made tangible by demanding that the developer produce 'deliverables' that can be examined for quality.
- *Accumulating errors during software development* As computer system development comprises steps where the output from one step is the input to the next, the errors in the later deliverables will be added to those in the earlier steps, leading to an accumulating detrimental effect. In general, the later in a project that an error is found the more expensive it will be to fix. In addition, because the number of errors in the system is unknown, the debugging phases of a project are particularly difficult to control.

For these reasons quality management is an essential part of effective overall project management.

13.4 Defining Software Quality

In Chapter 1 we noted that a system has functional, quality and resource requirements. Functional requirements define what the system is to do, the resource requirements specify allowable costs and the quality requirements state how well this system is to operate.

Exercise 13.1

At Brightmouth College, Brigette has to select the best off-the-shelf payroll package for the college. How should she go about this in a methodical manner?

One element of the approach could be the identification of criteria against which payroll packages are to be judged. What might these criteria be? How could you check the extent to which packages match these criteria?

Some qualities of a software product reflect the external view of software held by ***users***, as in the case of usability. These *external qualities* have to be mapped to *internal factors* of which the ***developers*** would be aware. It could be argued, for example, that well-structured code is likely to have fewer errors and thus improve reliability.

Defining quality is not enough. If we are to judge whether a system meets our requirements we need to be able to measure its qualities.

The BS ISO/IEC 15939:2007 standard Systems and software engineering – measurement process has codified many of the practices discussed in this section.

A good measure must relate the number of units to the maximum possible. The maximum number of faults in a program, for example, is related to the size of the program, so a measure of *faults per thousand lines of code* is more helpful than *total faults in a program*.

Trying to find measures for a particular quality helps to clarify and communicate what that quality really is. What is being asked is, in effect, 'how do we know when we have been successful?'

The measures may be *direct*, where we can measure the quality directly, or *indirect*, where the thing being measured is not the quality itself but an indicator that the quality is present. For example, the number of enquiries by users received by a help desk about how one operates a particular software application might be an indirect measurement of its usability.

When project managers identify quality measurements they effectively set targets for project team members, so care has to be taken that an improvement in the measured quality is always meaningful. For example, the number of errors found in program inspections could be counted, on the grounds that the more thorough the inspection process, the more errors will be discovered. This count could, of course, be improved by allowing more errors to go through to the inspection stage rather than eradicating them earlier – which is not quite the point.

When there is concern about the need for a specific quality characteristic in a software product then a quality specification with the following minimum details should be drafted:

- *Definition/description:* definition of the quality characteristic
- *Scale:* the unit of measurement
- *Test:* the practical test of the extent to which the attribute quality exists
- *Minimally acceptable:* the worst value which might be acceptable if other characteristics compensated for it, and below which the product would have to be rejected out of hand
- *Target range:* the range of values within which it is planned the quality measurement value should lie
- *Now:* the value that applies currently

Exercise 13.2

Suggest quality specifications for a word processing package. Give particular attention to the way that practical tests of these attributes could be conducted.

There could be several measurements applicable to a quality characteristic. For example, in the case of reliability, this might be measured in terms of:

- *Availability:* the percentage of a particular time interval that a system is usable
- *Mean time between failures:* the total service time divided by the number of failures
- *Failure on demand:* the probability that a system will not be available at the time required or the probability that a transaction will fail
- *Support activity:* the number of fault reports that are generated and processed

Exercise 13.3

The enhanced IOE maintenance jobs system has been installed, and is normally available to users from 8.00 a.m. until 6.00 p.m. from Monday to Friday. Over a four-week period the system was unavailable for one whole day because of problems with a disk drive and was not available on two other days until 10.00 in the morning because of problems with overnight batch processing runs.

What were the availability and the mean time between failures of the service?

Associated with reliability is *maintainability*, which is how quickly a fault, once detected, can be corrected. A key component of this is *changeability*, which is the ease with which the software can be modified. However, before an amendment can be made, the fault has to be diagnosed. Maintainability can therefore be seen as changeability plus a new quality, *analysability*, which is the ease with which causes of failure can be identified.

Maintainability can be seen from two different perspectives. The user will be concerned with the *elapsed time* between a fault being detected and it being corrected, while the software development managers will be concerned about the *effort* involved.

13.5 Software Quality Models

The need to be able to quantitatively measure the quality of a software is often felt. For example, one may want to set quantitative quality requirements for a software, or to verify whether a software meets the quality requirements set of it. Unfortunately, it is hard to directly measure the quality of a software. However, it can be expressed in terms of several attributes of a software that can be directly measured. The quality models give a characterization (often hierarchical) of software quality in terms of a set of characteristics of the software. The bottom level of the hierarchy can be directly measured, thereby, enabling a quantitative assessment of the quality of the software. There are several well-established quality models, including McCall's, Dromey's and Boehm's. Since there was no standardization among the large number of quality models that became available, the ISO 9126 model of quality was developed. We briefly discuss Garvin's, McCall's, Dromey's and Boehm's quality models in this section and discuss ISO 9126 in the next section.

Garvin's quality dimensions: David Garvin, a professor of Harvard Business school in his book, *Total Quality Management*, defined the quality of any product in terms of eight general attributes of the product, some of these are measurable and some are not. Garvin reasoned that sometimes users have subjective judgment of the quality of a program (perceived quality) that must be taken into account to judge its quality.

- **Performance:** How well it performs the jobs.
- **Features:** How well it supports the required features.
- **Reliability:** Probability of a product working satisfactorily within a specific period of time.
- **Conformance:** Degree to which the product meets the requirements.
- **Durability:** Measure of the product life
- **Serviceability:** Speed and effectiveness maintenance.
- **Aesthetics:** The look and feel of the product.
- **Perceived quality:** User's opinion about the product quality.

McCall' model: McCall defined the quality of a software in terms of three broad parameters: its operational characteristics, how easy it is to fix defects and how easy it is to port it to different platforms. These three high-level quality attributes are defined based on the following eleven attributes of the software:

- **Correctness:** The extent to which a software product satisfies its specifications.
- **Reliability:** The probability of the software product working satisfactorily over a given duration.
- **Efficiency:** The amount of computing resources required to perform the required functions.
- **Integrity:** The extent to which the data of the software product remains valid.
- **Usability:** The effort required to operate the software product.
- **Maintainability:** The ease with which it is possible to locate and fix bugs in the software product.
- **Flexibility:** The effort required to adapt the software product to changing requirements.
- **Testability:** The effort required to test a software product to ensure that it performs its intended function.
- **Portability:** The effort required to transfer the software product from one hardware or software system environment to another.
- **Reusability:** The extent to which a software can be reused in other applications.
- **Interoperability:** The effort required to integrate the software with other software.

Dromey's model: Dromey proposed that software product quality depends on four major high-level properties of the software: Correctness, internal characteristics, contextual characteristics and certain descriptive properties. Each of these high-level properties of a software product, in turn, depends on several lower-level quality attributes of the software. Dromey's hierarchical quality model is shown in Figure 13.2.

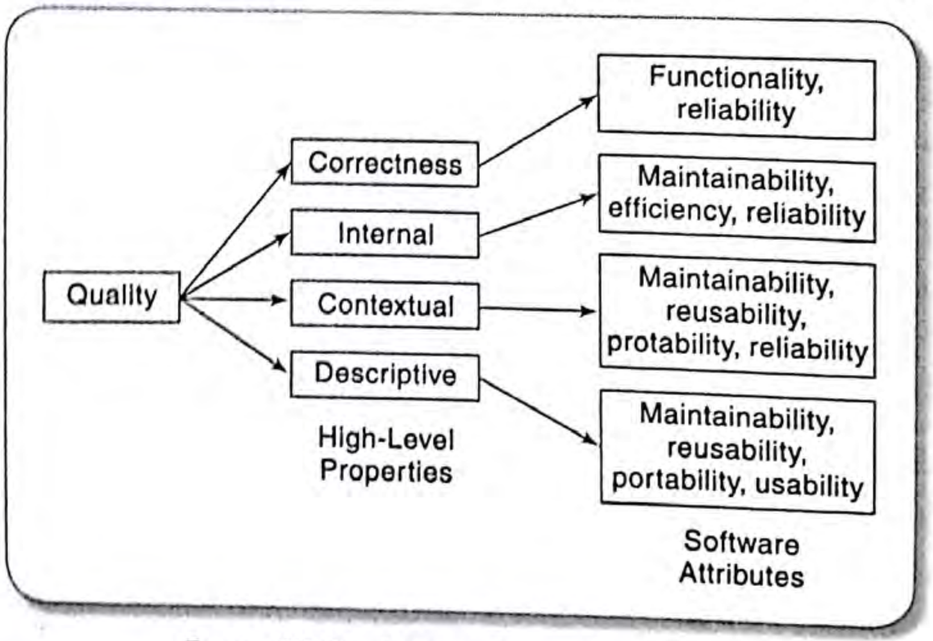

Quality
Correctness
Internal
Contextual
Descriptive
High-Level Properties
Functionality, reliability
Maintainability, efficiency, reliability
Maintainability, reusability, protability, reliability
Maintainability, reusability, portability, usability
Software Attributes

FIGURE 13.2 Dromey's quality model

Boehm's model: Boehm postulated that the quality of a software can be defined based on three high-level characteristics that are important for the users of the software. These three high-level characteristics are the following:

- **As-is utility:** How well (easily, reliably and efficiently) can it be used?

- **Maintainability:** How easy is it to understand, modify and then retest the software?
- **Portability:** How difficult would it be to make the software in a changed environment?

Boehm expressed these high-level product quality attributes in terms of several measurable product attributes. As compared to McCall's and Dromey's quality models, Boehm's quality model is based on a wider range of software attributes and with greater focus on software maintainability. Boehm's hierarchical quality model is shown schematically in Figure 13.3.

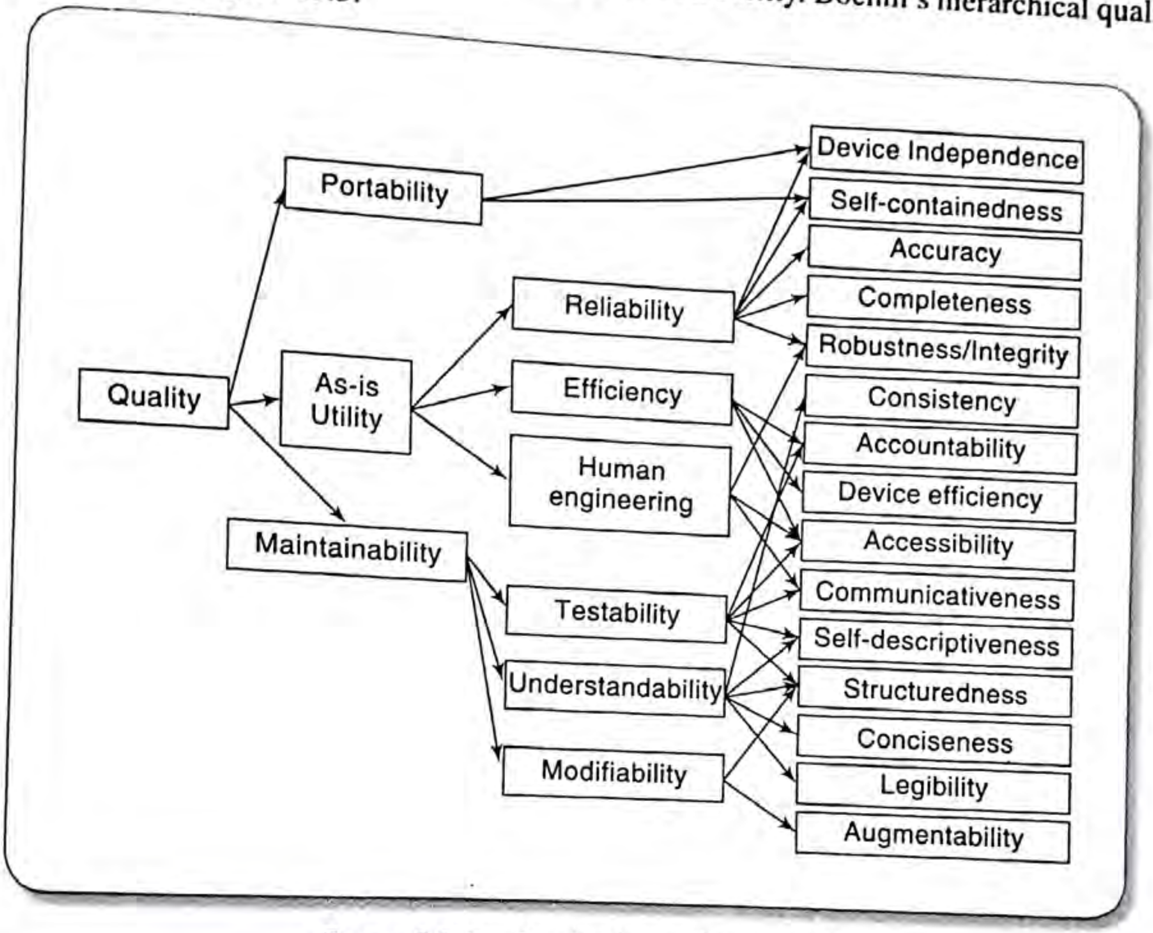


FIGURE 13.3 Boehm's quality model

13.6 ISO 9126

Over the years, various lists of software quality characteristics have been put forward, such as those of James McCall and of Barry Boehm. A difficulty has been the lack of agreed definitions of the qualities of good software. The term 'maintainability' has been used, for example, to refer to the ease with which an error can be located and corrected in a piece of software, and also in a wider sense to include the ease of making any changes. For some, 'robustness' has meant the software's tolerance of incorrect input, while for others it has meant the ability to change program code without introducing errors. The ISO 9126 standard was first introduced in 1991 to tackle the question of the definition of software quality. The original 13-page document was designed as a foundation upon which further, more detailed, standards could be built. The ISO 9126 standards documents are now very lengthy. Partly this is because people with differing motivations might be interested in software quality, namely:

Currently, in the UK, the main ISO 9126 standard is known as BS ISO/IEC 9126-1:2001. This is supplemented by some 'technical reports' (TRs), published in 2003, which are provisional standards. At the time of writing, a new standard in this area, ISO 25000, is being developed.

- *Acquirers* who are obtaining software from external suppliers
- *Developers* who are building a software product
- *Independent evaluators* who are assessing the quality of a software product, not for themselves but for a community of users – for example, those who might use a particular type of software tool as part of their professional practice

ISO 9126 has separate documents to cater for these three sets of needs. Despite the size of this set of documentation, it relates only to the definition of software quality attributes. A separate standard, ISO 14598, describes the procedures that should be carried out when assessing the degree to which a software product conforms to the selected ISO 9126 quality characteristics. This might seem unnecessary, but it is argued that ISO 14598 could be used to carry out an assessment using a different set of quality characteristics from those in ISO 9126 if circumstances required it.

The difference between internal and external quality attributes has already been noted. ISO 9126 also introduces another type of quality – *quality in use* – for which the following elements have been identified:

- *Effectiveness:* the ability to achieve user goals with accuracy and completeness
- *Productivity:* avoiding the excessive use of resources, such as staff effort, in achieving user goals
- *Safety:* within reasonable levels of risk of harm to people and other entities such as business, software, property and the environment
- *Satisfaction:* smiling users

'Users' in this context includes not just those who operate the system containing the software, but also those who maintain and enhance the software. The idea of quality in use underlines how the required quality of the software is an attribute not just of the software but also of the context of use. For instance, in the IOE scenario, suppose the maintenance job reporting procedure varies considerably, depending on the type of equipment being serviced, because different inputs are needed to calculate the cost to IOE. Say that 95% of jobs currently involve maintaining photocopiers and 5% concern maintenance of printers. If the software is written for this application, then despite good testing, some errors might still get into the operational system. As these are reported and corrected, the software would become more 'mature' as faults become rarer. If there were a rapid switch so that more printer maintenance jobs were being processed, there could be an increase in reported faults as coding bugs in previously less heavily used parts of the software code for printer maintenance were flushed out by the larger number of printer maintenance transactions. Thus, changes to software use involve changes to quality requirements.

ISO 9126 identifies six major external software quality characteristics:

- *Functionality*, which covers the functions that a software product provides to satisfy user needs
- *Reliability*, which relates to the capability of the software to maintain its level of performance
- *Usability*, which relates to the effort needed to use the software
- *Efficiency*, which relates to the physical resources used when the software is executed
- *Maintainability*, which relates to the effort needed to the make changes to the software
- *Portability*, which relates to the ability of the software to be transferred to a different environment

ISO 9126 suggests sub-characteristics for each of the primary characteristics. They are useful as they clarify what is meant by each of the main characteristics.

Characteristic	Sub-characteristics
Functionality	Suitability
	Accuracy
	Interoperability
	Functionality compliance
	Security

'Functionality compliance' refers to the degree to which the software adheres to application-related standards or legal requirements. Typically these could be auditing requirements. Since the original 1999 draft, a sub-characteristic called 'compliance' has been added to all six ISO external characteristics. In each case, this refers to any specific standards that might apply to the particular quality attribute.

'Interoperability' is a good illustration of the efforts of ISO 9126 to clarify terminology. 'Interoperability' refers to the ability of the software to interact with other systems. The framers of ISO 9126 have chosen this word rather than 'compatibility' because the latter causes confusion with the characteristic referred to by ISO 9126 as 'replaceability' (see below).

Characteristic	Sub-characteristics
Reliability	Maturity
	Fault tolerance
	Recoverability
	Reliability compliance

'Maturity' refers to the frequency of failure due to faults in a software product, the implication being that the more the software has been used, the more faults will have been uncovered and removed. It is also interesting to note that 'recoverability' has been clearly distinguished from 'security' which describes the control of access to a system.

Characteristic	Sub-characteristics
Usability	Understandability
	Learnability
	Operability
	Attractiveness
	Usability compliance

Note how 'learnability' is distinguished from 'operability'. A software tool could be easy to learn but time-consuming to use because, say, it uses a large number of nested menus. This might be fine for a package used intermittently, but not where the system is used for many hours each day. In this case 'learnability' has been incorporated at the expense of 'operability'.

'Attractiveness' is a recent addition to the sub-characteristics of usability and is especially important when users are not compelled to use a particular software product, as in the case of games and other entertainmen products.

Characteristic	Sub-characteristics
Efficiency	Time behaviour
	Resource utilization
	Efficiency compliance
Maintainability	Analysability
	Changeability
	Stability
	Testability
	Maintainability compliance

'Analysability' is the ease with which the cause of a failure can be determined. 'Changeability' is the quality that others call 'flexibility': the latter name is a better one as 'changeability' has a different connotation in plain English – it might imply that the suppliers of the software are always changing it!

'Stability', on the other hand, does not refer to software never changing: it means that there is a low risk of a modification to the software having unexpected effects.

Characteristic	Sub-characteristics
Portability	Adaptability
	Installability
	Coexistence
	Replaceability
	Portability compliance

'Portability compliance' relates to those standards that have a bearing on portability. The use of a standard programming language common to many software/hardware environments would be an example of this. 'Replaceability' refers to the factors that give 'upwards compatibility' between old software components and the new ones. 'Downwards' compatibility is not implied by the definition.

A new version of a word processing package might read the documents produced by previous versions and thus be able to replace them, but previous versions might not be able to read all documents created by the new version.

'Coexistence' refers to the ability of the software to share resources with other software components; unlike 'interoperability', no direct data passing is necessarily involved.

ISO 9126 provides guidelines for the use of the quality characteristics. Variation in the importance of different quality characteristics depending on the type of product is stressed. Once the requirements for the software product have been established, the following steps are suggested:

1. *Judge the importance of each quality characteristic for the application* Thus reliability will be of particular concern with safety-critical systems while efficiency will be important for some real-time systems.
2. *Select the external quality measurements within the ISO 9126 framework relevant to the qualities prioritized above* Thus for reliability mean time between failures would be an important measurement, while for efficiency, and more specifically 'time behaviour', response time would be an obvious measurement.
3. *Map measurements onto ratings that reflect user satisfaction* For response time, for example, the mappings might be as in Table 13.1.
4. *Identify the relevant internal measurements and the intermediate products in which they appear* This would only be important where software was being developed, rather than existing software being evaluated. For new software, the likely quality of the final product would need to be assessed during development. For example, where the external quality in question was time behaviour, at the software design stage an estimated execution time for a transaction could be produced by examining the software code and calculating the time for each instruction in a typical execution of the transaction. In our view the mappings between internal and external quality characteristics and measurements suggested in the ISO 9126 standard are the least convincing elements in the approach. The part of the standard that provides guidance at this point is a 'technical report' which is less authoritative than a full standard. It concedes that mapping external and internal measurements can be difficult and that validation to check that there is a meaningful correlation between the two in a specific environment needs to be done. This reflects a real problem in the practical world of software development of examining code structure and from that attempting to predict accurately external qualities such as reliability.

TABLE 13.1 Mapping measurements to user satisfaction

Response time (seconds)	Rating
<2	Exceeds expectation
2–5	Within the target range
6–10	Minimally acceptable
>10	Unacceptable

According to ISO 9126, measurements that might act as indicators of the final quality of the software can be taken at different stages of the development life cycle. For products at the early stages these indicators might be qualitative. They could, for example, be based on checklists where compliance with predefined criteria is assessed by expert judgement. As the product nears completion, objective, quantitative, measurements would increasingly be taken.

5. *Overall assessment of product quality* To what extent is it possible to combine ratings for different quality characteristics into a single overall rating for the software? A factor which discourages attempts at combining the assessments of different quality characteristics is that they can, in practice, be measured in very different ways, which makes comparison and combination difficult. Sometimes the presence of one quality could be to the detriment of another. For example, the efficiency characteristics of time behaviour and resource utilization could be enhanced by exploiting the particular characteristics of the operating system and hardware environments within which the software will perform. This, however, would probably be at the expense of portability.

It was noted above that quality assessment could be carried out for a number of different reasons: to assist software development, acquisition or independent assessment.

During the development of a software product, the assessment would be driven by the need to focus the minds of the developers on key quality requirements. The aim would be to identify possible weaknesses early on and there would be no need for an overall quality rating.

The problem here is to map an objective measurement onto an indicator of customer satisfaction which is subjective.

TABLE 13.2 Mapping response times onto user satisfaction

Response time (seconds)	Quality score
<2	5
2–3	4
4–5	3
6–7	2
8–9	1
>9	0

Where potential users are assessing a number of different software products in order to choose the best one, the outcome will be along the lines that product A is more satisfactory than product B or C. Here some idea of relative satisfaction exists and there is a justification in trying to model how this satisfaction might be formed. One approach recognizes some *mandatory* quality rating levels which a product must reach or be rejected, regardless of how good it is otherwise. Other characteristics might be *desirable* but not essential. For these a user satisfaction rating could be allocated in the range, say, 0–5. This could be based on having an objective measurement of some function and then relating different measurement values to different levels of user satisfaction – see Table 13.2.

Along with the rating for satisfaction, a rating in the range 1–5, say, could be assigned to reflect how important each quality characteristic was. The scores for each quality could be given due weight by multiplying it by its importance weighting. These weighted scores can then be summed to obtain an overall score for the product. The scores for various products are then put in the order of preference. For example, two products might be compared as to usability, efficiency and maintainability. The importance of each of these qualities might be rated as 3, 4 and 2, respectively, out of a possible maximum of 5. Quality tests might result in the situation shown in Table 13.3.

TABLE 13.3 Weighted quality scores

Product quality	Importance rating (a)	Product A		Product B	
		Quality score (b)	Weighted score (a × b)	Quality score (c)	Weighted score (a × c)
Usability	3	1	3	3	9
Efficiency	4	2	8	2	8
Maintainability	2	3	6	1	2
Overall			17		19

Finally, a quality assessment can be made on behalf of a user community as a whole. For example, a professional body might assess software tools that support the working practices of its members. Unlike the selection by an individual user/purchaser, this is an attempt to produce an objective assessment of the software independently of a particular user environment. It is clear that the result of such an exercise would vary considerably depending on the weightings given to each software characteristic, and different users could have different requirements. Caution would be needed here.

13.7 Product and Process Metrics

We have already discussed in Section 13.4 that the users assess the quality of a software product based on its external attributes, whereas during development, the developers assess the product's quality based on various internal attributes. We can also say that during development, the developers can ensure the quality of a software product based on a measurement of the relevant internal attributes. The internal attributes may measure either some aspects of the product (called product or of the development process (called process metrics). Let us understand the basic differences between product and process metrics.

- Product metrics help measure the characteristics of a product being developed. A few examples of product metrics and the specific product characteristics that they measure are the following: the LOC and function point metrics are used to measure size, the PM (person-month) metric is used to measure the effort required to develop a product, and the time required to develop the product is measured in months.
- Process metrics help measure how a development process is performing. Examples of process metrics are review effectiveness, average number of defects found per hour of inspection, average defect correction time, productivity, average number of failures detected during testing per LOC, and the number of latent defects per line of code in the developed product.

13.8 Product versus Process Quality Management

The measurements described above relate to *products*. With a product-based approach to planning and control, as advocated by the PRINCE2 project management method, this focus on products is convenient. However, we saw that it is often easier to measure these product qualities in a completed computer application rather than during its development. Trying to use the attributes of intermediate products created at earlier stages to predict the quality of the final application is difficult. An alternative approach is to scrutinize the quality of the *processes* used to develop software product.

The system development process comprises a number of activities linked so that the output from one activity is the input to the next (Figure 13.4). Errors can enter the process at any stage. They can be caused either by defects in a process, as when software developers make mistakes in the logic of their software, or by information not passing clearly and accurately between development stages.

Note that Extreme Programming advocates suggest that the extra effort needed to amend software at later stages can be exaggerated and is, in any case, often justified as adding value to the software.

Errors not removed at early stages become more expensive to correct at later stages. Each development step that passes before the error is found increases the amount of rework needed. An error in the specification found in testing will mean rework at all the stages between specification and testing. Each successive step of development is also more detailed and less able to absorb change.

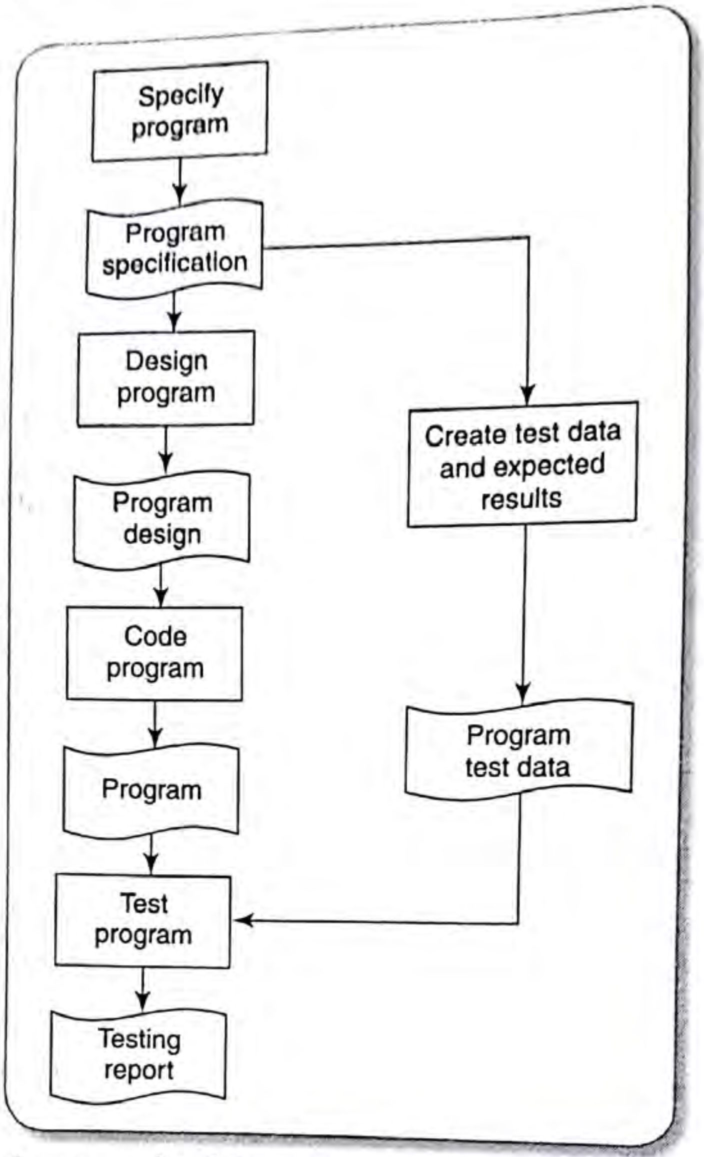


FIGURE 13.4 An example of the sequence of processes and deliverables

Errors should therefore be eradicated by careful examination of the deliverables of each step before they are passed on. One way of doing this is by having the following *process requirements* for each step.

- *Entry requirements*, which have to be in place before an activity can start. An example would be that a comprehensive set of test data and expected results be prepared and approved before program testing can commence.

These requirements may be laid out in installation standards, or a *Software Quality Plan* may be drawn up for the specific project if it is a major one.

- *Implementation requirements*, which define how the process is to be conducted. In the testing phase, for example, it could be laid down that whenever an error is found and corrected, all test runs must be repeated, even those that have previously been found to run correctly.
- *Exit requirements*, which have to be fulfilled before an activity is deemed to have been completed. For example, for the testing phase to be recognized as being completed, all tests will have to have been run successfully with no outstanding errors.

Exercise 13.4

In what cases might the entry conditions for one activity be different from the exit conditions for another activity that immediately precedes it?

Exercise 13.5

What might be the entry and exit requirements for the process *code program* shown in Figure 13.2?

13.9 Quality Management Systems

BS EN ISO 9001:2000

At IOE, a decision might be made to use an outside contractor to produce the annual maintenance contracts subsystem. A natural concern would be the standard of the contractor's deliverables. *Quality control* would involve the rigorous testing of all the software produced by the contractor, insisting on rework where defects are found. This would be very time-consuming. An alternative approach would focus on *quality assurance*. In this case IOE would check that the contractors themselves were carrying out effective quality control. A key element of this would be ensuring that the contractor had the right quality management system in place.

Various national and international standards bodies, including the British Standards Institution (BSI), have engaged in the creation of standards for quality management systems. The British Standard is now called BS EN ISO 9001:2000, which is identical to the international standard, ISO 9001:2000. Standards such as the ISO 9000 series try to ensure that a monitoring and control system to check quality is in place. They are concerned with the certification of the development process, not of the end-product as in the case of crash helmets and electrical appliances with their familiar CE marks. Standards in the ISO 9000 series relate to quality systems in general and not just those in software development.

ISO 9000 describes the fundamental features of a quality management system (QMS) and its terminology. ISO 9001 describes how a QMS can be applied to the creation of products and the provision of services. ISO 9004 applies to process improvement.

There has been some controversy over the value of these standards. Stephen Halliday, writing in *The Observer*, had misgivings that these standards are taken by many customers to imply that the final product is of a certified standard although, as Halliday says, '*It has nothing to do with the quality of the product going out of the gate. You set down your own specifications and just have to maintain them, however low they may be.*' Obtaining certification can be expensive and time-consuming which can put smaller, but still well-run, businesses at a disadvantage. Finally, there has been a concern that a preoccupation with certification might distract attention from the real problems of producing quality products. This would be another example of means–ends inversion, discussed in Chapter 4.

Putting aside these reservations, let us examine how the standard works. First, we identify those things to be the subject of quality requirements. We then put a system in place which checks that the requirements are being fulfilled and corrective action taken when necessary.

An overview of BS EN ISO 9001:2000 QMS requirements

The standard is built on a foundation of the following principles:

Remember that these standards are designed for all kinds of production – not just software development

- Understanding the requirements of customers so that they can be met, or even exceeded
- Leadership to provide the unity of purpose and direction needed to achieve quality objectives
- Involvement of staff at all levels
- A focus on the individual processes which create intermediate or deliverable products and services
- A focus on the systems of interrelated processes that create delivered products and services
- Continuous improvement of processes
- Decision making based on factual evidence
- Building mutually beneficial relationships with suppliers

These principles are applied through cycles which involve the following activities:

1. Determining the needs and expectations of the customer
2. Establishing a *quality policy*, that is, a framework which allows the organization's objectives in relation to quality to be defined
3. Design of the *processes* which will create the products (or deliver the services) which will have the qualities implied in the organization's quality objectives
4. Allocation of the responsibilities for meeting these requirements for each element of each process
5. Ensuring that resources are available to execute these processes properly
6. Design of methods for measuring the effectiveness and efficiency of each process in contributing to the organization's quality objectives
7. Gathering of measurements
8. Identification of any discrepancies between the actual measurements and the target values
9. Analysis and elimination of the causes of discrepancies

The procedures above should be designed and executed so that there is continual improvement. They should, if carried out properly, lead to an effective QMS. More detailed ISO 9001 requirements include:

- *Documentation* of objectives, procedures (in the form of a *quality manual*), plans, and records relating to the actual operation of processes. The documentation must be subject to a change control system that ensures that it is current. Essentially one needs to be able to demonstrate to an outsider that the QMS exists and is actually adhered to.
- *Management responsibility* – the organization needs to show that the QMS and the processes that produce goods and services conforming to the quality objectives are actively and properly managed.
- *Resources* – an organization must ensure that adequate resources, including appropriately trained staff and appropriate infrastructure, are applied to the processes.
- *Production* should be characterized by:
  - Planning
  - Determination and review of customer requirements

- Effective communications between the customer and supplier
- Design and development being subject to planning, control and review
- Requirements and other information used in design being adequately and clearly recorded
- Design outcomes being verified, validated and documented in a way that provides sufficient information for those who have to use the designs
- Changes to the designs should be properly controlled
- Adequate measures to specify and evaluate the quality of purchased components
- Production of goods and the provision of services should be under controlled conditions to ensure adequate provision of information, work instruction, equipment, measurement devices, and post-delivery activities
- Measurement – to demonstrate that products conform to standards, and the QMS is effective, and to improve the effectiveness of processes that create products or services

Exercise 13.6

One of the processes involved in developing software is system testing and subsequent modification to the application in the light of errors found. If a software development organization were to attempt to conform to BS EN ISO 9001:2000, how might this affect system testing?

Exercise 13.7

Bearing in mind the criticisms of BS EN ISO 9001 that have been mentioned, what precautionary steps could a project manager take where some work for which quality is important is to be contracted out to an organization which has BS EN ISO 9001 accreditation?

13.10 Process Capability Models

As compared to the product metrics, the process metrics are more meaningfully measured during product development. Consequently, to manage quality during development, process-based techniques are very important. In this section, we discuss SEI CMM, CMMI, ISO 15504, and Six Sigma, which are popular process capability models.

A historical perspective

Before the 1950s, the primary means of realizing quality products was by undertaking extensive testing of the finished products. However, the emphasis of the quality paradigms later shifted from product assurance (extensive testing of the finished product) to process assurance (ensuring that a good quality process is used for product development). In this context, it needs to be emphasized that a basic assumption made by all modern quality paradigms is that if an organization's processes are good and are followed rigorously, then the products developed by using it would certainly be of good quality. Therefore, all modern quality assurance techniques focus on providing sufficient guidance for recognizing, defining, analysing, and improving the process.

A good documented process enables setting up of a good quality system. However, to reach the next quality level, it is necessary to improve the process whenever any shortcomings in it are noticed. It is also necessary to incorporate into the development process any new tools or techniques that may become available. This forms the essential idea behind Total Quality Management (TQM). In a nutshell, TQM advocates that the process followed by an organization must continuously be improved through process measurements. Continuous process improvement is achieved through process redesign. A term related to TQM is Business Process Reengineering (BPR). BPR aims at reengineering the way business is carried out in an organization.

SEI capability maturity model (CMM)

The United States Department of Defence (US DoD) is one of the largest buyers of software products in the world. It has often faced difficulties dealing with the quality of performance of vendors, to whom it assigned contracts. The department had to live with recurring problems of delivery of low quality products, late delivery, and cost escalations. In this context, DoD worked with the Software Engineering Institute (SEI) of the Carnegie Mellon University to develop CMM. Originally, the objective of CMM was to assist DoD in developing an effective software acquisition method by predicting the likely contractor performance through an evaluation of their development practices.

Most of the DoD contractors began to undertake CMM-based process improvement initiatives as they vied for DoD contracts. It was soon observed that the SEI CMM model helped organizations to actually improve the quality of the software they developed. These organizations were quickly convinced that adoption of SEI CMM model had significant business benefits even when they were developing software for clients other than the DoD. Gradually many other commercial organizations began to adopt CMM in their own internal improvement initiatives.

In simple words, CMM is a reference model for appraising a software development organization into one of five process maturity levels. The maturity level of an organization is a ranking of the quality of the development process used by the organization. This information can be used to predict the most likely outcome of a project that the organization undertakes.

It should be remembered that SEI CMM can be used in two different ways, viz., capability evaluation and process assessment. Capability evaluation and software process assessment differ in motivation, objective, and the final use of the result. Capability evaluation essentially concerns assessing the software process capability of an organization. Capability evaluation is administered by the contract awarding authority, and therefore the results are indicative of the likely contractor performance if the contractor is awarded a work. On the other hand, process assessment is used by an organization with the objective of improving its own process capability. Thus, the result of the latter type of assessment is purely for internal use by a company.

In process assessment, the quality level is assessed by a team of assessors coming into an organization and interviewing the key staff about their practices, using a standard questionnaire to capture information. It needs to be remembered that in this case, a key objective is not just to assess, but to recommend specific actions to bring the organization up to a higher process maturity level. The different levels of SEI CMM have been designed so that it is easy for an organization to slowly ramp up its quality system starting from scratch. SEI CMM classifies software development organizations into the following five maturity levels.

Level 1: Initial A software development organization at this level is characterized by haphazard activities by the members of project teams. The chaotic activities are primarily brought about by the lack of any definition of the development and management processes. Each developer feels free to follow any process that he or she may like. Due to the chaotic development process practised, when a developer leaves the organization, the new incumbent usually faces great difficulty in understanding the process that was followed for the portion of the work that has been completed. Besides the lack of any agreed development processes in the organization, no systematic project management process is prevalent. Consequently, time pressure builds up towards the product delivery time. To cope up with the time pressure, many short cuts are tried out leading to low quality products. Though project failures and project completion delays are commonplace in these level 1 organizations, yet it is possible that some projects may get successfully completed. But an analysis of any incidence of successful completion of a project would reveal the heroic efforts put in by some members of the project team. Thus, it can be said that the chances of a successful project execution by a level 1 organization depends to a large extent on who exactly are the members of the development team.

Level 2: Repeatable Organizations at this level usually practise some basic project management practices such as planning and tracking cost and schedule. Further, these organizations make use of configuration management tools to keep the deliverable items under configuration control. As level 1 organizations, level 2 organizations are characterized by any documented process. However, the developers usually have a rough understanding of the process being followed in the organization. As a result, such an organization can usually repeat its success on one project on other similar projects.

Level 3: Defined At this level, the processes for both management and development activities are defined and documented. There is a common organization-wide understanding of activities, roles, and responsibilities. At this level, the organization builds up the capabilities of its employees through periodic training programs. Also, systematic reviews are practised to achieve phase containment of errors.

Level 4: Managed Organizations at this level focus on effectively managing development tasks by collecting appropriate process and product metrics. Quantitative quality goals are set for the products and processes. At the time of project completion, it is checked whether the quantitative quality goals for these have been met. The process metrics are used to check if project activities were performed satisfactorily. In other words, the collected metrics are used to measure and track project performance rather than improve the process.

Level 5: Optimizing Organizations operating at this level not only collect process and product metrics, but analyze them to identify scopes for improving and optimizing the various development and management activities. In other words, these organizations strive for *continuous process improvement*. As an example of a process optimization that may be made, consider that from an analysis of the process measurement results, it is observed that the code reviews are not very effective and a large number of errors are detected only during the unit testing. In this case, the review process would be fine-tuned to make it more effective. In a level 5 organization, the lessons learned from specific projects are incorporated in to the process. Continuous process improvement is achieved both by careful analysis of the process measurement results and assimilation of innovative ideas and technologies. Level 5 organizations usually have a department whose sole responsibility is to assimilate latest tools and technologies and propagate them across the organization. Since the processes change continuously in these organizations, it becomes necessary to effectively manage these changing processes. To effectively manage process changes, level 5 organizations use configuration management techniques.

Key process areas

Except for level 1, each maturity level is characterized by several Key Process Areas (KPAs). The KPAs of a level indicate the areas that an organization at the lower maturity level needs to focus to reach this level. The KPAs for the different process maturity levels are shown in Table 13.4. Note that level 1 has no KPAs associated with it, since by default all organizations are in level 1.

KPAs provide a way for an organization to gradually improve its quality of over several stages. In other words, at each stage of process maturity, KPAs identify the key areas on which an organization needs to focus to take it to the next level of maturity. Each stage has been carefully designed such that one stage enhances the capability already built up. For example, trying to implement a defined process (level 3) before a repeatable process (level 2) would be counterproductive as it becomes difficult to follow the defined process due to schedule and budget pressures. In other words, trying to focus on some higher level KPAs without achieving the lower level KPAs would be counterproductive.

CMMI (Capability Maturity Model Integration)

CMMI is the successor of the Capability Maturity Model (CMM). In 2002, CMMI Version 1.1 was released. Version 1.2 followed in 2006. The genesis of CMMI is the following. After CMMI was first released in 1990, it was adopted and used in many domains other than software development, such as human resource management (HRM). CMMs were developed for disciplines such as systems engineering (SE-CMM), people management (PCMM), software acquisition (SA-CMM), and others. Although many organizations found these models to be useful, they faced difficulties arising from overlap, inconsistencies, as well as integration of the models. In this context, CMMI is generalized to be applicable to many domains using a single framework. However, this unification has resulted in making CMMI much more abstract than its predecessors such as CMM. For example, all the terminologies that are used are very generic in nature and even the word software does not appear in the definition documentation of CMMI. However, CMMI has much in common with CMM, and also describes the five distinct levels of process maturity of CMM.

TABLE 13.4 CMMI key process areas

Level	Key process areas
1. Initial	Not applicable
2. Managed	Requirements management, project planning and monitoring and control, supplier agreement management, measurement and analysis, process and product quality assurance, configuration management
3. Defined	Requirements development, technical solution, product integration, verification, validation, organizational process focus and definition, training, integrated project management, risk management, integrated teaming, integrated supplier management, decision analysis and resolution, organizational environment for integration
4. Quantitatively managed	Organizational process performance, quantitative project management
5. Optimizing	Organizational innovation and deployment, causal analysis and resolution

ISO 15504 process assessment

ISO/IEC 15504 is a standard for process assessment that shares many concepts with CMMI. The two standards should be compatible. Like CMMI the standard is designed to provide guidance on the assessment of software development processes. To do this there must be some benchmark or *process reference model* which represents the ideal development life cycle against which the actual processes can be compared. Various process reference models could be used but the default is the one described in ISO 12207, which has been briefly discussed in Chapter 1 and which describes the main processes – such as requirements analysis and architectural design – in the classic software development life cycle.

The main reference in the UK for this standard is BS ISO/IEC 15504-1:2004.

Processes are assessed on the basis of nine process attributes – see Table 13.5.

For a process to be judged to be at Level 3, for example, Levels 1 and 2 must also have been achieved.

Table 13.5 ISO 15504 framework for process capability

Level	Attribute	Comments
0. Incomplete		The process is not implemented or is unsuccessful
1. Performed process	1.1 Process performance	The process produces its defined outcomes
2. Managed process	2.1 Performance management	The process is properly planned and monitored
	2.2 Work product management	Work products are properly defined and reviewed to ensure they meet requirements
3. Established process	3.1 Process definition	The processes to be carried out are carefully defined
	3.2 Process deployment	The processes defined above are properly executed by properly trained staff
4. Predictable process	4.1 Process measurement	Quantitatively measurable targets are set for each sub-process and data collected to monitor performance
	4.2 Process control	On the basis of the data collected by 4.1 corrective action is taken if there is unacceptable variation from the targets
5. Optimizing	5.1 Process innovation	As a result of the data collected by 4.1, opportunities for improving processes are identified
	5.2 Process optimization	The opportunities for process improvement are properly evaluated and where appropriate are effectively implemented

When assessors are judging the degree to which a process attribute is being fulfilled they allocate one of the following scores:

Level	Interpretation
N – not achieved	0 to 15% achievement
P – partially achieved	15% to 50% achievement
L – largely achieved	50% to 85% achievement
F – fully achieved	85% achievement

In order to assess the process attribute of a process as being at a certain level of achievement, indicators have to be found that provide evidence for the assessment. For example, say the requirement analysis processes of an organization were being assessed. Assessors might wish to test whether the organization is at Level 3, which relates to there being an established process. The assessor might find a section in a procedures manual relating to the conduct of requirements. This could be evidence of the process being defined (3.1 in Table 13.5). They might also come across control documents which have been signed off as each step of the requirements analysis process has been completed. This would indicate that the defined process is actually deployed (3.2).

Implementing process improvement

The CMMI standard has now grown to over 500 pages. Without getting bogged down in detail, this section explores how the general approach might usefully be employed. To do this we will take a scenario from industry.

UVW is a company that builds machine tool equipment containing sophisticated control software. This equipment also produces log files of fault and other performance data in electronic format. UVW produces software that can read these log files and produce analysis reports and execute queries.

Both the control and analysis software is produced and maintained by the Software Engineering department. Within this department there are separate teams who deal with the software for different types of equipment. Lisa is a Software Team Leader in the Software Engineering department with a team of six systems designers reporting to her.

Her group is responsible for new control systems and the maintenance of existing systems for a particular product line. The dividing line between new development and maintenance is sometimes blurred as a new control system often makes use of existing software components which are modified to create the new software.

A separate Systems Testing Group test software for new control systems, but not fault correction and adaptive maintenance of released systems.

A project for a new control system is controlled by a Project Engineer with overall responsibility for managing both the hardware and software sides of the project. The Project Engineer is not primarily a software specialist and would make heavy demands on the Software Team Leader, such as Lisa, in an advisory capacity. Lisa may, as a Software Team Leader, work for a number of different Project Engineers in respect of different projects, but in the UVW organizational chart she is shown as reporting to the Head of Software Engineering.

A new control system starts with the Project Engineer writing a software requirement document which is reviewed by a Software Team Leader, who will then agree to the document, usually after some amendment. A copy of the requirements document will pass to the Systems Testing Group so that they can create system test cases and a systems test environment.

Lisa, if she were the designated Software Team Leader, would then write an Architecture Design document mapping the requirements to actual software components. These would be allocated to Work Packages carried out by individual members of Lisa's team.

UVW teams get the software quickly written and uploaded onto the newly developed hardware platform for initial debugging. The hardware and software engineers will then invariably have to alter the requirement and consequently the software as they find inconsistencies, faults and missing functions. The Systems Testing Group should be notified of these changes, but this can be patchy. Once the system seems to be satisfactory to the developers, it is released to the Systems Testing Group for final testing before shipping to customers.

Lisa's work problems mainly relate to late deliveries of software by her group because:

(i) The Head of Software Engineering and the Project Leaders may not liaise properly, leading to the over-commitment of resources to both new systems and maintenance jobs at the same time

(ii) The initial testing of the prototype often leads to major new requirements being identified

(iii) There is no proper control over change requests – the volume of these can sometimes increase the demand for software development well beyond that originally planned

(iv) Completion of system testing can be delayed because of the number of bug fixes

We can see that there is plenty of scope for improvements. One problem is knowing where to start. However, approaches like that of CMMI can help us identify the order in which steps in improvement have to take place. Some steps need to build on the completion of others. An immediate step would be to introduce more formal planning and control. This would at least enable us to assess the size of the problems even if we are not yet able to solve them all. Given a software requirement, formal plans enable staff workloads to be distributed more carefully. The monitoring of plans would also allow managers to identify emerging problems with particular projects. Effective change control procedures would make managers more aware of how changes in the system's functionality can force project deadlines to be breached. These process developments would help an organization move from Level 1 to Level 2. Figure 13.5 illustrates how a project control system could be envisaged at the level of maturity.

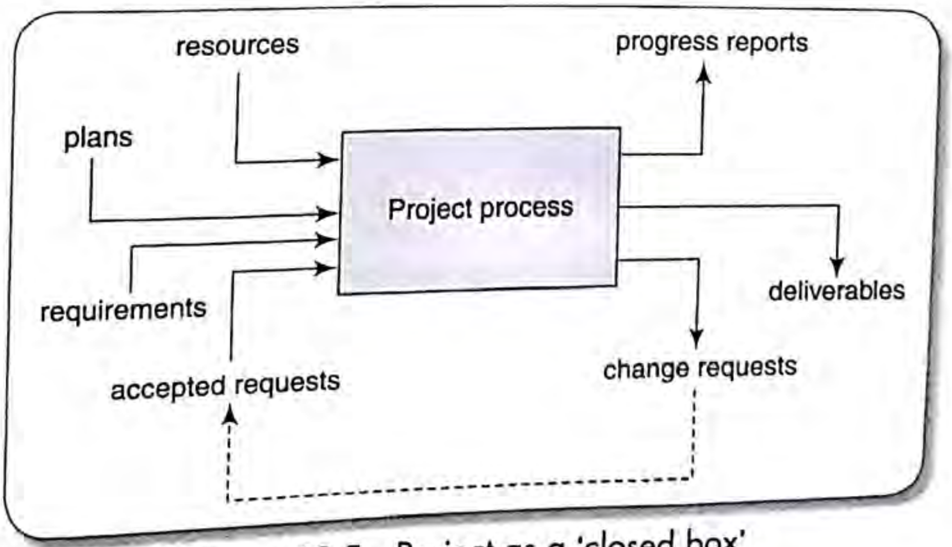


FIGURE 13.5 Project as a 'closed box'

The next step would be to define carefully the processes involved in each stage of the development life cycle – see Figure 13.6. The steps of defining procedures for each development task and ensuring that they are actually carried out help to bring an organization up to Level 3.

Exercise 13.8

The diagram in Figure 13.6 does not show the flows of information needed to indicate how managers could ensure that the correct amount of staff time is allocated to development activities. Amend the diagram to show these flows.

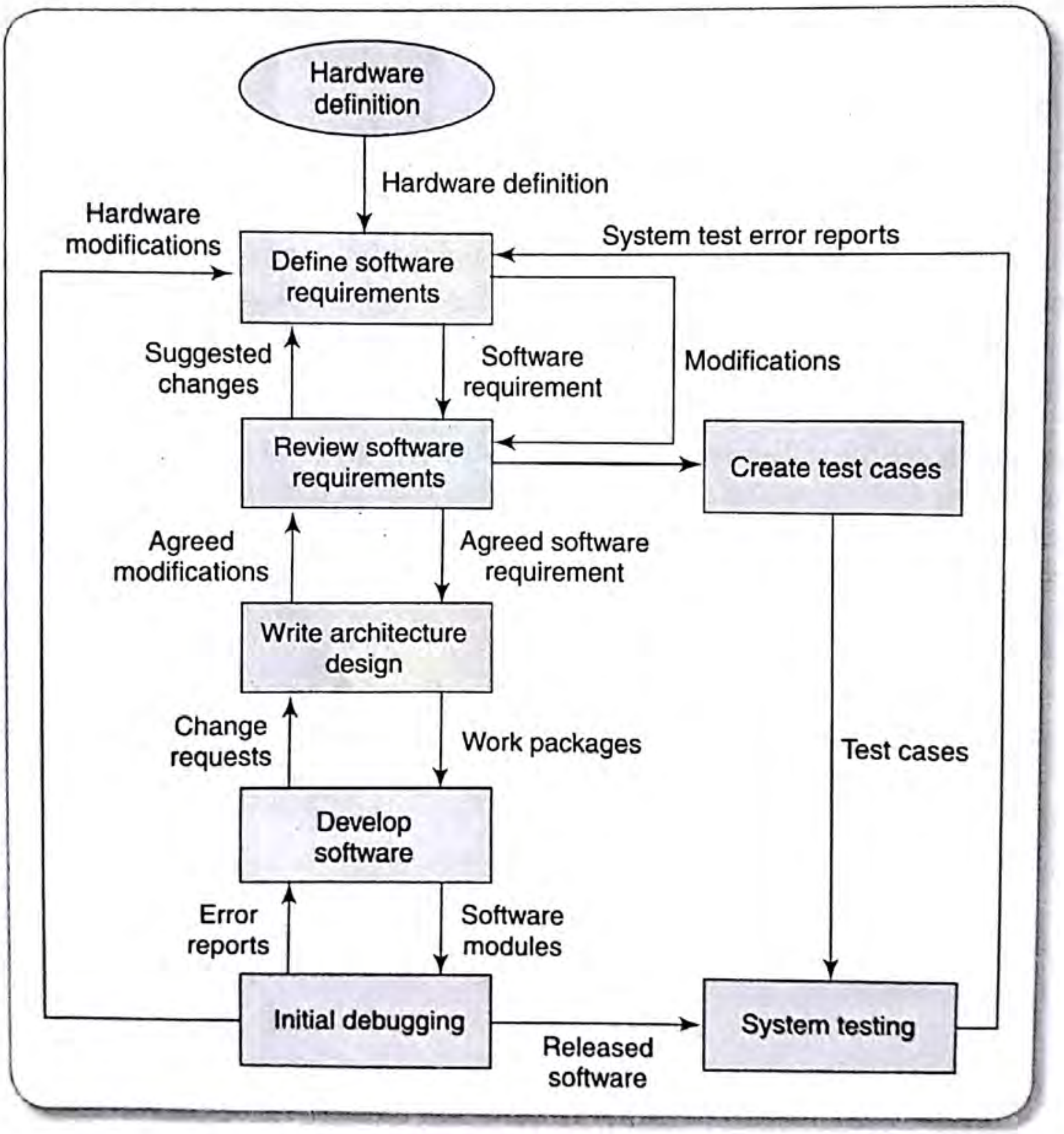


FIGURE 13.6 Process diagram

When more formalized processes exist, the behaviour of component processes can be monitored. We can see, for example, the numbers of change reports generated and system defects detected at the system testing phase. Apart from information about the products passing between processes, we can also collect effort information about each process itself. This enables effective remedial action to be taken speedily when problems are found. The development processes are now properly managed, bringing the organization up to Level 4.

Finally, at Level 5 of process management, the information collected is used to improve the process model itself. It might, for example, become apparent that the changes to software requirements are a major source of defects. Steps could therefore be taken to improve this process. For example, the hardware component of the system could be simulated using software tools. This could help the hardware engineers to produce more realistic designs and reduce changes. It might even be possible to build control software and test it against a simulated hardware system. This could enable earlier and cheaper resolution of technical problems.

Personal Software Process (PSP)

See Watts Humphrey, 'The Personal Software Process, Technical report, SEI-CMU, November, 2000

PSP is based on the work of Watts Humphrey. Unlike CMMI that is intended for companies, PSP is suitable for individual use. It is important to note that SEI CMM does not tell software developers how to analyze, design, code, test or document software products, but assumes that engineers use effective personal practices. PSP recognizes that the process for individual use is different from that necessary for a team. The quality and productivity of an engineer is to a great extent dependent on his process. PSP is a framework that helps engineers to measure and improve the way they work. It helps in developing personal skills and methods by estimating, planning and tracking performance against plans, and provides a defined process which can be tuned by individuals.

Time measurement. PSP advocates that developers should rack the way they spend time. Because, boring activities seem longer than actual and interesting activities seem short. Therefore, the actual time spent on a task should be measured with the help of a stop-clock to get an objective picture of the time spent. For example, he may stop the clock when attending a telephone call, taking a coffee break, etc. An engineer should measure the time he spends for various development activities such as designing, writing code, testing, etc.

PSP Planning. Individuals must plan their project. Unless an individual properly plans his activities, disproportionately high effort may be spent on trivial activities and important activities may be compromised, leading to poor quality results. The developers must estimate the maximum, minimum and the average LOC required for the product. They should use their productivity in minutes/LOC to calculate the maximum, minimum and the average development time. They must record the plan data in a project plan summary.

The PSP is schematically shown in Figure 13.7. As has been shown in Figure 13.7, an individual developer must plan the personal activities and make the basic plans before starting the development work. While carrying out the activities of different phases of software development, the individual developer must record the log data using time measurement. During post implementation project review, the developer can compare

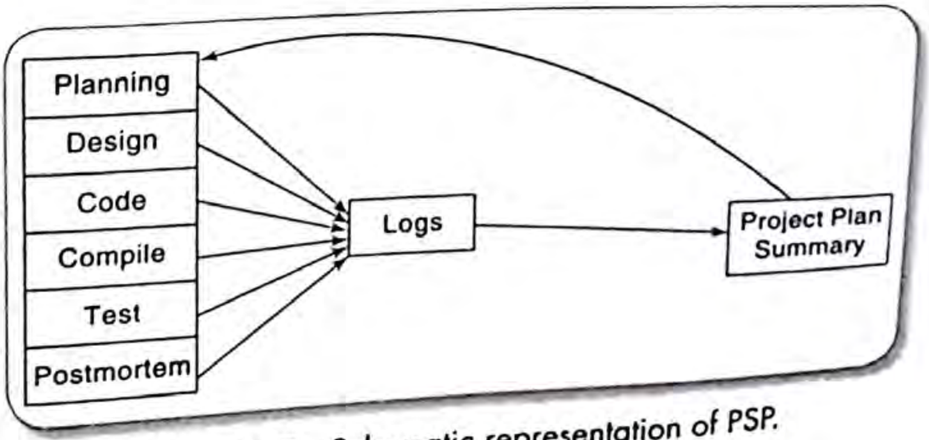


FIGURE 13.7 Schematic representation of PSP.

the log data with the initial plan to achieve better planning in the future projects, to improve his process, etc. The four maturity levels of PSP have schematically been shown in Figure 13.8. The activities that the developer must perform for achieving a higher level of maturity have also been annotated on the diagram. PSP2 introduces defect management via the use of checklists for code and design reviews. The checklists are developed by analysing the defect data gathered from earlier projects.

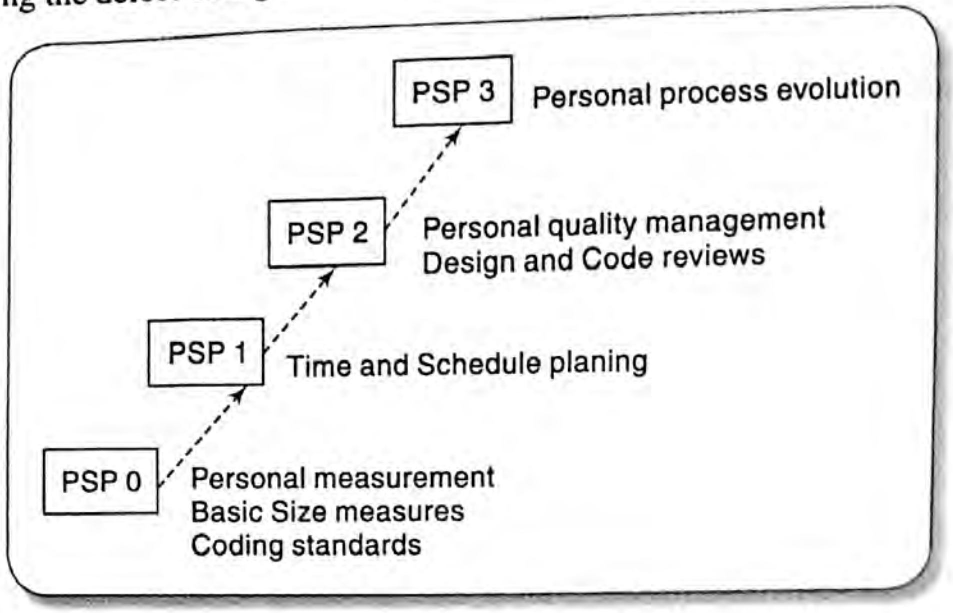


FIGURE 13.8 PSP levels

Six Sigma

Motorola, USA, initially developed the six sigma method in the early 1980s. Since then, thousands of companies around the world have discovered the benefits of adopting six sigma methodologies. The purpose of six sigma is to improve processes to do things better, faster, and at a lower cost. It can in fact, be used to improve every facet of business, i.e., production, human resources, order entry, and technical support areas. Six sigma becomes applicable to any activity that is concerned with cost, timeliness, and quality of results. Therefore, it is applicable to virtually every industry. Six sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects and minimizing variability in the use of process. It uses many quality management methods, including statistical methods, and requires presence of six sigma experts within the organization (black belts, green belts, etc.).

Six sigma is essentially a disciplined, data-driven approach to eliminate defects in any process. The statistical representation of six sigma describes quantitatively how a process is performing. To achieve six sigma, a process must not produce more than 3.4 defects per million defect opportunities. A six sigma defect is defined as any system behaviour that is not as per customer specifications. Total number of six sigma defect opportunities is then the total number of chances for committing an error. Sigma of a process can easily be calculated using a six sigma calculator.

As already mentioned, a basic objective of the six sigma methodology is the implementation of a measurement-based strategy that focuses on process improvement and variation reduction through the application of six sigma improvement methodologies. This is accomplished through the use of two six sigma sub-methodologies: DMAIC and DMADV. The six sigma DMAIC process (define, measure, analyze, improve, control) is an improvement system for existing processes falling below specification and looking for incremental improvement. The six sigma DMADV process (define, measure, analyze, design, verify) is an improvement system used to develop new processes or products at six sigma quality levels. Both six sigma processes are executed by six sigma green belts and six sigma black belts, and are overseen by six sigma master black belts.

Many frameworks exist for implementing the six sigma methodology. Six sigma consultants all over the world have also developed proprietary methodologies for implementing six sigma quality that is based on various philosophies and tools.

13.11 Techniques to Help Enhance Software Quality

Three main themes emerge in this discussion of software quality:

- *Increasing visibility* A landmark in the movement towards a focus on software quality was Gerald Weinberg's advocacy of 'egoless programming'. Weinberg encouraged the simple practice of programmers looking at each other's code.

Gerald Weinberg (1998) *The Psychology of Computer Programming*, Silver Anniversary Edition, Dorset House.

- *Procedural structure* At first, programmers were left to get on with writing programs as best they could. Over the years there has been the growth of methodologies where every process in the software development cycle has carefully laid down steps.
- *Checking intermediate stages* It is tempting to push forward quickly with the development of any engineered object until a 'working' model, however imperfect, has been produced which can then be 'debugged'. The move towards quality practices has emphasized checking the correctness of work at its earlier, conceptual, stages.

The creation of an early working model of a system may still be useful, as the creation of prototypes shows.

However, recently focus has shifted from relying solely on checking the products of intermediate stages and towards building an application as a number of smaller, relatively independent components developed quickly and tested at an early stage. This can reduce some of the problems, noted earlier, of attempting to predict the external quality of the software from early design documents. It does not preclude careful checking of the design of components.

We are now going to look at some specific techniques. The push towards more visibility has been dominated by the increasing use of *walk-throughs, inspections* and *reviews*. The movement towards a more procedural structure inevitably leads to discussion of structured programming techniques and to its later manifestation in the ideas of '*clean-room*' *software development*.

The interest in the dramatic improvements made by the Japanese in product quality has led to much discussion of the quality techniques they have adopted, such as the use of *quality circles*, and these will be looked at briefly. Some of these ideas are variations on the theme of inspection and clean-room development.

Inspections

Inspections can be applied to documents produced at any development stage. For instance, test cases need to be reviewed – their production is usually not a high-profile task even though errors can get through to operational running because of their poor quality.

When a piece of work is completed, copies are distributed to co-workers who examine the work, noting defects. A meeting then discusses the work and a list of defects requiring rework is produced. The work to be examined could be, typically, a program listing that is free of compilation errors.

The main problem is maintaining the commitment of participants to a thorough examination of the work distributed to them after the novelty value of reviews has worn off a little.

Our own experience of using this technique has been that:

- it is a very effective way of removing superficial errors;
- it motivates developers to produce better structured and self-explanatory software;
- it helps spread good programming practices as the participants discuss specific pieces of code;
- it can enhance team spirit.

This is sometimes called 'peer review', where 'peers' are people who are equals.

The item will usually be reviewed by colleagues who work in the same area, so that software developers, for example, will have their work reviewed by fellow developers. To reduce the problems of communication between different stages, there may be representatives from the stages preceding and following the one which produced the work under review.

IBM made the review process more structured and formal, producing statistics to show its effectiveness. A Fagan inspection (named after the IBM employee who pioneered the technique) is led, not by the author of the work, but by a specially trained 'moderator'.

The general principles behind the Fagan method

See M. E. Fagan's (1976) article 'Design and code inspections to reduce errors in program development', *IBM Systems Journal* 15(3).

- Inspections are carried out on all major deliverables.
- All types of defect are noted – not just logic or function errors.
- Inspections can be carried out by colleagues at all levels except the very top.
- Inspections are carried out using a predefined set of steps.
- Inspection meetings do not last for more than two hours.
- The inspection is led by a *moderator* who has had specific training in the technique.
- The other participants have defined roles. For example, one person will act as a *recorder* and note all defects found, and another will act as *reader* and take the other participants through the document under inspection.
- Checklists are used to assist the fault-finding process.
- Material is inspected at an optimal rate of about 100 lines an hour.
- Statistics are maintained so that the effectiveness of the inspection process can be monitored.

Exercise 13.9

Compare and contrast the peer review process described above with pair programming which is advocated as part of extreme programming (XP).

Structured programming and clean-room software development

In the late 1960s, software was seen to be getting more complex while the capacity of the human mind to hold detail remained limited. It was also realized that it was impossible to test any substantial piece of software completely given the huge number of possible input combinations. Testing, at best, could prove the presence of errors, not their absence. Thus Dijkstra and others suggested that the only way to reassure ourselves about the correctness of software was by examining the code.

The way to deal with complex systems, it was contended, was to break them down into components of a size the human mind could comprehend. For a large system there would be a hierarchy of components and subcomponents. For this decomposition to work properly, each component would have to be self-contained, with only one entry and exit point.

E. W. Dijkstra in 1968 wrote a letter to a learned computing journal which was entitled 'Go To Statement Considered Harmful'. This unfortunately led to the common idea that structured programming was simply about not using GO TOs.

The ideas of structured programming have been further developed into the ideas of clean-room software development by people such as the late Harlan Mills of IBM.

With this type of development there are three separate teams:

- *a specification team*, which obtains the user requirements and also a *usage profile* estimating the volume of use for each feature in the system;
- *a development team*, which develops the code but which does no machine testing of the program code produced;
- *a certification team*, which carries out testing.

Usage profiles reflect the need to assess *quality in use* as discussed earlier in relation to ISO 9126. They will be further discussed in the Section 13.11 on testing below.

Any system is produced in increments – recall Section 4.10 – each of which should be capable of actual operation by the end-user. The development team does no debugging; instead, all software has to be verified by them using mathematical techniques. The argument is that software which is constructed by throwing up a crude program, which then has test data thrown at it and a series of hit-and-miss amendments made to it until it works, is bound to be unreliable.

The certification team carry out the testing, which is continued until a statistical model shows that the failure intensity has been reduced to an acceptable level.

Formal methods

Clean-room development, mentioned above, uses mathematical verification techniques. These techniques use unambiguous, mathematically based, specification languages of which Z and VDM are examples. They are used to define *preconditions* and *postconditions* for each procedure. Preconditions define the allowable states, before processing, of the data items upon which a procedure is to work. The postconditions define the state of those data items after processing. The mathematical notation should ensure that such a specification is precise and unambiguous. It should also be possible to prove mathematically (in much the same way that at school you learnt to prove Pythagoras' theorem) that a particular algorithm will work on the data defined by the preconditions in such a way as to produce the postconditions. Despite the claims of the effectiveness of the use of a formal notation to define software specifications for many years now, it is rarely used in mainstream software development. This is despite it being quite widely being taught in universities. A newer development that may meet with more success is the development of Object Constraint Language (OCL). It adds precise, unambiguous, detail to the UML models, for example about the ranges of values that would be valid for a named attribute. It uses an unambiguous, but non-mathematical, notation which developers who are familiar with Java-like programming languages should grasp relatively easily.

Software quality circles

Much interest has been shown in Japanese software quality practices. The aim of the 'Japanese' approach is to examine and modify the activities in the development process in order to reduce the number of errors that they have in their end-products. Testing and Fagan inspections can assist the removal of errors – but the same types of error could occur repeatedly in successive products created by a faculty process. By uncovering the source of errors, this repetition can be eliminated.

Staff are involved in the identification of sources of errors through the formation of *quality circles*. These can be set up in all departments of an organization, including those producing software where they are known as software quality circles (SWQC).

A quality circle is a group of four to ten volunteers working in the same area who meet for, say, an hour a week to identify, analyze and solve their work-related problems. One of their number is the group leader and there could be an outsider, a *facilitator*, who can advise on procedural matters. In order to make the quality circle work effectively, training needs to be given.

Together the quality group select a pressing problem that affects their work. They identify what they think are the causes of the problem and decide on a course of action to remove these causes. Often, because of resource or possible organizational constraints, they will have to present their ideas to management to obtain approval before implementing the process improvement.

Exercise 13.10

What are the important differences between a quality circle and a review group?

Associated with quality circles is the compilation of *most probable error lists*. For example, at IOE, Amanda might find that the annual maintenance contracts project is being delayed because of errors in the requirements specifications. The project team could be assembled and spend some time producing a list of the most common types of error that occur in requirements specifications. This is then used to identify measures which can reduce the occurrence of each type of error. They might suggest, for instance, that test cases be produced at the same time as the requirements specification and that these test cases should be dry run at an inspection. The result is a checklist for use when conducting inspections of requirement specifications.

Lessons learnt reports

Another way by which an organization can improve its performance is by reflecting on the performance of a project at its immediate end when the experience is still fresh. This reflection may identify lessons to be applied to future projects. Project managers are required to write a *Lessons Learnt* report at the end of the project. This should be distinguished from a *Post Implementation Review* (PIR). A PIR takes place after a significant period of operation of the new system, and focuses on the effectiveness of the new system, rather than the original project process. The PIR is often produced by someone who was not involved in the original project, in order to ensure neutrality. An outcome of the PIR will often be changes to enhance the effectiveness of the installed system.

The Lessons Learnt report, on the other hand, is written by the project manager as soon as possible after the completion of the project. This urgency is because the project team is often dispersed to new work soon after the finish of the project. One problem that is frequently voiced is that there is often very little follow-up on the recommendations of such reports, as there is often no body within the organization with the responsibility and authority to do so.

13.12 Testing

The final judgement of the quality of a software application is whether it actually works correctly when executed. This section looks at aspects of the planning and management of testing. A major headache with testing is estimating how much testing remains at any point. This estimate of the work still to be done depends on an unknown, the number of bugs left in the code. We will briefly discuss how we can deal with this problem.

In Chapter 4, the *V-process model* was introduced as an extension to the waterfall process model. Figure 13.9 gives a diagrammatic representation of this model. This stresses the necessity for validation activities that match the activities creating the products of the project.

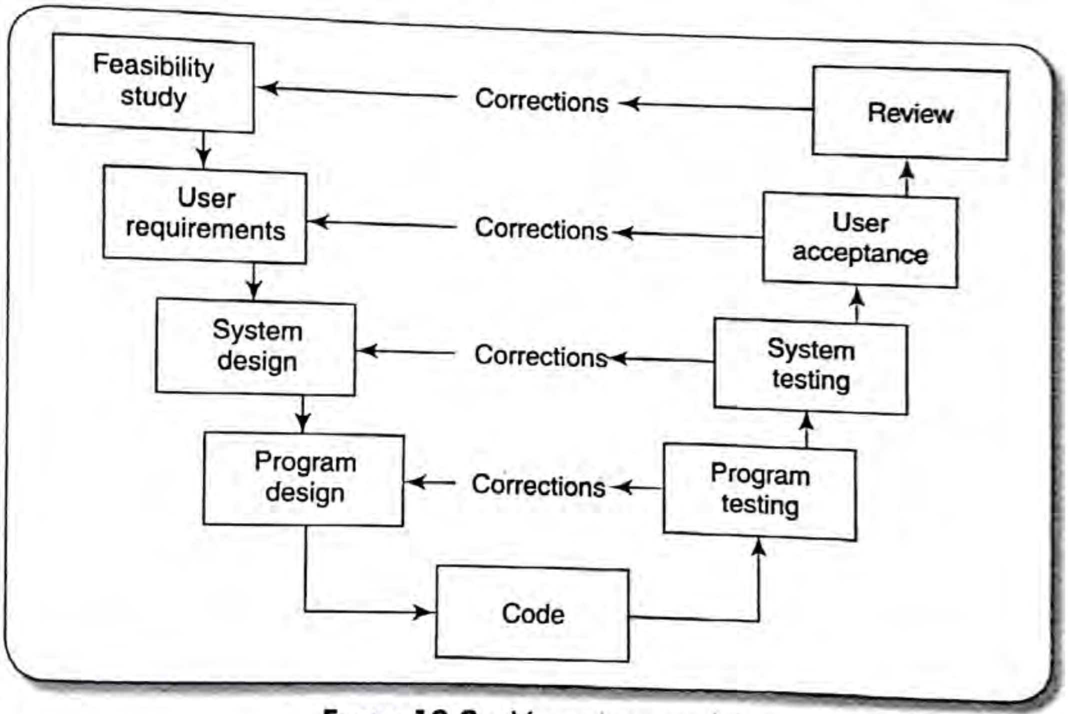


FIGURE 13.9 V-process model

The V-process model can be seen as expanding the activity box 'testing' in the waterfall model. Each step has a matching validation process which can, where defects are found, cause a loop back to the corresponding development stage and a reworking of the following steps. Ideally this feeding back should occur only where a discrepancy has been found between what was specified by a particular activity and what was actually implemented in the next lower activity on the descent of the V loop. For example, the system designer might have written that a calculation be carried out in a certain way. A developer building code to meet this design might have misunderstood what was required. At system testing stage, the original designer would be responsible for checking that the software is doing what was specified and this would discover the coder's misreading of that document.

Using the V-process model as a framework, planning decisions can be made at the outset as to the types and amounts of testing to be done. An obvious example of this would be that if the software were acquired 'off-the-shelf', the program design and code stages would not be relevant and so program testing would not be needed. User requirements would still be produced so user acceptance tests would still be valid.

Verification versus validation

The objectives of both verification and validation techniques are very similar. Both these techniques have been designed to help remove errors in software. In spite of the apparent similarity between their objectives, the underlying principles of these two bug detection techniques and their applicability are very different. The main differences between these two techniques are the following:

- Verification is the process of determining whether the output of one phase of software development conforms to that of its previous phase. Validation is the process of determining whether fully developed software conforms to its requirements specification. We can therefore say that the objective of verification is to check if the artifacts produced after a phase conforms to that of the previous phase. For example, a verification step can be to check if the design documents produced after the design step conform to the requirements specification. On the other hand, validation is applied to the fully developed and integrated software to check if it satisfies the customer's requirements. The primary techniques used for verification include review, simulation, and formal verification. On the other hand, validation techniques are primarily based on product testing.
- Verification is carried out during the development process to check if the development activities are being carried out correctly, whereas validation is carried out towards the end of the development process to check if the right product as required by the customer has been developed. Verification techniques can be viewed as an attempt to achieve phase containment of errors. Phase containment of errors has been acknowledged to be a cost-effective way to eliminate program bugs, and accepted as an important software engineering principle.

All the boxes shown in the right hand side of the V-process model of Figure 13.9 correspond to verification activities except the system testing block which corresponds to validation activity.

Exercise 13.11

Is it at all possible to develop highly reliable software using validation techniques alone? If so, can we say that whenever thorough validation is carried out, verification is redundant?

Test case design

There are essentially two main approaches to systematically design test cases: black-box approach and white-box (or glass-box) approach.

In the black-box approach, test cases are designed using only the functional specification of the software. That is, test cases are designed solely based on an analysis of the input/output behaviour (that is, functional behaviour) and does not require any knowledge of the internal structure of a program. For this reason, black-box testing is also known as *functional testing* and also as *requirements-driven testing*. Design of white-box test cases on the other hand, requires analysis of the source code. Consequently, white-box testing is also called *structural testing* or *structure-driven testing*.

Levels of testing

A software product is normally tested at three different stages or levels. These three testing stages are

- Unit testing
- Integration testing
- System testing

During unit testing, the individual components (or units) of a program are tested. For every module, unit testing is carried out as soon as the coding for it is complete. Since every module is tested separately, there is a good scope for parallel activities during unit testing. The objective of integration testing is to check whether the modules have any errors pertaining to interfacing with each other.

Unit testing is referred to as testing in the small, whereas integration and system testing are referred to as testing in the large. After testing all the units individually, the units are integrated over a number of steps and tested after each step of integration (integration testing). Finally, the fully integrated system is tested (system testing).

Exercise 13.12

Why is it necessary to test each module of a program in isolation first, then integrate these modules and re-test, and again test the integrated set of modules? Why not just test the fully integrated set of modules once thoroughly?

Testing activities

Testing involves performing the following main activities:

Test Planning Since many activities are carried out during testing, careful planning is needed. The specific test case design strategies that would be deployed are also planned. Test planning consists of determining the relevant test strategies and planning for any test bed that may be required. A suitable test bed is an especially important concern while testing embedded applications. A test bed usually includes setting up the hardware or simulator.

Test Suite Design Planned testing strategies are used to design the set of test cases (called test suite) using which a program is to be tested.

Test Case Execution and Result Checking Each test case is run and the results are compared with the expected results. A mismatch between the actual result and expected results indicates a failure. The test cases for which the system fails are noted down for test reporting.

Test Reporting When the test cases are run, the tester may raise issues, that is, report discrepancies between the expected and the actual findings. A means of formally recording these issues and their history is needed. A review body adjudicates these issues. The outcome of this scrutiny would be one of the following:

- The issue is dismissed on the grounds that there has been a misunderstanding of a requirement by the tester.
- The issue is identified as a fault which the developers need to correct–Where development is being done by contractors, they would be expected to cover the cost of the correction.

- It is recognized that the software is behaving as specified, but the requirement originally agreed is in fact incorrect–Remedying this means adding a new requirement and a contractor could expect to receive payment for the additional work.
- The issue is identified as a fault but is treated as an *off-specification*–It is decided that the application can be made operational with the error still in place.

In a commercial project, execution of the entire test suite can take several weeks to complete. Therefore, in order to optimize the turnaround time, the test failure information is usually informally intimated to the development team as and when failures are noticed.

Debugging For each failure observed during testing, debugging is carried out to identify the statements that are in error. There are several debugging strategies, but essentially in each the failure symptoms are analyzed to locate the errors.

Error Correction After an error is located through a debugging activity; the code is appropriately changed to correct the error.

Defect Retesting Once a defect has been dealt with by the development team; the corrected code is retested by the testing team to check whether the defect has successfully been addressed. Defect retest is also popularly called *resolution testing*. The resolution tests are a subset of the complete test suite (see Figure 13.10).

Regression Testing While resolution testing checks whether the defect has been fixed, regression testing checks whether the unmodified functionalities still continue to work correctly. Thus, whenever a defect is corrected and the change is incorporated in the program code, a danger is that a change introduced to correct an error could actually introduce errors in functionalities that were previously working correctly. The regression tests check whether the unmodified functionalities continue to work correctly. As a result, after a bug-fixing session, both the resolution and regression test cases need to be run. This is where the additional effort required to create automated test scripts can pay off. As shown in Figure 13.6, some test cases may no more be valid after the change. These have been shown as invalid test case. The rest are redundant test cases, which check those parts of the program code that are not at all affected by the change.

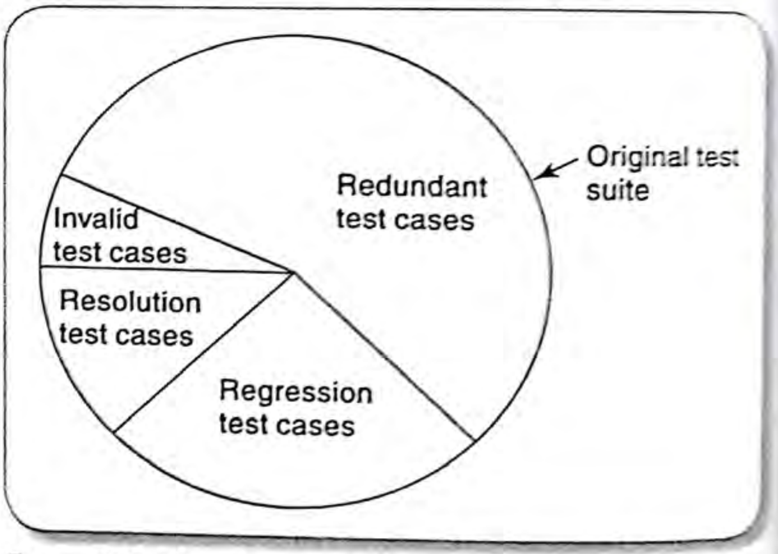


FIGURE 13.10 Types of test cases in the original test suite after a change

Test Closure Once the system successfully passes all the tests, documents related to lessons learned, test results, logs, etc., are archived for use as a reference in future projects.

Of all the above-mentioned testing activities, debugging is usually the most time-consuming activity.

Who performs testing?

A question to be settled at the planning stage is who would carry out testing. Many organizations have separate system testing groups to provide an independent assessment of the correctness of software before release. In other organizations, staff is allocated to a purely testing role but work alongside the developers instead of a separate group. While an independent testing group can provide final quality check, it has been argued that developers may take less care of their work if they know the existence of this safety net.

Test automation

Testing is usually the most time consuming and laborious of all software development activities. This is especially true for large and complex software products that are being developed currently. In fact at present, testing cost often exceeds all other development life-cycle costs. With the growing size of programs and the increased importance being given to product quality, test automation is drawing considerable attention from both industry circles and academia. Test automation is a generic term for automating one or some activities of the test process.

Other than reducing human effort and time in this otherwise time and effort-intensive work, test automation also significantly improves the thoroughness of testing. This is because more testing can be carried out using a large number of test cases within a short period of time without any significant cost overhead.

The effectiveness of testing, to a large extent, depends on the exact test case design strategy used. Considering the large overheads that sophisticated testing techniques incur, in many industrial projects, often testing is carried out using randomly selected test values. With automation, more sophisticated test case design techniques can be deployed. Without the use of proper tools, testing large and complex software products can especially be extremely time consuming and laborious. A further advantage of using testing tools is that automated test results are much more reliable and eliminate human errors during testing. Regression testing after every change or error correction requires running several old test cases. In this situation, test automation simplifies repeated running of the test cases. Testing tools hold out the promise of substantial cost and time reduction even in the testing and maintenance phases.

Every software product undergoes significant change overtime. Each time the code changes, it needs to be tested whether the changes induce any failures in the unchanged features. Thus the originally designed test suite needs to be run repeatedly each time the code changes. Of course additional tests have to be designed and carried out on the enhanced features. Repeated running of the same set of test cases over and over after every change is monotonous, boring, and error-prone. Automated testing tools can be of considerable use in repeatedly running the same set of test cases. Testing tools can entirely or at least substantially eliminate the drudgery of running same test cases and also significantly reduce testing costs. A large number of tools are at present available both in the public domain as well as from commercial sources. It is possible to classify these tools into the following types with regard to the specific methodology on which they are based.

Capture and Playback In this type of tools, the test cases are executed manually only once. During the manual execution, the sequence and values of various inputs as well as the outputs produced are recorded. On any subsequent occasion, the test can be automatically replayed and the results are checked against the recorded output. An important advantage of the capture playback tools is that once test data are captured and the results verified, the tests can be rerun several times over easily and cheaply. Thus, these tools are very useful for regression testing. However, capture and playback tools have a few disadvantages as well. Test maintenance can be costly when the unit under test changes, since some of the captured tests may become invalid. It would require considerable effort to determine and remove the invalid test cases or modify the test input and output data. Also new test cases would have to be added for the altered code.

Automated Test Script Test scripts are used to drive an automated test tool. The scripts provide input to the unit under test and record the output. The testers employ a variety of languages to express test scripts. An important advantage of test script-based tools is that once the test script is debugged and verified, it can be rerun a large number of times easily and cheaply. However, debugging the test script to ensure its accuracy requires significant effort. Also, every subsequent change to the unit under test entails effort to identify impacted test scripts, modify, rerun and reconfirm them.

Random Input Test In this type of an automatic testing tool, test values are randomly generated to cover the input space of the unit under test. The outputs are ignored because analysing them would be extremely expensive. The goal is usually to crash the unit under test and not to check if the produced results are correct. An advantage of random input testing tools is that it is relatively easy. This approach however can be the most cost-effective for finding some types of defects. However, random input testing is a very limited form of testing. It finds only the defects that crash the unit under test and not the majority of defects that do not crash the system but simply produce incorrect results.

Model-based Test A model is a simplified representation of program. There can be several types of models of a program. These models can either be structural models or behavioural models. Examples of behavioral models are state models and activity models. A state model-based testing generates tests that adequately cover the state space described by the model.

Estimation of latent errors

Earlier, we noted the problem of estimating the number of errors left in an application under test. At the start of testing, there is one relatively straightforward way of estimating the number of errors in code. Simply put, bigger programs are likely to have more errors. If you have collected error data from past projects, you can arrive at the historic number of errors per 1000 lines of code. This can then be used to arrive at a reasonable estimate of the number of errors likely to be found in a new system development of a known size.

This estimate could be confirmed during the actual testing. One suggestion is that known errors can be seeded in the software. This seeding could be done by having one or more people doing a desk-check of code, but then leaving any errors found in the code. Say 10 such errors are found. Then suppose that after the first set of tests 30 errors were found of which six were known errors, that is 60% of the seeded errors. This suggests that around 40% of the errors have still to be detected, that is 20 errors (of which four are already known). The method of calculating an estimate of the errors in the software is

(total errors found)/(seeded errors found) × (total number of seeded errors)

Tom Gilb (1977)
Software Metrics
Winthrop Publishers,
Cambridge, MA.

You may be thinking that deliberately putting (or leaving) known errors in software is a bit sneaky. It might be more acceptable to use a slightly different approach originally suggested by Tom Gilb. Two different reviewers, or groups of reviewers, are asked to inspect or test the same code. They must be completely independent of one another. Three counts are collected:

- $n1$, the number of valid errors found by A
- $n2$, the number of valid errors found by B
- $n12$, the number of cases where the same error is found by both A and B.

The smaller the proportion of errors found by both A and B compared to those found by only one reviewer, the larger the total number of errors likely to be in the software. An estimate of the total number of errors (n) can be calculated by the formula:

$$n = (n1 \times n2)/n12$$

For example, A finds 30 errors and B finds 20 errors of which 15 are common to both A and B. The estimated total number of errors would be:

$$(30 \times 20)/15 = 40$$

13.13 Software Reliability

We have pointed out in Section 13.6 that reliability is an important quality attribute. In this section, we discuss some basic concepts in software reliability engineering. The reliability of a software product essentially denotes its *trustworthiness* or *dependability*. Alternatively, the reliability of a software product can be defined as the probability of its working *correctly* over a given period of time.

Intuitively, it is obvious that a software product having a large number of defects is unreliable. It is also very reasonable to assume that the reliability of a system would improve if the number of defects in it is reduced. However, it is very difficult to formulate a mathematical expression to characterize the reliability of a system in terms of the number of latent defects in it. To get an insight into this issue, consider the following. Removing errors from those parts of a software product that are infrequently executed makes little difference to the reliability of the product. It has been experimentally observed by analysing the behaviour of a large number of programs that 90% of the execution time of a typical program is spent in executing only 10% of the instructions in the program. Therefore, in addition to the number of defects, the specific point in the program (core or non-core part) where the bug is located also matters. Further, reliability is observer dependent, in the sense that it depends on the relative frequency with which different users invoke the functionalities of a system. It is possible that because of different usage patterns of the available functionalities of software, a bug which frequently shows up for one user, may not show up at all for another user, or may show up very infrequently.

Reliability of a software product usually keeps on improving with time during the testing and operational phases as defects are identified and repaired. In this context, the growth of reliability over the testing and operational phases can be modelled using a mathematical expression called Reliability Growth Model (RGM). Thus, RGM models show how the reliability of a software product improves as failures are reported and bugs are corrected. A large number of RGMs have been proposed by researchers based on various failure and bug repair patterns. A few popular reliability growth models are Jelinski–Moranda model, Littlewood–Verall's model, and Goel–Okutomo's model. For a given development project, a suitable RGM can be used to predict when (or if at all) a particular level of reliability is likely to be attained. Thus, reliability growth modelling can be used to determine when during the testing phase a given reliability level will be attained, so that testing can be stopped.

Based on the above discussions, we can summarize the main reasons that make software reliability more difficult to measure than hardware reliability:

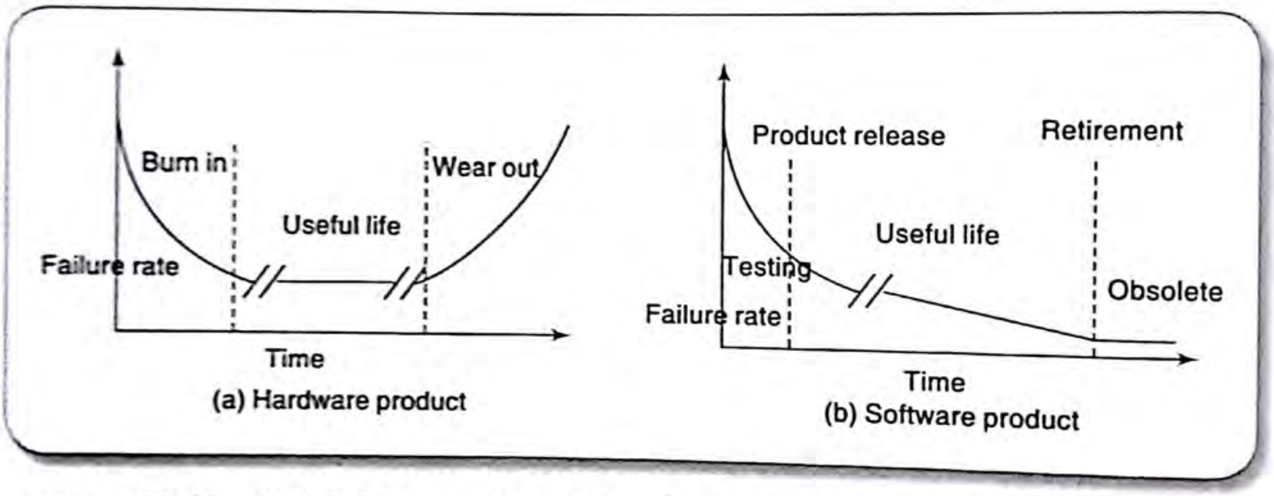
- The reliability improvement due to fixing a single bug depends on where the bug is located in the code.
- The perceived reliability of a software product is observer-dependent.
- The reliability of a product keeps changing as errors are detected and fixed.

Hardware *versus* Software Reliability

A fundamental issue that sets the reliability study of software apart from hardware reliability study is the difference between their failure patterns. Hardware components fail due to very different reasons as compared to failure of software components. Hardware components fail mostly due to wear and tear, whereas software components fail due to presence of bugs.

As an example of a hardware, consider an electronic circuit. In this circuit, a failure may occur as a logic gate may be stuck at 1 or 0, or a resistor might short circuit. To fix a hardware fault, one has to either replace or repair the failed part. In contrast, a software product would continue to fail until the error is tracked down and either the design or the code is changed to fix the bug. For this reason, when a hardware part is repaired its reliability would be maintained at the level that existed before the failure occurred; whereas when a software failure is repaired, the reliability may either increase or decrease (reliability may decrease if a bug fix introduces new errors). To put this fact in a different perspective, hardware reliability study is concerned with stability (e.g. the inter-failure times remain constant). On the other hand, the aim of software reliability study would be reliability growth (i.e. increase in inter-failure times).

A comparison of the changes in failure rate over the product life time for a typical hardware product as well as a software product is sketched in Figure 13.11. Observe that the plot of change of reliability with time for a hardware component [Figure 13.11(a)] appears like a 'bath tub'. As shown in Figure 13.11(a), for a hardware system the failure rate is initially high, but decreases as the faulty components are identified and are either repaired or replaced.



(a) Hardware product

(b) Software product

Figure 13.11 Reliability growth with time for hardware and software products

A hardware system enters its useful life, where the rate of failure is almost constant. After some time (called product life time) the major components wear out, and the failure rate increases. The initial failures are usually covered through manufacturer's warranty. A corollary of this observation (though a digression from our topic of discussion) is that it may be unwise to buy a product (even at a good discount to its face value) towards the end of its life time, That is, one need not feel happy to buy a 10-year-old car at one-tenth of the price of a new car, since it would be near the rising edge of the bath tub curve, and one would have to spend unduly large time, effort and money on repairing and end up as loser.

In contrast to the hardware products, software products show the highest failure rate just after purchase and installation [see the initial portion of the plot in Figure 13.11(b)]. As the system is used, more and more errors are identified and removed resulting in reduced failure rate. This error removal continues at a slower pace during the useful life of the product. As the software becomes obsolete no more error correction occurs and the failure rate remains unchanged.

Reliability Metrics

The reliability requirements for different categories of software products may be different. For this reason, it is necessary that the level of reliability required for a software product should be specified in the SRS (software requirements specification) document. In order to be able to do this, we need some metrics to quantitatively express the reliability of a software product.

A good reliability measure should be observer-independent, so that different people can agree on the degree of reliability a system has. However, in practice, it is very difficult to formulate a metric using which precise reliability measurement would be possible. In the absence of such measures, we discuss six metrics that correlate with reliability as follows.

Rate of occurrence of failure (ROCOF)

ROCOF measures the frequency of occurrence of failures. ROCOF measure of a software product can be obtained by observing the behaviour of a software product in operation over a specified time interval and then calculating the ROCOF value as the ratio of the total number of failures observed and the duration of observation.

However, many software products do not run continuously (unlike a car or a mixer), but deliver certain service when a demand is placed on them. For example, a library software is idle until a book issue request is made. Therefore, for a typical software product such as a pay-roll software, applicability of ROCOF is limited.

Mean Time to Failure (MTTF)

MTTF is the time between two successive failures, averaged over a large number of failures. To measure MTTF, we can record the failure data for n failures. Let the failures occur at the time instants t_1, t_2, ... and t_n. Then, MTTF can be calculated as $\sum t_i/n$. It is important to note that only run time is considered in the time measurements. That is, the time for which the system is down to fix the error, the boot time, etc., are not taken into account in the time measurements and the clock is stopped at these times.

Mean Time to Repair (MTTR)

Once failure occurs, sometime is required to fix the error. MTTR measures the average time it takes to track the errors causing the failure and to fix them.

Mean Time between Failure (MTBF)

The MTTF and MTTR metrics can be combined to get the MTBF metric: MTBF = MTTF + MTTR. Thus, MTBF of 300 hours indicates that once a failure occurs, the next failure is expected after 300 hours. In this case, the time measurements are real time and not the execution time as in MTTF.

Probability of Failure on Demand (POFOD)

Unlike the other metrics discussed, this metric does not explicitly involve time measurements. POFOD measures the likelihood of the system failing when a service request is made. For example, a POFOD of 0.001 would mean that 1 out of every 1000 service requests would result in a failure. We have already mentioned that the reliability of a software product should be determined through specific service invocations, rather than making the software run continuously. Thus, POFOD metric is very appropriate for software products that are not required to run continuously.

Availability. Availability of a system is a measure of how likely would the system be available for use over a given period of time. This metric not only considers the number of failures occurring during a time interval but also takes into account the repair time (down time) of a system when a failure occurs. This metric is important for systems such as telecommunication systems, operating systems and embedded controllers, etc. which are supposed to be never down and where repair and restart time are significant and loss of service during that time cannot be overlooked.

Failures which are transient and whose consequences are not serious are in practice of little concern in the operational use of a software product. These types of failures can at best be minor irritants. On the other hand, more severe types of failures may render the system totally unusable. In order to estimate the reliability of a software product more accurately, it is necessary to classify various types of failures. In the following, we give a simple classification of software failures into different types.

Transient. Transient failures occur only for certain input values while invoking a function of the system.

Permanent. Permanent failures occur for all input values while invoking a function of the system.

Recoverable. When a recoverable failure occurs, the system can recover without having to shut down and restart the system (with or without operator intervention).

Unrecoverable. In unrecoverable failures, the system may need to be restarted.

Cosmetic. These classes of failures cause only minor irritations, and do not lead to incorrect results. An example of a cosmetic failure is the situation where the mouse button has to be clicked twice instead of once to invoke a given function through the graphical user interface.

Reliability Growth Modelling

A reliability growth model is a mathematical model of how software reliability improves as errors are detected and repaired.

A reliability growth model can be used to predict when (or if at all) a particular level of reliability is likely to be attained. Thus, reliability growth modelling can be used to determine when to stop testing to attain a given reliability level.

Jelinski and Moranda Model

The simplest reliability growth model is a step function model where it is assumed that the reliability increases by a constant increment each time an error is detected and repaired. Therefore, perfect error fixing is implicit in this model. Another implicit assumption in this model is that all errors contribute equally to reliability growth (reflected in equal step size). Both the assumptions are unrealistic since different errors contribute differently to reliability growth and also the error fixed may not be perfect. Typical reliability growth predicted using this model has been shown in

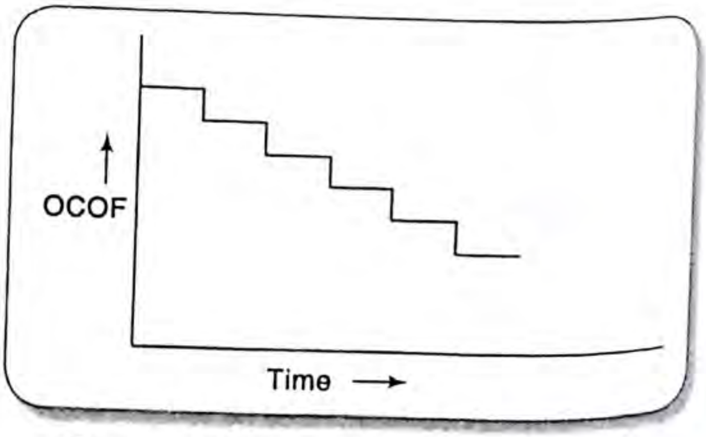


FIGURE 13.12 Jelinski–Moranda model

Figure 13.12. The instantaneous failure rate (or the hazard rate) in this model is given by $Z(t) = K(N - i)$; where K is a constant, N is the total number of errors in the program, and t is any time between the ith and $(i + 1)$th failure.

Littlewood and Verall's Model

This model allows for negative reliability growth to reflect the fact that when a repair is carried out, it may introduce additional errors. It also models the fact that as errors are repaired, the average improvement to the product reliability per repair decreases. It treats an error's contribution to reliability improvement to be an independent random variable having Gamma distribution. This distribution models the fact that error corrections with large contributions to reliability growth are removed first. This represents diminishing return as the test continues.

Goel–Okutomo Model

In this model, it is assumed that the execution times between the failures are exponentially distributed. The cumulative number of failures at any time can therefore be given in terms of $\mu(t)$, the expected value of failures between time t and time $t + \Delta t$. It is assumed that it follows a non-homogeneous Poisson process (NHPP). That is, the expected number of error occurrences for any time t to $t+\Delta t$ is proportional to the expected number of undetected errors at time t. Once a failure has been detected, it is assumed that the error correction is perfect and immediate. The number of failures over time is given in Figure 13.13. The number of failures at time t can be given by, $\mu(t) = N(1 - e^{-bt})$, where N = Expected total number of defects in the code and b is the rate at which the failure rate decreases.

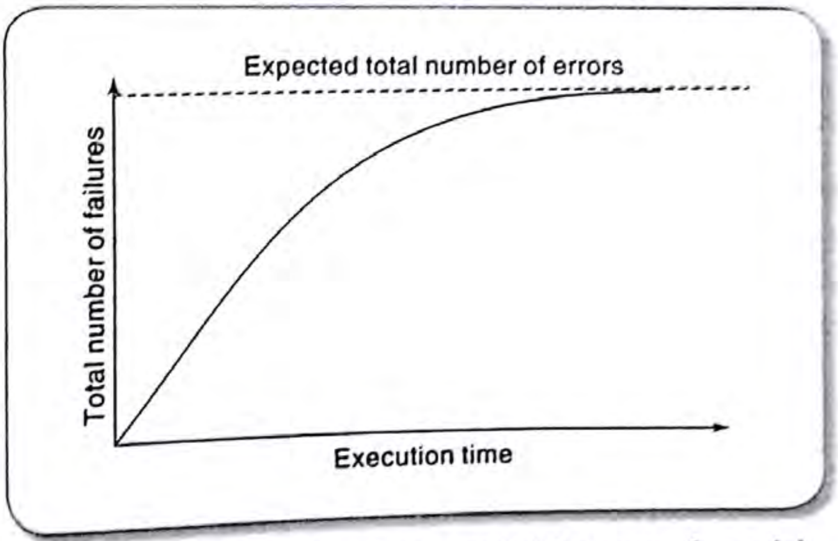


FIGURE 13.13 Goel–Okutomo reliability growth model

13.14 Quality Plans

Some organizations produce *quality plans* for each project. These show how the standard quality procedures and standards laid down in an organization's *quality manual* will actually be applied to the project. If an approach to planning such as Step Wise has been followed, quality-related activities and requirements will have been identified by the main planning process with no need for a separate quality plan. However, where software is being produced for an external client, the client's quality assurance staff might require that a quality plan be produced to ensure the quality of the delivered products. A quality plan can be seen as a checklist that all quality issues have been dealt with by the planning process. Thus, most of the content will be references to other documents.

A quality plan might have entries for:

This contents list is based on a draft IEEE standard for software quality assurance plans.

- Purpose – scope of plan
- List of references to other documents
- Management arrangements, including organization, tasks and responsibilities
- Documentation to be produced
- Standards, practices and conventions
- Reviews and audits
- Testing
- Problem reporting and corrective action
- Tools, techniques and methodologies
- Code, media and supplier control
- Records collection, maintenance and retention
- Training
- Risk management – the methods of risk management that are to be used

Conclusion

Important points to remember about software quality include the following.

- Quality by itself is a vague concept and practical quality requirements have to be carefully defined.
- There have to be practical ways of testing for the relative presence or absence of quality.
- Most of the qualities that are apparent to the users of software can only be tested for when the system is completed.
- Therefore ways are needed of checking during development what the quality of the final system is likely to be.
- Some quality-enhancing techniques concentrate on testing the products of the development process, while others try to evaluate the quality of the development processes used.

Further Exercises

1. An organization is contemplating the purchase of a project planning software tool, such as MS Project, and has decided to draw up quality specifications for the package. The features that they are particularly concerned with are:
   - Setting up details of new projects
   - Allocating resources to project tasks, taking account of the need for resource smoothing
   - Updating the project details with information about actual tasks completed

- Effective presentation of plans

Draw up quality specifications in respect of the qualities of:

- Usability
- Reliability
- Recoverability

2. The following is an excerpt from a report generated from a help-desk logging system.

Module	Date fault reported	Fault corrected	Effort (hours)
AA247	1.4.2004	2.4.2004	5
AA247	10.4.2004	5.5.2004	4
AA247	12.4.2004	5.5.2004	3
AA247	6.5.2004	7.5.2004	2

Assess the maintainability of module AA247 from the point of view of:

- User management
- Developer management

3. Discuss how meaningful the following measurements are.
   (a) The number of error messages produced on the first compilation of a program.
   (b) The average effort to implement changes requested by users to a system.
   (c) The percentage of lines in program listings that are comments.
   (d) The number of pages in a requirements document.
4. How might you measure the effectiveness of a user manual for a software package? Consider both the measurements that might be applicable and the procedures by which the measurements might be taken.
5. What might the entry, implementation and exit requirements be for the process *design program structure*?
6. Identify a task that you do as part of your everyday work. For that task identify entry, process and exit requirements.
7. What BS EN ISO 9001 requirements have a bearing on the need for an effective configuration management system?
8. In a software development organization, identify the persons responsible for carrying out the quality assurance activities. Explain the principal tasks they perform to meet this responsibility.
9. Suppose an organization mentions in its job advertisement that it has been assessed at level 3 of SEI CMM. What can you infer about the current quality practices at the organization? What does this organization have to do to reach SEI CMM level 4?
10. Suppose as the president of a company, you have the choice to either go for ISO 9000 based quality model or SEI CMM based model, which one would you prefer? Give the reasons for your choice.
11. In a software development organization whose responsibility is it to ensure that the products are of high quality? Explain the principal tasks they perform to meet this responsibility.

12. What do you understand by repeatable software development? Organizations assessed at which level of SEI CMM maturity achieve repeatable software development?

13. What do you understand by Key Process Area (KPA), in the context of SEI CMM? Would there be any problem if an organization tries to implement higher level SEI CMM KPAs before achieving lower level KPAs? Justify your answer using a suitable example.

14. What do you understand by the six sigma quality initiative? To which category of industries is it applicable? Explain the six sigma technique with respect to its goal, the procedure followed, and the outcome expected.

15. What is the difference between process and product metrics? Give two examples of each. How does computation of process and product metrics help in developing quality products?

16. Identify the persons responsible for carrying out testing in a software development organization. Explain the principal tasks they perform.

17. Identify the factors which make the measurement of software reliability a much harder problem than the measurement of hardware reliability.

18. Through a simple plot, explain how the reliability of a software product changes over its lifetime.

19. Draw the reliability change for a hardware product over its life time and explain why the two plots look so different?

20. What do you understand by a reliability growth model? How is reliability growth modelling useful?

21. Suppose an organization mentions in its job advertisement that it has been assessed at level 3 of SEI CMM, what can you infer about the current quality practices at the organization? What does this organization have to do to reach SEI CMM level 4?

22. Suppose as the president of a company, you have the choice to either go for ISO 9000-based quality model or SEI CMM-based model, which one would you prefer? Give the reasoning behind your choice.

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

    (i) Which of the following is a practical use of reliability growth modelling?

    (a) Determine the operational life of an application software.

    (b) Determine when to stop testing.

    (c) Incorporate reliability information while designing.

    (d) Incorporate reliability growth information in the code.

    (ii) Which one of the following can be considered to be a software defect?

    (a) A mistake made by a team member during any development activity

    (b) A change that the team needs to make based on the finding in code review

    (c) A configuration management plan that is too elaborate

    (d) A change request that has been launched by the customer

    (iii) Which one of the following is true of formal reviews?

    (a) Identification of faults without suggesting any solutions

    (b) Identification of faults and fixing responsibility without suggesting any solutions

    (c) Identification of faults, fixing responsibility and suggesting possible solution

    (d) Identification of faults and suggest possible solutions

(iv) Which one of the following is the basic focus of the modern quality assurance paradigms?

(a) Process assurance

(b) Product assurance

(c) Thorough testing

(d) Thorough testing and rejection of bad products

(v) Which one of the following ISO quality assurance standard applies to software development organizations?

(a) ISO 9000 (b) ISO 9001

(c) ISO 9002 (d) ISO 9003

(vi) A software organization has been assessed at SEI CMM Level 4. Which one of the following does the organization need to set up, as one of the KPAs to achieve Level 5?

(a) Defect detection (b) Defect prevention

(c) Defect isolation (d) Defect seeding

(vii) Which one of the following can be considered as the focus of 'quality control'?

(a) All development work products are delivered on time and under budget

(b) The development process is completely documented and adhered to during development

(c) The performance of the development work products are measured

(d) All development work products are thoroughly tested before delivery to the customer

(viii) After a software is maintained, which one of the following types of testing involves repeating execution of tests that were already performed to ensure that the code modifications that were done during maintenance have not introduced faults into previously operational software?

(a) Beta testing

(b) Functional testing

(c) Bottom-up testing

(d) Regression testing

(ix) Which of the following is indicated by the SEI CMM repeatable software development:

(a) Success in development of a software can be repeated.

(b) Success in development of a software can be repeated in related software development projects.

(c) Success in development of a software can be repeated in all the software development projects that the organization might undertake.

(d) When the same development team is chosen to develop another software, they can repeat their success.

(x) Which one of the following is a requirement for ISO 9001 certification?

(a) Demonstrate achievement of quality requirements by the developed software.

(b) Submit the reliability assessment of the developed software.

(c) Document the process being followed.

(d) Demonstrate that through stringent design and coding standards, testing is made redundant.

(xi) In CMMI, which one of the following is the name of the maturity level 5?

(a) Six Sigma (b) Optimized

(c) Statistical (d) Optimizing

(xii) Which one of the following statements is not an objective of software verification?

(a) Ensuring that the software development steps are carried out correctly

(b) Ensuring that the correct software has been developed

(c) Achieving phase containment of errors

(d) Ensuring that the outputs produced at a development stage conform to the outputs of the previous phase

(xiii) During which one of the following phases of the V model of software development are the integration test cases designed?

(a) Requirements specification

(b) High-level design

(c) Detailed design

(d) Coding

(xiv) Which one of the following can be said about the reliability of a typical software during its life time?

(a) Initially increases, but later decreases

(b) Initially decreases, but later increases

(c) Increasing trend throughout the life cycle

(d) Decreasing trend throughout the life cycle

(xv) The purpose of error seeding is which one of the following?

(a) Determine the origin of the bugs.

(b) Plant Trojans.

(c) Determine the number of latent bugs.

(d) Plant bugs in the code to check the efficacy of maintenance.

(xvi) Suppose in order to estimate the number of latent errors in a program, you seed it with 100 errors of different kinds. After testing the software using its full test suite, you discover only 80 of the introduced errors. You discover 16 other errors also. Estimate the number of latent errors in the software.

(a) 4 (b) 8

(c) 16 (d) 20

(xvii) Which one of the following statements is not true about the typical usage of a quality model?

(a) It forms the basis for specifying the quality requirements for a software product.

(b) It forms the basis for quantitatively measuring the quality of a software product.

(c) It helps to improve the quality of a software product by improving the attributes constituting the quality model.

(d) The quality assurance activities for a software product are defined based on the characteristics of software products that constitute the quality model.

(xviii) Which one of the following is not a valid justification for using automated tools for carrying out regression testing of a software product?

(a) Regression test cases are executed frequently

(b) Regression test cases are essentially test cases that have already been executed once

(c) At present highly effective capture and replay type of automated testing tools are available both from open source repositories as well as from commercial offerings; however, effective test case generation tools are yet to become available

(d) Some of the original test cases may require maintenance after a code change

(xix) Which one of the following is not a factor contributing to the increased difficulty of software reliability measurement, as compared to hardware reliability measurement?

(a) The reliability improvement due to fixing a single bug depends on where the bug is located in the code

(b) The perceived reliability of a software product is observer-dependent

(c) The reliability of a software product keeps changing as errors are detected and fixed

(d) Software is invisible in contrast to hardware, though the effect of execution of software can be observed

14 Project Closeout

Learning Objectives

- Understand the need to carry out project closure
- Discuss the problems that may arise if proper project closure is not carried out
- Assess the activities needed to be performed to close a project

14.1 Introduction

All projects are by definition temporary endeavours. Therefore, every project must come to an end sometime or other. It is the responsibility of the project manager to decide the appropriate time to close a project. Once it is decided to close a project, the project manager needs to ensure that the project is properly closed by carrying out the project closure activities and this forms the last phase of the project management life cycle. Unless project closure activities are properly carried out and that too at an appropriate time, several problems may arise. We discuss these problems, later in this chapter. We also discuss various project closeout activities.

Project closeout activities can broadly be classified into administrative closure and contract closure activities. The contract closure activities involve verifying that all the terms of the contract with the customer as well as various subcontractors are met and are satisfactorily closed. It may be mentioned that in many projects, especially in the large ones, subcontractors are engaged to either fully perform or assist with various project work such as hardware maintenance, development or testing of certain components and providing specific consultancy. With respect to the contract closure with the subcontractors, it needs to be verified whether they have performed as per the requirements and the terms of the contract are met. On the other hand, administrative closure activities consist of ensuring that all of the project deliverables are archived and the project know-how are transferred to other personnel and are properly documented and archived. In case of a multi-phase project, the various closeout activities may have to be carried out at the end of every phase.

In this chapter, we first discuss the reasons for project closure and a few other issues associated with project closure. Subsequently, we discuss a closeout process in terms of the activities that need to be undertaken for proper project closure.

14.2 Reasons for Project Closure

There are two main reasons for closing a project. The most common reason for project closure is that all the project goals have been successfully accomplished. The project goals are considered to have been accomplished when all the project deliverables have been handed over to the customers, and the customers have confirmed that all project objectives have been met. The second reason for closing a project is that it has been found that the project is unlikely to achieve its stated objectives and has to be prematurely terminated. When it becomes evident that for a certain project, the project objectives cannot be satisfactorily met, it often makes sense to reach a negotiated project closure. According to a report, about a third of all projects are cancelled during the development phases. In any case, a negotiated closure where all concerned parties agree to the terms of a modified contract is preferred over a unilateral project closure. It needs considerable wisdom to determine when it is desirable to terminate a project, and then to carry out the closure. Otherwise, the project can become only a drag on the resources without achieving anything tangible.

There can be many reasons for prematurely terminating a project. A few important reasons for project termination are the following:

- *Lack of resources:* A project may need to be terminated when there is a severe resource shortfall. Resource shortfall for a project may occur due to several reasons. As an example, consider that in a certain company, there is a change in the top management of the company. The new management may show a lack of commitment to the projects initiated by the previous management. This may result in inadequate budget provisioning for a project. A few other reasons for resource shortfall include change of priority of the company due to business reasons, severe financial strain on the company and bankruptcy of the company.
- *Changed business need of the customer:* The business interests or business process of the customer may change after the initiation of the project. This may make the project outcome not useful in the changed situation. For example, suppose a customer after initiating a project to develop an inventory management software decides to outsource its entire inventory management activities to a third party, then the project outcome would be of little use to the company.
- *The perceived benefits accruing from the project no longer remain valid:* The expected quantum of benefits of developing a software might get altered after the start of the project. This may occur on account of certain events that may arise during the project execution. As an example, consider a project that has been initiated to develop a novel and unique software product. Now suppose during the project's execution, some competing products become available in the market. This may make the profit projections made during the feasibility study stage to become invalid and may necessitate project termination to reduce losses.
- *Changes to the regulatory policies:* Many times, external factors such as changes to the government's regulatory policies can have adverse impact on a project and may require the project to be terminated. For example, a company initiating project to develop a satellite telephone system may have to abandon the project if the regulatory policy formulated by the government is changed to disallow any satellite communication-based product in the country.

- *Key technologies used in the project becoming obsolete during project execution:* Suppose a software is being developed based on a few technologies at its core. Now consider that these technologies get outdated before the project completes. Then, there may be reason for the project to be terminated. As an example of such a situation, suppose a software to provide faster communication over a slower communication protocol may have to be abandoned, if a new version of the protocol gets released that by itself supports sufficiently fast communication.
- *Risks becoming unacceptably high:* Even when a project might have been initiated after carrying out thorough risk analysis, it may be found out after the start of the project that the risks to the project that could not be foreseen have become so high that continuation of the project would have serious adverse impact on the company such as unsettling its financial soundness, inviting negative publicity or posing health and safety hazards. In such situations, premature project termination may be recommended.

Even though there may be compelling reasons to prematurely terminate a project, before premature termination of a project, the company should carefully consider the various contractual and ethical issues. For example, when the personnel recruited for the project are not deployable in any other project, there may be ethical issues to be addressed before termination of the project can be contemplated. Another example could be that even when it becomes known that the customer of a project is facing acute financial hardship and is unlikely to pay for the project, it may first have to be examined whether termination of the project is possible under the terms of the contract. Even if the terms of the contract permit termination of the project, the impact of the project termination on the developing organization's reputation and client relationships must be considered.

Why are projects not properly closed?

There are many real-life instances of project closures getting unduly delayed in several companies, and even project closure activities getting altogether skipped. In the following, we identify a few common reasons as to why project closure may be delayed or projects may not be properly closed.

- *Lack of interest by the project team:* Since project closing activities are usually rather mundane and require little creativity, the project team may lose interest to participate in these activities. This may especially be the case, if the project team members have already started working on other projects. There can also be reluctance on the part of the project team to actively participate in project termination activities for reasons such as apprehension about their redeployment, once the project gets closed.
- *Underestimation of how fast know-how can get lost and how much implicit knowledge exists with the team members:* Usually team members working on a project build up significant knowledge on the project and the associated technologies. One of the important outcomes of proper project termination is transfer of know-how to other employees of the company, documentation and archival of the knowledge pertaining to the project. However, it is often underestimated by the stakeholders as to how much knowledge pertaining to the project exists with the team members and how fast can the knowledge decay and get lost. Unless the knowledge with the team members is appropriately transferred to others or is archived, it may be lost forever. If the project manager and the other stakeholders overlook this, they may get busy with other activities and accord low priority to project closure.
- *Emotional factors:* After working for some time on a project, it may be possible that the team members and the project manager may become emotionally attached to the project and would want the project to continue as long as possible.
- *Indecision regarding project closure:* Often some tough decisions might have to be taken by the project manager and the senior management regarding projects facing premature termination. At times, they may delay taking the required decisions, thereby, letting the project to run longer than necessary.

Problems of improper project closure

When projects are either not closed properly at the appropriate time or are not closed at all, several problems can arise. Some of the important problems that may be faced include the following:

- *Time and cost overrun:* If project termination is delayed, the project as a cost centre runs up expenditure in the meanwhile, leading to cost overrun. Also the project duration appears to be longer than what it should actually be.
- *Locking up valuable human and other resources:* When there is delay in closing a project, redeployment of project personnel and other resources gets delayed. As a result, valuable resources and manpower that could have been gainfully utilized in other projects gets wasted.
- *Stress on the project personnel:* The project personnel often lose out on experience that they could have gathered on other projects on which they might have been deployed, had the project closeout occurred at the appropriate time. The feeling of not doing anything challenging, missing out on the learning opportunities, and the impact of these on their future career can be stressful for the team members.

Issues associated with project termination

The problems with project termination are two-fold. One is emotional and the other intellectual. The emotional issues can concern both the team members and the clients. The emotional issues that the team members may experience include the uncertainties and apprehensions concerning their assignment to the next project. This may manifest as general loss of interest in work and lack of enthusiasm to perform the remaining project work. There can also be diversion of attention. The team members may pay more attention to issues such as getting reassigned to a project of their choice and the project work can take a back seat. On the client side, there can be a sudden change in attitude and loss of interest in the project. The client may even change the personnel dealing with the project, and thereby causing further disconnect and difficulties in project closure.

The intellectual project termination problems may include handling some sensitive issues. When a project is to be prematurely terminated, the terms of contract and the list of deliverables need to be renegotiated. Also, even when some deliverables and tasks that are considered to be not necessary any more, however, before dropping these it needs to be verified with the client. If any subcontractors have been deployed in the project, then the outstanding commitments with the subcontractors need to be renegotiated. Also, the closure decision has to be effectively communicated to all stakeholders.

14.3 Project Closure Process

Effective project closure requires certain sequence of steps to be carried out. We discuss these steps in the following. However, before the project closure process can be initiated, the decision regarding closing the project needs to have been taken in consultation with the top management. For successful projects, it is expected that the requisite technical documentation, user manuals, testing and user training should have been completed and it should have been ensured that the project outputs are usable by the customer without any difficulty. If outside vendors have been subcontracted in the project, then it has to be ensured that all work performed by them and all the deliverables given by them are acceptable. It also needs to be ensured that administrative activities such as settling their claims and archiving their deliverables for future use have been accomplished.

For a project facing premature termination, the project manager in consultation with the top management and the customers has to take the decision as to whether to terminate the project immediately or to keep it under watch for some more time. For both normal closure and premature termination categories of projects, it has to be ensured that there are no further obligations, and the project closure activities can proceed to achieve taking stock of the accomplishments and the shortfalls, transfer of know-how and documentation and archival of knowledge. The following steps form a typical project closure process:

- Getting client acceptance
- Archiving project deliverables
- Preserving project know-how
- Performing a financial closure
- Performing postImplementation project review
- Preparing postimplementation review report
- Releasing staff

In the following, we elaborate the above steps of the project closure process.

Getting client acceptance

The mechanism for client acceptance varies widely across different types of projects. When the client is a sister organization, or another department in the same organization, usually no formal record for acceptance of the project deliverables is required. In this case, the acceptance tends to be informal and gets conveyed in meetings. However, when the project client is an external organization, and especially when the project was awarded through a formal contract awarding process, a formal procedure for accepting the project deliverables is needed. In this case, the client approval is obtained after a formal acceptance testing by the client and a written acceptance of the project deliverables is required. In case of premature termination, negotiation with the client has to be made regarding the deliverables to be included in the reduced scope of the project. The client acceptance of these reduced set of deliverables is to be obtained.

Archiving project deliverables

The project documents are usually archived electronically, so that these can be easily retrieved whenever required in the future. For example, the documents might have to be retrieved when the company undertakes maintenance of the delivered software or when a similar software product needs to be developed for different clients. The project archive should be properly documented, so that anyone trying to use the archive in the future does not face any problem. This document should at least contain information regarding the description of the documents archived, the application used to create the archive, the locations where these are stored and the persons to contact for further information.

14.4 Performing a Financial Closure

Every project is usually undertaken based on some financial grant. This grant can have different components such as capital and contingency budgets. All these components have to be reconciled and book transfer of any capital goods that were purchased should be carried out. Also, it has to be ensured that all the subcontractor payments are complete and have been reconciled.

Postimplementation project review

The goal of a postimplementation project review (sometimes called post-mortem) is to perform a critical analysis of the project in order to learn and improve, and avoid repeating the same mistakes in future projects.

By analysing past mistakes the project teams can learn to do better by improving their methods and practices. Not only the successful ones, even the unsuccessful projects implicitly hold a lot of information that can be identified, documented and disseminated to benefit other projects. The typical learning from the projects centre around what initiatives worked well, what did not work and what we could have done better. Over the years, several guidelines regarding how to conduct postimplementation project review effectively, so that maximal learning is achieved in the minimal time has emerged. In the following, we discuss the steps of conducting a postimplementation project review.

- Conduct project survey
- Collect objective information
- Hold a debriefing meeting
- Prepare postimplementation review report
- Publish the report

Project survey: The objective of the project survey is to collect various types of information pertaining to the project, without compromising the confidentiality of the respondents. An electronic survey is usually very effective. The information is collected through a set of carefully designed questionnaire that can bring out the important process and management issues that have a strong bearing on the success or failure of the project. The following important points should be included in the questionnaire.

- *Project performance:* The set of questions pertaining to this should elicit qualitative comparison of project achievements with the plan.
- *Administrative performance:* The questions pertaining to this item are an evaluation of the administrative practices followed.
- *Organizational structure:* These pertain to any recommendations for changes to the organizational and team structure.
- *Team performance:* These pertain to the highlights of team performance and the obstacles faced
- *Techniques of project management:* These get the feedback regarding the methods used for estimating, planning, monitoring and control.
- *Risk management:* How effective was the risk management practices that were followed.

Summarized feedback would be used during the debriefing meeting as a starting point for identifying lessons learned and best practices to use in future projects. It will also be included in the postimplementation report created at the end of project closeout process.

Collection of objective information A critical aspect of the post-mortem review is to collect various project metrics. Real data helps to focus discussions on most crucial issues during the post-mortem review. The different types of metrics that are collected include the cost metrics, schedule metrics and quality metrics.

A quantitative assessment of various parameters of a project allows evaluation of the project in more precise terms. Also quantitative measures allow comparison of different projects objectively and can help to identify the techniques and new initiatives that worked better and the ones that did not work well. The historical data can be used to fine tune the coefficients of the project estimation expressions being used. Besides contributing to the historical data of a company, these metrics can be used to determine any shortfall in the techniques used and can guide in improving the techniques. In the following we discuss a few important metrics.

Estimated SLOC versus actual SLOC: SLOC is a fundamental project parameter based on which other important parameters used for project planning such as effort and duration are estimated. The variations of the estimated SLOC and the actual SLOC can be analysed and the size-estimation technique used can be fine-tuned and incorporated in carrying out the estimations for other projects.

Estimated SLOC and effort versus actual SLOC and effort: Effort is a vital project parameter based on which other project parameters such as duration and staffing level are estimated. Also, several project management activities such as project scheduling take place on the effort estimations. The variations between the estimated effort and the actual effort can be analysed to fine-tune the effort-estimation techniques being used.

Extent of rework due to requirement changes: The extent to which rework was needed due to requirement changes can be tracked and the factors which led to these can be identified.

Estimated project duration versus actual duration: The extent to which the estimated project duration differed from the actual duration can be determined and this result can be used to fine-tune the parameters of the estimation equation used.

Percentage of errors detected at each stage: Substantial savings in development effort and development cost can be achieved by detecting the bugs as soon as these are introduced in the different development stages. To achieve this, usually a series of bug detection filters are used throughout the development cycle. Examples of these bug detection filters are review, simulation and various strategies deployed for unit, integration and system testing. The extent to which these bug detection filters could detect the errors and the extent to which the errors were missed by the different bug detection filters are important data to be gathered. These data can be used to determine which bug detection techniques are more effective, so that more effort can be given and the ones which are not so effective and can be allocated less effort. Also, the effectiveness results can be used to fine-tune the bug detection techniques.

Debriefing meeting: A debriefing meeting is a preparatory meeting that helps to make the final project review meeting focused to the most relevant aspects. In this meeting, only the senior members of the team and a few select members participate. The summarized survey results and the collected objective data are circulated among the members beforehand and guide the topics covered during the meeting. After an initial briefing by the project manager, the discussions centre around various aspects of the completed project. The main objective of the meeting is to gain consensus on what was successful and what was not and identify the best practices and lessons learned. The debriefing meeting helps the project manager to obtain some direct feedback about the project.

Final project review: In addition to the project team, the project manager should consider inviting the project managers of related projects. It is usually a good idea for the project manager to distribute the summarized survey results to each participant in advance of the project assessment meeting, to allow them to come prepared to address the contents. This meeting usually addresses various issues arising out of project planning and tracking, the results of various development phases such as requirements analysis, specification, design and testing. It also discusses risk management, configuration management and quality management. Guided by the information collected in the previous steps, the project leaders determine the focus of the review discussions only on the relevant topics in various project activities. For example, if the collected data or the debriefing meeting data suggest schedule slippage, the discussions centre around how the schedule slippage could have been avoided. It should be remembered that fault finding or blaming individuals should be avoided.

14.5 Project Closeout Report

A project closeout report documents the important results obtained from various project closeout tasks. This report typically starts with a historical summary of the projects deliverables and baseline activities over the course of the project. It subsequently presents the summary of the survey results and the quantitative data gathering about the project's performance. Finally, the results of the final project review are presented. As part of this, the reasons for variances from the baseline plan, lessons learned, best practices and disposition of project resources are highlighted. It also contains recommendations for improvement to be used by other projects of similar size and scope. In summary, the project closeout report is intended to provide a concise evaluation of the project.

Result publication: The project leader summarizes the positive and negative findings as well as the prescriptions for improvement. The summary is published so that all the teams can refer to it and also the management can take initiative for any necessary corrections based on it.

The important findings of the postimplementation project review audit can be published in a document. The document can be used to disseminate the lessons learned and to work as a reference for similar future projects. A typical way in which the postimplementation project review report can be organized is as follows:

- Project description: Information about the project, to give context
- What worked well
- The factors that impeded the performance of the project
- A prescription for other projects to follow

Releasing Staff

This is the final step of the project closeout process. This is the last meeting before the project team members disburse to different projects. However, it is important that the project manager should have taken care that the team members have been assigned to proper projects according to their expertise and skill set. This meeting is also the ground for celebration before the team members disperse to different projects and for recognizing exceptional performance by the team members and recognizing the experience and proficiency gained by the team members.

Conclusion

Project closing is the last phase of a project, when the project outputs are handed over to the stakeholders, contractual agreements properly taken care of, and project records elicited and stored for future reference. Unless a project is closed at an appropriate time, it can lead to several problems. Therefore, it is imperative that a project manager needs to identify an opportune time to close a project and carry out the project closure activities. The project closure activities can broadly be divided into contract closure and administrative closure. The contract closure activities concern ensuring the terms of every contract is met. On the other hand, the main objectives of administrative closure are to preserve the project documents, transfer the project know-how and document and archive these as much as possible and to conduct the project review and to document the lessons learned.

Exercise

1. For each of the following questions, exactly one option is correct. Select the appropriate option.
   (i) Which one of the following most accurately states the main aim of a postproject review?
      (a) Validate overall progress to date against the budget and schedule.
      (b) Capture knowledge and document it for future usage.
      (c) Ensure all documentation is accepted and signed by the sponsor.
      (d) Establish that project benefits have been identified.
   (ii) Which one of the following is not an objective of the postimplementation review?
      (a) To review the qualitative and quantitative data about the project
      (b) To determine which practices worked well and which did not
      (c) To fix accountability for performance shortfalls
      (d) To suggest means to fine-tune various techniques used for project estimations
   (iii) In the process of postimplementation project review, which one of the following is not a reason for collecting the data concerning the errors detected at various stages of development?
      (a) To fine-tune the error-detection techniques used
      (b) To determine which techniques worked well, so that more effort can be allocated to these
      (c) To determine which techniques did not work well, so that less effort can be allocated to these
      (d) To fix accountability for the errors committed at each stage of development
2. Explain the common reasons for delay in project closure. What problems can arise if the project closure is delayed?
3. Explain the different reasons for which a project may need to be terminated.
4. Suppose you are a project manager and have undertaken to develop a customized package for automation of various activities of an educational institute. Briefly explain the project closure activities that you would follow.
5. Explain the important reasons as to why projects are either not closed at all or closure is overly delayed?