33

Project and Contract Management

P A Thompson BSc(Eng), MSc, CEng, FICE, MIWES
University of Manchester Institute of Science and Technology

Contents

33.1 Introduction

Management is concerned with the setting and achievement of realistic objectives for the project or contract. This will demand effort – it will not happen as a matter of course – and it will require the dedication and motivation of people. The provision and training of an adequate management team is therefore an essential prerequisite for a successful job for it is their drive and judgement, their ability to persuade and lead, which will ensure that the project objectives are achieved.

Managers of projects and contracts involving engineering construction will frequently encounter a mixture of technical, environmental, logistical and physical problems. The style of management required for such work will therefore differ in many ways from that required in the relatively static surroundings of line management in a factory. The temporary nature of the organization and the considerably greater element of uncertainty associated with construction projects will be particularly significant.

Uncertainty is the source of many of the problems encountered in construction work and will influence project appraisal, estimating, planning, the form of contract and the procedures for contractual measurement and valuation. Excessive uncertainty which leads to continuous or multiple changes to design will reduce productivity and will almost certainly affect adversely the morale of the workforce. It will also result in extra cost to both client and contractor. All parties involved in construction projects and contracts would therefore benefit greatly from reduction in uncertainty prior to financial commitment. Effort should be devoted to risk management and the person(s) ultimately responsible for the financial outcome should be appraised fully of the full risk spectrum before committing his or her organization to the project or contract.

When considering planning techniques, construction contracts and their valuation and other aspects of management in this chapter there may be a tendency for the reader to think of each system as a separate entity. He or she is advised to remember that the purpose of all these techniques and procedures is to help people make the judgements and decisions and to perform the administrative functions which are necessary for the successful accomplishment of the project or contract. The project or contract manager is primarily concerned with the direction and motivation of other human beings.

33.2 Project and contract organization

33.2.1 Introduction

There are many steps between the inception of a new capital project and its successful operation and maintenance. For efficient project management it is helpful to group these steps together into the following project stages, which are also identified in Figure 33.1:

APPRAISAL	Assess alternative strategies for meeting needs
	Establish technical and economic feasibility
	Derive the master plan
DEFINITION	Statement of project objectives
	Conceptual design and associated cost estimates
	Design review
	Arrange project funding
	Sanction
DESIGN	Detailed design
	Design review
	Contract strategy report and definition of contract packages
	Detailed cost estimates
	Procurement/tendering
	Contract award
CONSTRUCTION	Site construction
	Offsite fabrication and manufacture
	Installation
	Quality control

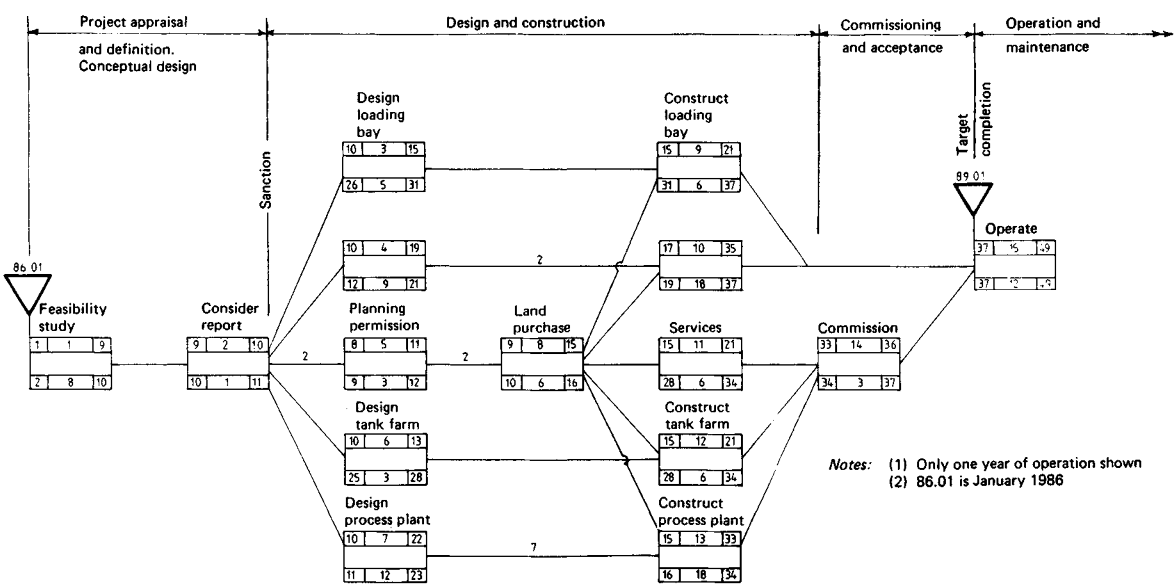

Figure 33.1 Precedence diagram for new manufacturing plant. This simple network will later be developed into a time-and-money model for appraisal of the project

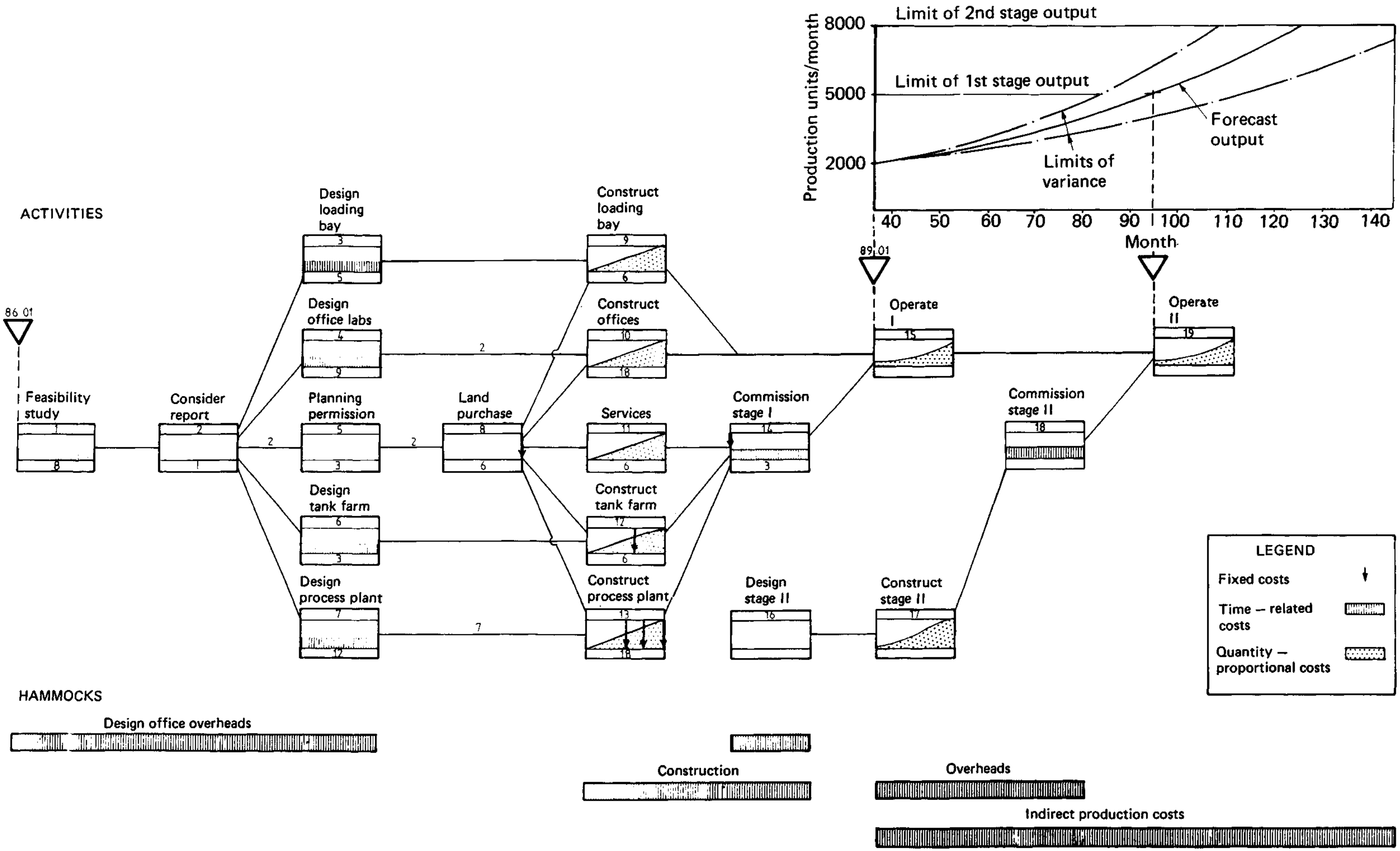

Figure 33.2 Flow chart for new manufacturing plant. The precedence diagram is developed and extended as the framework for cost/benefit analysis

	Expediting
	Construction management
	Contract administration
COMMISSIONING	Engineering and performance tests
	Acceptance
OPERATION	Organization for operation and maintenance
	Project review

These stages may frequently overlap and their relative durations can vary greatly. For public works projects the early stages of appraisal and definition are likely to extend over many years and the facility, say a road or a water-treatment plant, will also be utilized over a period frequently exceeding 25 years. Commercial projects, such as the new manufacturing plant illustrated in Figure 33.2, are more likely to be appraised, sanctioned and implemented rapidly before a competitor enters the market.

33.2.2 Organization of design and construction

In the traditional system for the procurement of civil engineering works[1] it is normal for the client to employ an experienced consulting engineer to assist him with project development and implementation. The consultant is likely to play an important role in project appraisal and definition, to undertake the design and contract documentation, to oversee tendering by contractors, to supervise construction work on site and administer the construction contracts. A contractor or group of contractors complete the fabrication and construction of the works. Management of design and construction is therefore the responsibility of different organizations.

This well-established system is still widely used but many variations are adopted to meet the particular requirements of the client, particularly in the private sector. In general, these reflect alternatives used in the related process plant, offshore and building industries[2] and frequently respond to pressure for quicker and timely completion to reduce the payback period. There is also increasing emphasis on effective project management and on the overall management of design and construction.

33.2.3 Decision making and control

Control is concerned with regulation of the future. This implies the ability to predict the consequences of specific courses of action and necessitates decision making under conditions of uncertainty. That is to say that the decision maker must choose a specific course of action from those available to him even though the consequences of the possible courses of action will depend on events that cannot be predicted with certainty. Decision making on construction projects is inextricably linked with uncertainty and also frequently encounters conditions of urgency and constraint. Many decisions are required during each of the stages listed above and may be influenced by a need to keep options open or a need to reduce uncertainty.

The scope for control diminishes as the project proceeds. The key events for the client are *sanction* – when he commits himself to a project of particular characteristics – and *contract award* – when he commits himself to specific contractors and to major cost expenditure. The contractor's commitment is, of course, made in his tender: thereafter he will exert control mainly through the allocation and use of resources.

33.2.4 Project management

The role of project management is to exercise overall control of the project from its inception through to the completion of commissioning. Thus, the ultimate responsibility for project management lies squarely with the client. His primary function is to define the parameters of the project and thereafter to provide decisions, approvals and guidance. Several reports on the performance of the construction industry over the last 10 to 20 years have concluded that good project management by the client is an essential ingredient for a successful project.[3] Regrettably, it was found that many projects lacked an appropriate project management structure, resources and expertise.

For each project, a single individual from within the client's organization should be named as project manager, and given the necessary authority and responsibility.[4] His role, therefore, is to manage the client's investment, and he should have sufficient seniority to exercise effective control both within and outside the client organization. For most projects he will need the support of a small project management team.

Brief guidelines for effective project management are given in section 33.9.

33.2.5 Project objectives

The client will have a number of overall objectives for undertaking the project. These may be commercial, reflect the perceived needs of society and/or have political overtones. Specific project management objectives must be compatible with the overall objectives and should be clearly formulated early in the definition stage of project development.

The dominant considerations must be fitness for purpose of the completed project and safety during both the construction and operational phases. Thereafter cost, time and functional performance form a minimum set of values from which the primary objectives will be drawn. The potential for conflict between these objectives, as problems arise during project implementation, is obvious.[5] The disasters which beset the Montreal Olympics stadium – a prestige project of novel design with an unrealistic budget and a fixed time constraint – offer salutory reading to all project managers.[6]

Consequently, it is necessary for the project objectives to be ranked in terms of their relative importance. Tolerances must also be specified – as range of acceptable variation in performance, float in the programme and tolerance and contingency allowances in the estimate. The greater the perceived uncertainty, the more flexible these criteria must be. Unclear or ill-defined objectives will have a detrimental effect on decision making and progress.

Thereafter, the monitoring of progress and performance against these objectives will determine the need for replanning, revision of estimates and changes in project scope and specifications. The latter are normally reductions in work content or quality which are accepted in order to meet stringent financial constraints. This approach is prevalent in public works projects,[7] is disruptive, has an adverse effect on morale, and is likely to lead to client or public dissatisfaction with the project however well the remainder of the work may be completed. Far better to expose the uncertainties, allow for them in the estimate and adopt realistic objectives in the first place.

Quality control demands effective liaison between design office and the project management team both in terms of specification and verification of client requirements. Effective inspection and testing procedures should be established and agreed by all parties. There is a tendency for some clients to economize in the allocation of engineering staff to inspect fabrication and supervise construction. When this follows the award of a contract to a low bidder without prequalification it does not surprise the Author that the client may be dissatisfied with the completed works.

Quality Assurance systems can assist project management in the setting and achievement of project objectives. According to a recent Construction Industry Research and Information Association (CIRIA) report:[8]

> Quality Assurance is a systematic way of ensuring that organised activities happen the way they are planned. It is a management discipline concerned with anticipating problems and with creating the attitudes and controls which prevent problems arising.

The report continues:

> Quality Assurance is concerned with systematically providing evidence to the client that all reasonable actions have been taken to achieve the required quality. But it is also concerned with spelling out the risks involved in any civil engineering project, and advising the client on operation and maintenance.

Properly practised, the system requires precision of communication and this, in the Author's opinion, is its greatest value to project management.

Quality Assurance is usually associated with manufactured products and with complex multi-disciplinary projects where safety and quality of plant operation are the primary objectives. The application of such systems to any project should depend on whether there is benefit. In the civil engineering context, care must be taken to ensure that the adoption of a Quality Assurance system does not result in rigid adherence to unnecessarily demanding specifications. Neither must the system inhibit the flexibility and judgement required for the management of the uncertainties associated with the one-off job.

33.2.6 Safety

The nature of construction work makes it vulnerable to accidents and project management must at all times enforce safety procedures. This is an area where great benefit to the physical well-being of staff, to morale and to the progress of the works could be achieved by the adoption of effective safety Quality Assurance programmes.[9,10]

33.3 Commercial considerations and cashflow

Projects and contracts involving engineering construction are commercial ventures. Both the client promoting a project and a contractor employed by him are investing money and taking financial risks in order to achieve some desired return. Project and contract management is concerned with the control of both investment and risk with the aim of achieving this return.

The client invests money in the realization of the project to provide either a service or the production of goods. The project is conceived and developed to meet a predicted demand for the services or goods: a motorway, a hospital, a power station and a shoe factory are all examples of projects. In the first two cases, the return obtained from the investment is represented by benefit to the users, whereas the unit price charged for the product of a commercial factory will be calculated to ensure an attractive profit to the investors. The power station must both provide a statutory service and make a small profit.

The client may also be called the promoter or the employer. He is concerned with the flow of money to and from the project – the project cashflow – throughout the life of the project from its conception to the end of some defined period of operation, a period that may extend over many years. Projects are consequently capital intensive, i.e. a large amount of investment is required over a long period of time before a substantial benefit is achieved. This is well illustrated in Figure 33.3. Even in that manufacturing project with a relatively short life cycle of 12 years, the client will have capital committed for almost 7 years before a positive balance is shown in the project account.

He may also enter into a legal agreement or contract with a contractor, or a number of contractors, for the construction of the project. Contractors are commonly specialists in a particular field and may also undertake the detailed design of their work if so required by the client.

A contractor's pattern of investment is very different and the time-scale of his involvement is much shorter. His cashflow may well comprise a substantial investment in construction plant,

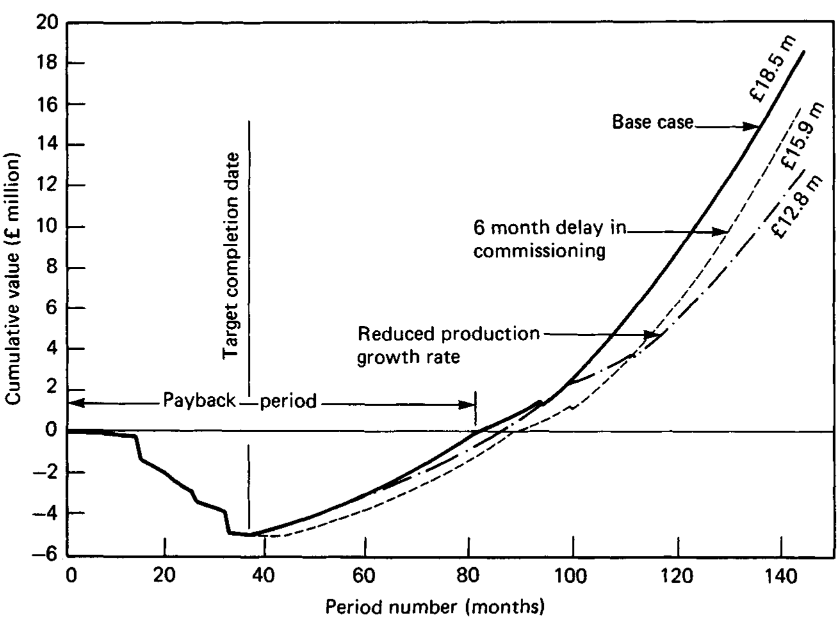

Figure 33.3 Cashflow diagram for new manufacturing plant. Delay in commissioning the plant generates a significant increase in capital investment

labour, and materials, particularly in the early stages of a contract, offset by regular monthly payments received from the client for work completed. The contractor must apply his expertise to produce a method statement for construction, assess the risks, and submit a tender that is both realistic and competitive. His targets are defined in his estimate and tender; thereafter he controls against them. The plan on which the tender is based will represent the most efficient use of the contractor's resources to achieve the work defined in the contract documents. It follows that any delay or change in the work content may also affect the timing of the flow of money to and from the contractor, and may involve additional funding from his capital as illustrated in the contract cashflow example given in section 33.3.2 below. If the disruption is caused by the client, the contractor will expect to be recompensed.

At any time, a contractor will probably be employed on a variety of contracts in different locations for different clients and will also be tendering for future work. His commercial skill is to utilize a relatively small amount of capital and to 'turn it over' as many times as possible by employing it to finance several contracts. The corporate cashflow and total financial risk will be very sensitive to changes in the timing of flows of money. It is important to appreciate the very different investment patterns experienced by clients and contractors as these greatly influence both attitudes and procedures adopted within the contractual relationship.

33.3.1 Cashflow

In order to quantify both the demand for money to meet the project or contract costs and the pattern of income it will generate it is necessary to predict the cashflow. A cashflow is a financial model of the project or contract which quantifies the actual flow of money, i.e. it takes account of delays between incurring a commitment and making a money transaction. The model is compiled simply by adding the costs and revenues to every activity on a bar chart programme which extends over the entire life-cycle of the project or contract.

When developing cashflow it is vital to distinguish between different categories of charge:

(1) Fixed charges which occur when certain stages are reached, e.g. a mobilization payment at the start of a construction contract.
(2) Time-related charges which are paid or received in regular increments over a period of time, e.g. the cost of site overheads, the weekly hire charge for a crane and payments to employees.
(3) Quantity proportional charges which are related to the quantity of material used or to the number of units of production of a factory or power station.

Only in this way will it be possible to use the model to predict realistically the effect on investment or return of such diverse factors as variations in output, delay, disruption, cost or wastage of materials.

33.3.2 Contract cashflow

The significance to the contractor's cashflow of different patterns of payment from the client and of delays is illustrated in Figure 33.4 by consideration of a small hypothetical contract of 2 years' duration.

The estimated cost curve (1) is seen in Figure 33.4(a) to be a flat 'S' due to the dominance of time-related costs for resources and overheads. The anticipated predicted revenue (2) assumes monthly payments for work completed and a 4-week delay between certification and payment by client. The shaded area between the curves represents the funding to be provided by the contractor. This would be considerably reduced if the client agreed to a 10% advance mobilization payment (3), or increased if payments were received late (4), as illustrated in Figure 33.4(b).

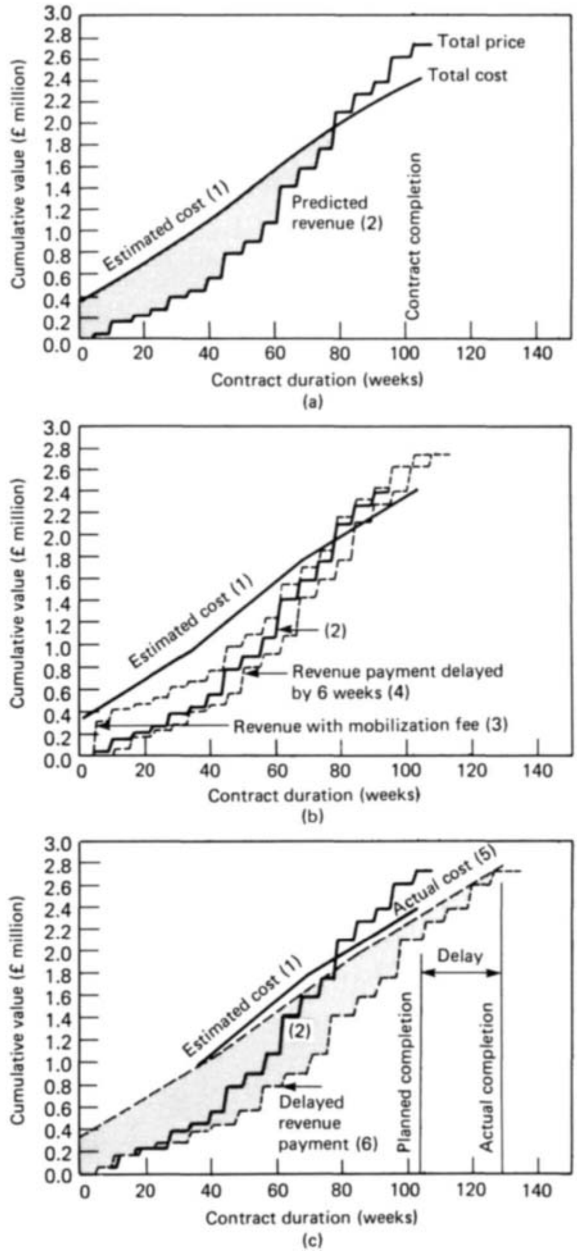

Figure 33.4 Contract cashflow. The contractors' investment is sensitive to change in payment and to delay

The effect of delay in completion is also serious as cost increases and payment for completed work is delayed (see Figure 33.4(c)). If the delay was caused by factors outside the contractor's control, an extension of time may be granted and payment increased but this will depend on the circumstances and the contract conditions.

In all cases, the effect on the contractor's investment is significant. The cumulative effects of reduction of credit by suppliers, delay in payment by the client, perhaps on several contracts, can be that a contractor will be led quickly into bankruptcy!

33.4 Construction planning

The success of a project or contract will depend greatly on careful and continuous planning. The activities of designers, manufacturers, suppliers and contractors must be organized and integrated to meet the objectives set by the client and/or the contractor. Sequences of activities will be defined and linked on a time-scale to form the programme to ensure that priorities are identified and that efficient use is made of expensive and/or scarce resources within the perceived physical constraints affecting the job.

Remember, however, that because of the uncertain nature of construction work it should be expected that the plan will change. It must therefore be updated quickly and regularly if it is to remain a guide to the most efficient way of completing the job. The programme should therefore be simple – so that updating is straightforward and does not demand the feedback of large amounts of data from busy men – and flexible, so that all alternative courses of action are obvious.

The purposes of planning are therefore:

(1) To persuade people to perform their tasks before they delay the operations of other groups of people, and in such a sequence that the best use is made of available resources.
(2) To communicate with those people.
(3) To provide a framework for decision making in the event of change.

It is difficult to enforce a plan which is conceived in isolation, and it is therefore essential continually to involve the people responsible for the constituent operations and to encourage their commitment as the plan is developed and revised. Ideally, it should provide a flexible framework within which they can exercise their own initiative.

Programmes are required at various stages in the contract; when considering feasibility or sanction, at the precontract stage and during the contract. They are required by the client and the contractors. They may be used for initial budget control or for day-to-day construction work. They may pertain to one contract, or a number of contracts in one large project.

Before compiling a programme, the planner is therefore faced with a number of decisions and must decide on:

(1) *The appropriate level of detail for the programme.* The golden rule is to keep it simple. A programme of 100 activities is easy to comprehend; one of 1000 activities is not. Initially, divide the job into the minimum number of large work packages and develop detail later only in specific areas where it is required due to the complexity of the work or when there is need to determine precise resource requirements.
(2) *The choice of programming technique.* Particularly important in this choice is the level of management at which the programme is to be used, and the level of detail required. The main programming techniques are given in section 33.4.3 below.

33.4.1 Compiling a programme

This is a process of repeated refinement. Before sketching out the first draft, the planner must be familiar with the objectives and priorities defined for the job and be aware of constraints. These will include: (1) restrictions on access to parts of the works; (2) likely periods of bad weather which may inhibit particular operations; and (3) availability of resources. Although the efficient use of key resources will be considered in detail at a later stage of the refining process, awareness of levels of skills, machines and materials likely to be available will, of course, aid the preparation of a realistic first draft.

Assumptions are invariably made as the plan is developed and it is essential that these should be stated clearly so that everyone using it is aware of its validity.

When compiling the programme the planner is concerned with:

(1) *Resources:* with the allocation and utilization of people with expertise and skills, fabrication facilities, construction plant and materials.
(2) *Activities:* packages of work which *consume resources* and are defined by considerations of:
    (a) the type of work (and therefore the type of resource required);
    (b) the location of the work;
    (c) any restraints on the continuity of the activity.
    Each activity will be identified and appear as a bar or other symbol on the programme.
(3) *Logic:* with the relationships and links between activities which will be represented by lines or arrows on the programme. Most programmes will contain obvious sequences of activities which will provide the basic shape of the diagram. It is also advantageous to identify any opportunity to *overlap* activities, i.e. an activity may start before the preceding one is completed. In this way the overall duration of the job may be minimized, frequently with consequential savings in cost. Initially each activity should be shown at its *earliest possible start.*
(4) *Duration* of each activity which is a function of the quantity of work to be done, the number of units of resource allocated to the activity, and their predicted output.
    It is important to think of duration in this way as all these factors may be variable. The quantity of work, e.g. volume of excavation or number of drawings, may be more or less than originally estimated, one or more teams may be allocated to the activity, and their predicted production may or may not be achieved. Any change will affect the activity duration and in turn alter the overall demand for resources, the total duration of the job, the cost and the cashflow.

The initial allocation of resources to an activity will be a matter of judgement and is quite likely to be changed subsequently.

(5) *Potential problems and uncertainties* must be identified and the implications and possible responses considered. The greater the uncertainty, the more flexible the programme must be in order to provide alternative courses of action. This may be achieved either by allocating additional resources or by extending the contract duration. In either case, the estimated cost will increase and it is therefore essential to link the programme with the cost forecast.
(6) *Overall duration of the job* calculated when all the activities at their assumed durations have been assembled within the overriding constraints which form the framework of the programme.

33.4.2 Resource scheduling

Whichever programming technique is used, the next important

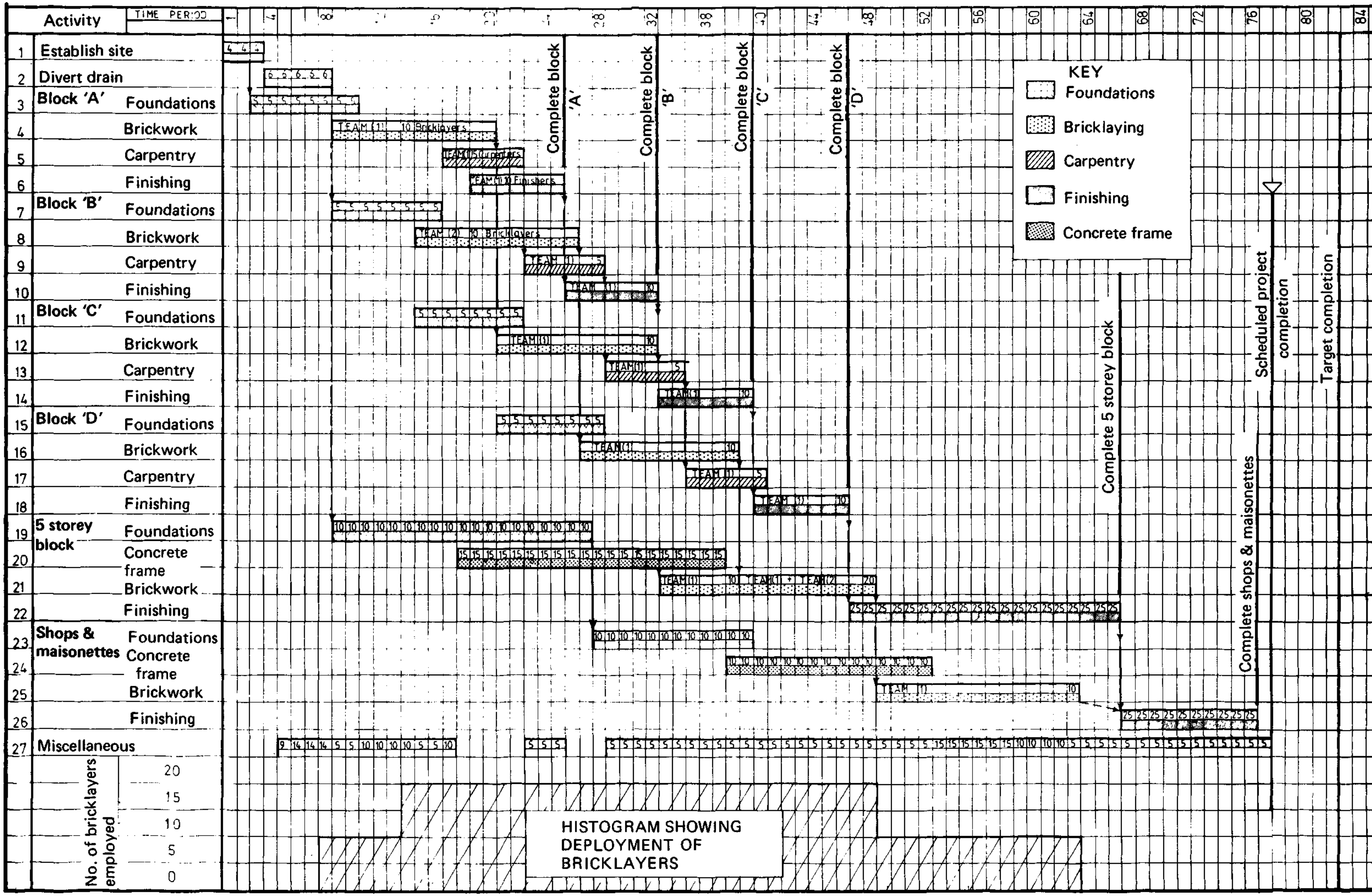

Figure 33.5 Bar chart programme. The work is organized to achieve the project objectives and efficient use of resources

step in refining the plan would be to consider the overall demand for key resources. The definition of key resources is likely to differ for different types of project and particularly for their location. Consideration will be given especially to those resources which are *scarce* and/or *expensive*. It is clear that the adjustment, or levelling, of one resource will have an effect on the usage of others. Generally, resource levelling is only applied to a few resources, particularly if it is being done manually. The use of a computer can allow greater sophistication.

33.4.3 Programming techniques

33.4.3.1 Bar charts

The best form of plan for site use is the bar chart (a simple example is shown in Figure 33.5). In this example the planner was required to give priority to construction of blocks A and B and to complete the housing development in 82 weeks. Bricklayers were seen to be the key resource. Note the following aspects of the diagram:

(1) Each activity is shown in its scheduled position which results in efficient use of resources. The histogram shows continuous use of the same teams of bricklayers.
(2) The logic of the inter-relationship of activities and movement of resource teams is shown clearly.
(3) The space within the bars can be used for figures of output or resource demand, and there is room beneath to mark actual progress.
(4) Important constraints and key dates are marked to ensure that these are clearly communicated to all concerned with the project.
(5) Five weeks of float have been allowed.

33.4.3.2 Line of balance

This simple technique was developed for house building and is also useful for other forms of repetitive work, such as producing and distributing prefabricated units. The axes are the number of completed units and time: the work of each gang appears as an inclined line, the inclination being related to the output of the gang.[11]

33.4.3.3 Location–time diagram

In cross-country jobs such as major roadworks, the erection of transmission lines, or pipelaying, the performance of individual activities will be greatly affected by their location and the various physical conditions encountered. Restricted access to the works, the relative positions of cuttings and embankments, sources of materials from quarries and temporary borrowpits, the need to provide temporary or permanent crossings for watercourses, roads and railways, and the nature of the ground, will all influence the continuity of the construction work. The output achieved by similar resources of men and machines may vary when they are working in different locations. In such circumstances the programme may best be developed on axes of location and time on which all obstacles or features may be marked. The work of each resource team will again appear as an inclined bar with inclination related to the output of the gang.[12]

33.4.3.4 Network analysis

These techniques are used to evaluate programmes where complex or multiple relationships exist between a number of activities. The greatest benefit is the discipline imposed on the planner when compiling the logic of the network, i.e. when specifying the individual activities and the links between them. A further major advantage is that the computer may be utilized to explore many possible combinations of the timing of individual activities in order to achieve really efficient use of resources. Networks are rarely the best method of communication with the people actually responsible for performing the constituent activities, and the results of the analyses will normally be translated into some other form of working programme such as a bar chart.

Precedence diagrams and activity networks. The Author advocates the use of a simple precedence system which is illustrated in Figure 33.1. This system utilizes preprinted node-sheets and thereby enables the engineer to devote less time to drawing and more to planning. It also offers a simple method of overlapping activities and is easy to update and revise. Individual activities are represented by rectangular nodes which are linked by dependency lines to form the network.

Several overlaps are shown in the example. The figure 7 on the dependency line between activities 7 and 13 indicates that construction of the plant should start a maximum of 7 months before completion of design. It has been the Author's experience that it is the activity durations and overlaps which change most frequently when updating a programme. Consequently, he has found that definition of overlaps in this simple manner simplifies revision of the programme.

Float is also identified quickly from the diagram. The imposition of fixed start and completion dates in this example has resulted in all activities displaying at least 1 month of total float – as calculated from the difference between earliest and latest start of any activity.

Precedence diagrams provide an excellent basis for the development of cost models as illustrated when Figure 33.1 is extended to cover the operational phase of the project in Figure 33.2.

33.5 Cost estimating

Estimates of cost and time are prepared and revised at many stages throughout the development of a project or contract. They are all *predictions* of the final outcome of the job and the degree of realism and confidence achieved will depend on the level of definition of the work and the extent of risk and uncertainty. Consequently, the accuracy of successive estimates should improve as the project or contract develops. The most important estimates prepared are probably for a project, at sanction, and for a contract, at tender, for it is at these points that the client and contractor become committed.

33.5.1 Requirements of an estimate

The requirements of an estimate are:

(1) To predict the most probable cost of the works and also to define the range within which the final cost is likely to lie.
(2) To produce a forecast of expenditure: the cashflow based on the project programme.

These predictions will be influenced by factors peculiar to the particular project under consideration. Location, logistics, weather, availability and capacity of resources and market factors will all affect the final price. The estimate must therefore be compiled with the circumstances of the project clearly in mind and all assumptions, uncertainties and exclusions should be stated. Ideally, any estimate should be presented as a most probable value and a tolerance together with a range of less likely values to emphasize that it is an estimate.

It is important to realize that the precise value of a specific single-figure estimate made at an early stage of the project or contract is most unlikely to be achieved due to the uncertainty associated with civil engineering work.

33.5.2 Cost-estimating techniques

All these techniques rely on historical data of some kind and it is prudent to note the following points:

(1) Ideally, the data should be from a sufficiently large sample of similar work in a similar location and constructed in similar circumstances. Unfortunately, this is rarely the case and corrections have to be applied.
(2) Cost data needs to be related to a specific historical date, chosen with care. Historical costs must be corrected for inflation, changes in exchange rates and market factors.

The five basic estimating techniques available to the estimator are summarized below.

(1) *Global*. This term describes the 'broadest brush' category of technique which is derived from libraries of achieved costs of similar projects related to the overall size or capacity of the asset provided. This technique may also be known as 'rule-of-thumb' or 'ballpark' estimating. Examples are:
 (a) cost per square metre of building floor area or per cubic metre of building volume;
 (b) cost per megawatt capacity of power stations;
 (c) cost per kilometre of roads;
 (d) cost per tonne of output for process plants.

 The technique relies entirely on historical data and therefore must be used in conjunction with inflation indices and a judgement of the influence of the construction market appropriate to the envisaged timing of the project. Global estimates can only be used to give a rough indication of the order of cost in the appraisal and definition stages of project development.
(2) *Factorial*. These techniques are used widely for early estimates of the cost of process plants, power stations, etc. where the core of the project consists of major items of plant which can be identified and for which current budget prices may be obtained from suppliers.

 The techniques provide factors for a comprehensive list of peripheral costs such as pipework, electrics, instruments, structures and foundations. The estimate for each peripheral will be the product of its factor and the estimate for the main plant item.[13]

 A detailed programme is not a necessity but it is recommended that one is prepared. This will be valuable particularly in identifying problems of construction which will go undetected if the technique is applied in a purely arithmetical way, and is required for cashflow prediction. The technique has the considerable advantage of being predominantly based on current costs, thereby taking account of market conditions and needing little, if any, reliance on inflation indices. Factorial techniques are not normally reliable for site works.
(3) *Manhours*. This technique is only suitable for labour-intensive construction, design-office activities, and operations such as mechanical erection work where reliable records of hourly productivity of different trades are available. The total manhours estimated for a given operation are then costed at the current labour rates and added to the costs of materials and equipment. The advantages of working in current costs is obtained.
(4) *Unit rates*. The estimator selects historical rates or prices for each item in the bill of quantities using either information from recent similar contracts, or published information, or 'built-up' rates from his own analysis. As the technique relies on historical data it is subject to the general dangers outlined above.

 The technique is most appropriate to building and repetitive work where the allocation of costs to specific operations is reasonably well-defined. It is essential that the rates are selected from an adequate sample of similar work with reasonably constant levels of productivity and limited distortions arising from construction risks and uncertainties, e.g. access problems. The technique is less appropriate for civil engineering where the method of construction is more variable and where the uncertainties of ground conditions are more significant.

 The unit rate technique does not demand an examination of the programme or method of construction and the estimate is frequently compiled by the direct application of historical 'prices'. It therefore does not require an analysis of the real costs of the work, neither does it encourage consideration of the peculiarities, constraints and risks affecting the particular project. Nevertheless, unit rate estimating is probably the most frequently used technique. It can result in reliable estimates when practised by experienced estimators with good, intuitive judgement and the ability to assess the realistic programme and circumstances of the work.
(5) *Operational (resource-cost)*. This is the fundamental estimating technique wherein the total cost of the work is compiled from consideration of the constituent operations or activities defined in the construction method statement and programme and from the accumulated demand for resources. Labour, plant and materials are costed at current rates. The advantage of working in current costs is obtained.

 The most difficult data to obtain are the productivities of labour and construction plant in the geographical location and special circumstances of the project under consideration. Claimed outputs of plant are obtainable from suppliers' handbooks but these need to be reviewed in the light of actual experience. Labour productivities will vary from site to site depending on management, organization, industrial relations, site conditions, etc. and also from country to country.

 The operational technique is, by far, the best method of evaluating uncertainties and risks, particularly those likely to cause delay.[12] Because the technique exposes the basic sources of costs, the sensitivities of the estimate to alternative assumptions/methods can be investigated easily and the reasons for variations in cost appreciated. It also provides a detailed current cost/time basis for the application of inflation forecasts and, hence, the compilation of a project cashflow.

 This is the most reliable estimating technique for civil engineering work. Compilation is relatively painstaking and time consuming compared with other techniques, but when preparing an operational estimate the estimator will gain a realistic appreciation of the risk and special circumstances of the project.

33.6 Project appraisal

Project appraisal is a process of investigation, review, and evaluation undertaken as the project or alternative concepts of the project are defined. This study is designed to assist the client to reach informed and rational choices concerning the nature and scale of investment in the project. The core of the process is an economic evaluation – based on a cashflow analysis of all costs and benefits which can be valued in money terms – which is also therefore called cost/benefit analysis.

Appraisal is likely to be a cyclical process repeated as new ideas are developed, additional information received and uncertainty reduced until the client is able to make the critical decision to sanction implementation of the project and commit the investment in anticipation of the predicted return.

33.6.1 Risk and uncertainty

The greatest degree of uncertainty about the future is encountered early in the life of a new project. Decisions taken during the appraisal stage can have a very large impact on final cost, duration and benefits. The extent and effects of change are frequently underestimated during this phase although these are often considerable, particularly in developing countries and remote locations.

At this stage, the engineering and project management input will normally concentrate on providing:

(1) Realistic estimates of capital and running costs.
(2) Realistic time-scales and programmes for project implementation.
(3) Appropriate specifications for performance standards.

At appraisal, the level of project definition is likely to be low and therefore risk response should be characterized by a broad-brush approach.[14] It is recommended that effort should be concentrated on:

(1) Seeking solutions which avoid/reduce risk.
(2) Considering whether the extent or nature of the major risks are such that the normal transfer routes may be unavailable or particularly expensive.
(3) Outlining any special treatments which may need to be considered for risk transfer, e.g. for insurance or unconventional contractual arrangements.
(4) Setting realistic contingencies and estimating tolerances consistent with the objective of preparing the best estimate of anticipated total project cost.
(5) Identifying comparative differences in the riskiness of alternative project schemes.

Engineers/project managers will usually have less responsibility for identifying the revenues and benefits from the project: this is usually the function of marketing or development planning departments. The involvement of engineers/project managers in the planning team is recommended as the appraisal is essentially a multi-disciplinary brainstorming exercise through which the client seeks to evaluate all alternative ways of achieving his objectives.

For many projects this assessment is complex, as not all the benefits/disbenefits may be quantifiable in monetary terms. For others it may be necessary to consider the development in the context of several different scenarios (or views of the future). In all cases, the predictions are concerned with the future needs of the customer or community. They must span the overall period of development and operations of the project which is likely to range from a minimum of 8 or 10 years for a plant manufacturing consumer products, to 30 years for a power station and much longer for public works projects. Phasing of the development should always be considered.

33.6.2 Project evaluation

The process of economic evaluation and the extent of uncertainty associated with project development is illustrated by the appraisal of a hypothetical new manufacturing plant.

The simple precedence diagram (Figure 33.1) has been developed into a flow chart (Figure 33.2) and extended to include 9 years of plant operation. The diagram also gives some indication of the patterns of costs and revenue.

The plant is designed for development in two stages, the first with a manufacturing capacity of 5000 units and the second raising this to the maximum of 8000 units. During an appraisal study, uncertainty frequently exists with regard to the demand for the product and is indicated by the definition of a range of possible output. The forecast curve assumes a 20% per annum growth in the market but a range of 15 to 25% is considered possible. If the growth rate fell below the favoured 20% it is likely that stage 2 would not be implemented.

If all the predictions of costs, revenues, markets and programme over the 12-year project life were correct, the project would require maximum investment of £4.96 million and would ultimately generate a surplus of £18.5 million as shown in the basecase cumulative cashflow curve (the full line in Figure 33.3).

Other parameters used to quantify this investment could be:

Payback period	80 months
Net present value @ 10% discount rate	£6.13 million
Internal rate of return (i.r.r.)	27.6%

and it is strongly advised that a similar range of criteria are employed when determining any investment.

It is, of course, most unlikely that those precise values will be achieved due to all the risks and uncertainties which exist at the early stage of project development. The chain line in Figure 33.3 indicates that, should the market growth rate be only 15%, the surplus would be reduced to £12.8 million and i.r.r. to 22.9%. The obvious effect of a 6-month delay in completion of the plant, shown by the broken line in Figure 33.3 would be to reduce the surplus to £15.9 million and i.r.r. to 23.7%. A far more serious consequence could be loss of the market to a competitor.

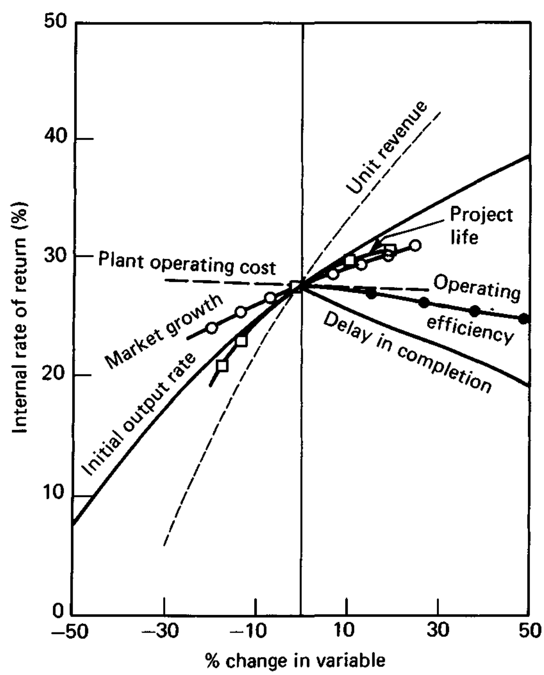

Figure 33.6 New manufacturing plant: sensitivity diagram. This 'spider' diagram communicates the relative effect of major variables on the viability of the project

The effect on the investment of variation in a whole range of factors is well shown in the sensitivity diagram (Figure 33.6). Each variable is considered independently and it is obvious that market factors are dominant. Delay in completion is also shown to have a serious effect on the return obtained from the investment. The great value of this diagram is that it indicates where further effort is needed to reduce uncertainty, perhaps by additional market surveys in this case. It also suggests that management policy must give priority to timely completion of the plant.

In practice, a combination of all these uncertainties and risks is likely to be experienced and a better prediction of the probable range of outcome of this project can be obtained from the cumulative probability diagram (Figure 33.7). This diagram is generated by substituting 1000 combinations of these factors in the basic model on a random basis in a Monte Carlo simulation.[14,16] The base case prediction is seen to be optimistic when uncertainties are taken into account as there is a 77% probability that i.r.r. will be less than 27.6%. It is predicted that there is 50/50 chance of achieving an i.r.r. of 21% but that extreme values of zero and 40% are just possible. Although analyses of this type require judgement to be made on the likely range and probability distribution of each variable, the Author strongly recommends that this discipline of a rigorous risk analysis is adopted for all major projects.

The output of power and market factors is also seen to dominate the sensitivity diagram for a real project, the proposed Severn tidal power scheme,[15] (see Figure 33.8). Again, the most sensitive engineering factors are delays in completion of the works and installations of the turbines.

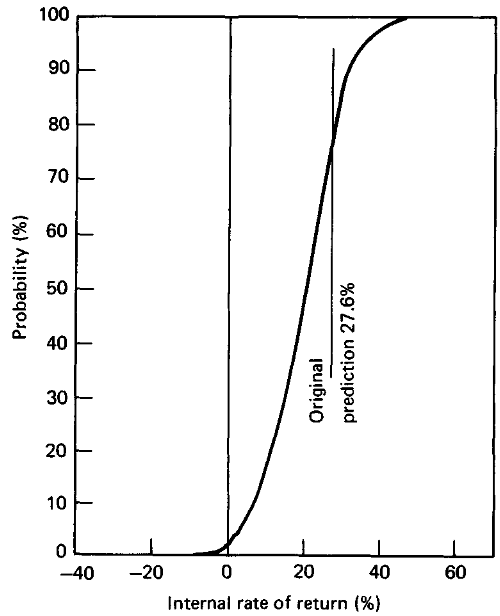

Figure 33.7 New manufacturing plant: cumulative probability diagram. There is a 77% probability that the internal rate of return will be less than the base case prediction of 27.6%

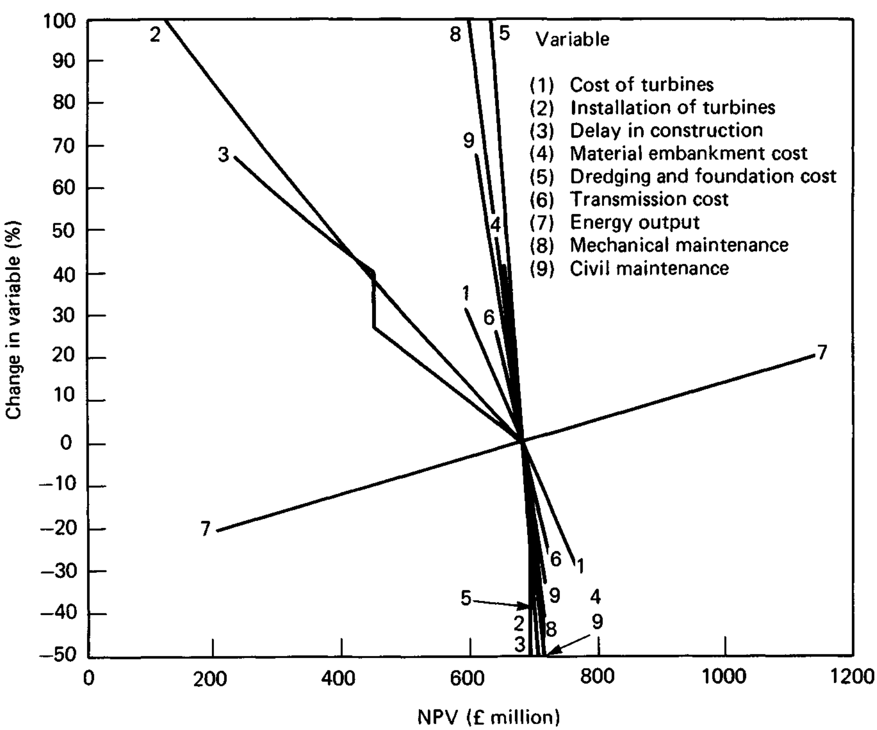

Figure 33.8 Severn tidal power scheme: sensitivity analysis. The amount of power produced, the selling price, and the delay in completion of the project again have the most serious effect on project viability

33.7 Engineering contracts

Construction work of all types is normally undertaken by a contractor, a specialist in the particular field of work, who is employed for this purpose by the client. In most cases, the client will invite a number of suitable contractors to submit tenders and subsequently will award the contract on the basis of the lowest realistic and acceptable tendered price.

This approach is adopted worldwide and has led to the development of well-defined systems of working and Standard Conditions of Contract for different types of work. Each of these traditional procedures has been developed to meet a particular set of circumstances and will work well, provided their limitations are accepted, as the associated case law is well established.

It is, however, important for engineers to realize that, because of the diversity of both construction work and clients' requirements, no single uniform approach to contractual arrangements can be specified or advocated. A number of alternative strategies are available to the client and each contract should be formulated with the specific job in mind. For example, a client may wish to be directly involved in site management or may prefer to delegate this responsibility entirely to the contractor, the need for early completion of the work may dictate that the contractor is appointed before design is completed, risks may be apportioned in various ways between the parties, the contractor may be required to undertake the detailed design or to provide varying amounts of finance – these and many other considerations will all influence the client's contract strategy.

Obviously, this strategy will also be greatly affected by the nature of the work to be completed under the contract. The fabrication and positioning of an offshore oil production platform is a high-risk venture which may involve advanced or new technology and will be subject to severe time constraints. The contract for building a chemical plant may include the provision of unique process know-how offered by the contractor who will consequently undertake detailed design, construction and commissioning of the plant. Tunnelling implies uncertainty – and therefore risk – about ground conditions, whilst minor roadworks or house building are likely to involve repetitive use of traditional techniques with relatively little financial risk and the overriding requirement of minimum cost.[16]

33.7.1 Contract strategy

The term 'contract strategy' is used to describe the organizational and contractual policies chosen for the execution of a specific project.[17] The development of a contract strategy is an important task for the client or his project manager. It comprises a thorough assessment of the choices available for the implementation and management of design and construction. A pattern of inter-related decisions is required which seeks to maximize the likelihood of achievement of key project objectives. The selected strategy is likely to be optimal in that it must satisfy a variety of constraints and be sufficiently robust to withstand the uncertainty associated with the project.

The decisions taken during the development of a contract strategy affect: (1) the responsibilities of the parties; (2) they influence the control of design, construction and commissioning and, hence, the co-ordination of the parties; (3) they allocate risk and define policies for risk management; and (4) they define the extent of control transferred to contractors. Therefore, they affect cost, time and quality.

The first step in the development of a contract strategy is to identify the areas which constitute the strategic choices. These are:

(1) The project management objectives as defined by the client.
(2) The organizational system for design and construction.
(3) The type of contract.
(4) The Conditions of Contract and other contract documents.
(5) The tendering procedure.

The project manager must then choose from the optious available within each of these five strategic areas.

33.7.2 Choice of contract type

There are three essential requirements of any contract:

(1) *Incentive.* The aim is to provide an adequate incentive for efficient performance from the contractor. This must be reflected by an incentive for the client to provide appropriate information and support in a timely manner.
(2) *Flexibility.* The aim is to provide the client with sufficient flexibility to introduce change which can be anticipated but not defined at the tender stage. An important and related requirement is that the contract should provide for systematic and equitable evaluation of such changes.
(3) *Risk sharing.* The aim should be to allocate all risk between client and contractor. This must take account of the management and control of the effects of risks which materialize. The contractor will include a risk contingency sum in his tender as protection against the risks he has been asked to carry.

The inter-relationship of these requirements with the type of contract is demonstrated in Figure 33.9 in which the requirements are expressed in terms of contractor's incentive, client's flexibility and exposure to risk. It is apparent that, generally, a contractor's incentive and a client's flexibility tend to be incompatible. For example, a lump-sum contract imposes maximum incentive on the contractor but also implies a very high level of constraint on the client against introducing change. The converse is true at the other extreme of a cost-reimbursable plus percentage fee contract.

There are many detailed points of difference between the various types of contract. Those of most importance to the client in making an appropriate choice are summarized below.

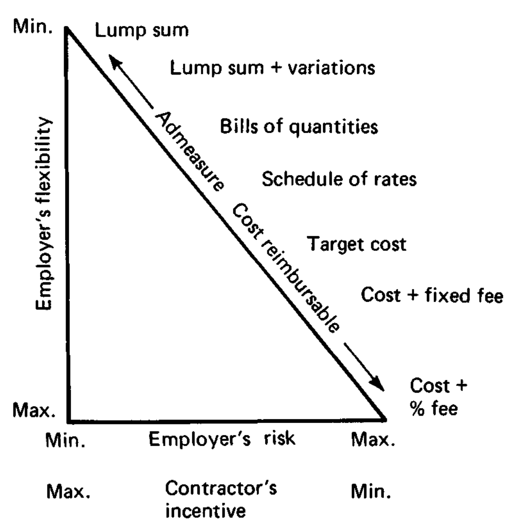

Figure 33.8 Characteristics of different types of construction contract

33.7.3 The main types of contract

Types of contract are virtually classified by their payment system: (1) *price-based* – lump sum and admeasurement (prices or rates are submitted by the contractor in his tender); and (2) *cost-based* – cost-reimbursable and target cost (the actual costs incurred by the contractor are reimbursed, together with a fee for overheads and profit).

33.7.2.1 Price-based contracts

Lump-sum contracts. Lump-sum contracts are based on a single price tendered for the whole works. Payment may be staged at time intervals or related to achieved milestones. Lump sum does not necessarily imply a fixed price; in particular, price may be adjusted for cost escalation.

The implications are that complete, final design is available at tender and that minimal changes or variations are expected. No contractual mechanism is specified for price adjustment and such contracts are therefore rarely used in engineering construction.

A high degree of tender competition may be achieved and the price may include a high level of financing by contractor.

Admeasurement contracts. These are based on bills of quantities or schedules of rates in which items of work are specified with quantities. Contractors then tender unit rates or prices against each item. Payment is usually monthly and is derived from measuring quantities of completed work and valuing at rates in the tender, or new rates negotiated from tender rates.

Mechanisms are provided for adjusting both price and time, as discussed in section 33.8 in the likely event of change. This facility to introduce limited variation is frequently abused and design may be only partially complete at tender. Extensive change and delay will generate claims and the final price is invariably different from the tender total. The price will include an allowance for any financing required by the contractor and a risk contingency.

Cost-reimbursable contracts. These are based on payment of actual cost incurred by the contractor plus a specified fee for overheads and profit. The contractor's cost accounts are open to audit by the client (Openbook Accounting). Payments may be monthly in advance, in arrears, or from an imprest account.

Cost-reimbursible contracts are normally used when the client wishes to employ a contractor at an early stage of project definition and design, or when there are major risks associated with the contract. There is little contractual incentive for the contractor to perform and the final price will depend both on the extent to which risks materialize and on the efficiency of the contractor. The client carries the risk and will therefore require to participate in contract management.

Target-cost contracts. Target cost is based on the setting of a probable (or target) cost for the work. The target cost will subsequently be adjusted for major changes in the work and cost inflation. The contractor's actual costs are monitored and reimbursed as in a cost-reimbursable contract. Any difference between actual cost and target cost is shared in a specified way between the client and the contractor. There is a separate fee for overheads and profit.

By using target-cost contracts, it has been possible to achieve a high degree of collaboration between the parties. They are most suitable for high-risk contracts where the work content is well defined, such as tunnels.[18]

33.7.4 Management contracting

Various forms of management contract are widely used in building construction but are rarely appropriate to civil engineering works. In these systems, an external organization – the management contractor or construction manager – is employed specifically to manage and co-ordinate design and construction on behalf of the client. The systems are frequently adopted to achieve early completion of the project by 'fast tracking' or by overlapping and integrating design and construction. They are most appropriate for construction which can be split into a series of well-defined contract packages, each of which is awarded immediately the relevant design is completed.

The management contractor is normally employed on a cost-reimbursable basis and, although the construction contracts are of the familiar admeasurement form, it is important to realize that the allocation of risk between the parties may be considerably changed.[2]

33.8 Contractual measurement and valuation

The type of contract, the level of detail required in contractual measurement and the method of valuation of the work are interrelated.

Several procedures are provided in admeasurement contracts for civil engineering works for valuation and payment in respect of changes to the work defined in the contract documents.

(1) Changes to quantities of measured work listed in the bill of quantities are priced on a pro rata basis, the actual quantity of work completed being substituted for the original estimated figure in the final account. Under the Institution of Civil Engineers[19] and Federation Internationale des Ingénieurs Confeils (FIDIC). Conditions of Contract there is, in theory, no limit to the adjustment permitted to any quantity but it should be noted that under Clause 56(2) of the former (fifth edition) the tendered rate may be varied following such adjustment. In some other Conditions of Contract, a definite range of adjustment to quantity, over which the tendered rate is deemed to be valid, is specified.

(2) Variations to the work defined in the contract may be ordered by the Engineer who will issue a written variation order. The Engineer is empowered to fix the value of the work covered by the variation order after consultation with the contractor and, wherever possible, utilizing tendered rates in the bill of quantities. Should the contractor dispute the engineer's valuation, the contractor may claim additional payment.

(3) The contractor may also claim additional payment and/or extension of time should he incur additional cost on account of 'unforeseen conditions' or delay. The Engineer will assess the value of each claim from evidence submitted by the contractor.

The Engineer is empowered to settle all disputes between the client and the contractor. If either party is dissatisfied with his decision they may then resort to arbitration.

33.8.1 Bills of quantities

The conventional British and international civil engineering contracts are of the admeasurement type wherein the contract price is accumulated in the bills of quantities. These list and quantify the constituent items of work, each of which is priced individually by a tendering contractor. The quantities of work are stated to be the best estimate which can be made by the Engineer prior to tender: all work items are subsequently remeasured during the course of the contract and valued at the rates tendered by the successful contractor.

The bill of quantities is one of the contract documents and has several main functions:

(1) To itemize and quantify the elements of work to be completed within the contract.
(2) To facilitate comparison of tender prices.
(3) Interim and final valuation of completed work.
(4) Evaluation of change and variation.

33.8.2 The concepts incorporated in the traditional bills of quantities

The admeasurement contract developed from the lump-sum contract in order to provide essential flexibility as jobs become larger and more complex and the traditional admeasurement procedures and bills of quantities have been developed from the following simple concepts:

(1) All prices are deemed to be proportional to the quantity of work completed: all quantities are remeasured on completion of the contract.
(2) The client will pay only for completed permanent works.
(3) The payment lines are specified.
(4) The contractor can price the component items in any way he wishes.
(5) The tender price is to be the total price for completing the works specified in the contract documents.

33.8.3 Development of the bills of quantities

The simple and expedient procedures outlined above proved acceptable and equitable for repetitive and labour-intensive work. They are rarely adequate nowadays for the evaluation of plant-intensive work or for contracts including significent items of temporary work when there is a significant incidence of variation or delay. There are several reasons for this. The prices entered in the traditional bill of quantities rarely represent the true cost of completing the work defined in the individual items as the contractor's costs are not all directly related to the quantity of work completed. It follows that any adjustment of price resulting from a change in quantity of a particular item is unlikely to represent the true variation in cost.

A significant part of a contractor's costs are time-related and it is these costs which are affected by disruption or delay. Time-related charges are not, however, separated in the traditional bill of quantities and it is therefore not possible to evaluate systematically the very issues which are a major source of contractual claims.

As the incidences of change and variation have increased, various attempts to improve measurement and valuation procedures have included:

(1) Additional 'preliminary' items for overheads and specified facilities to be provided by the contractor.
(2) Separation of major temporary works items.
(3) Limits on the range of permissible variation for individual billed items and for the total extent of variation within the contract.
(4) Separation of 'method-related' charges.

33.8.4 Method-related charges

Systematic evaluation of a range of changes and variations, including delays, may be achieved by the separation of method-related charges in the bill of quantities. This approach was introduced in the British Civil Engineering Standard Method of Measurement (CESMM) in 1976[20] and moves away from the concept that all charges are proportional to quantities of completed work. Method-related charges are introduced to permit tenderers to enter their own items in the first section of the bill of quantities for any operations whose costs are not directly linked to the quantities of permanent works. The rates entered against the bill of quantities are consequently more realistic and are dominated by material costs.

The principal improvements in measurement procedures are seen to be:

(1) Items and prices take account of method of construction.
(2) Systematic evaluation of variations and claims arising from disruption and delay.
(3) Greater similarity between cost and price.

The production of estimates in an operational form which is directly related to his programme has greatly facilitated cost forecasting by the contractor. Similarly the separation of method-related charges in the bill of quantities permits the meaningful correlation of price and time which is essential for cashflow forecasts by the contractor, budget forecasts by the client and the mutual evaluation of contractual changes.

Important points to note are:

(1) Method-related charges are specified as either fixed or time-related and are entered in the *Preliminary and General section* of the bill of quantities. They are all priced as *Lump Sums.*
(2) Where the contractor enters such method-related items arising from his method of construction, they must be defined in sufficient detail for the Engineer to be able to identify the particular resource.
(3) It is most important to note what method-related charges are not subject to remeasurement. They may, however, be adjusted where relevant under a variation order.

33.8.5 Pricing and tendering policy

The contractor may translate cost into the priced items in the bill of quantities in any way he wishes, i.e. he may separate all or some of his method-related charges and 'weight' items to improve cashflow. In doing so, he must consider both the effect on his investment and the possible consequences of variations to the work defined in the bill of quantities. The incentive for a contractor to separate method-related charges normally stems from an improvement in cashflow; in consequence, he provides less investment and may reduce his tender price.

33.9 Project management

The responsibility of the project manager normally spans design, construction and commissioning. His function is to control the sequence of events and decisions leading to the completion of the project. Indecision is costly, as resources – design teams, manufacturers and contractors – are employed and will require compensation if their work is disrupted. Nevertheless, change is a characteristic of the engineering phase of projects involving construction and the project manager must be prepared to take the necessary corrective action.

If he is to fulfil his task of control of the realization of the project on behalf of the client, the project manager cannot divorce decisions taken on engineering matters from all other factors affecting the investment. Control may only be achieved by regular reappraisal of the project as a whole so that the current situation in the design office, on fabrication, on the supply of materials, and on site may be related to the latest market predictions. If this is done the advantage to be gained, say, from early access of land may be equated with any additional costs in full knowledge of the value of early or timely completion. The continual updating of a simple 'time and money' model of the project originally compiled for appraisal as illustrated in section 33.6 will greatly facilitate effective control during the engineering phase.[21]

33.9.1 Guidelines for project management

The project management process is briefly summarized below:

(1) The success of a project or contract depends greatly on the management effort expended by the client prior to sanction and by both parties prior to award of a contract.

(2) The client commits himself to investment in the project on the basis of the appraisal completed prior to sanction. The appraisal must be realistic and identify all risk, uncertainties and potential problem areas. Single-figure estimates are misleading and should be supported by figures showing the range of likely outcome of the investment.

(3) The client has a crucial role to play during implementation of the project, and the early appointment of an experienced project manager to pursue his interests is essential. He must be supported by an adequate project team set up in good time. The function of this team is co-ordination of all aspects of the project and particularly the contribution of the client organization.

The prime roles of the project manager are to drive the project forward and to think ahead; he must therefore delegate routine functions and concern himself with any problem areas.

(4) It is essential that project management ensures that the client clearly defines the project objectives together with the ranking of their relative importance. The likelihood of a successful project is greatly improved when all key managers of design, construction and supporting groups are fully informed and committed to these objectives. The project objectives should also be communicated to the other parties (contractors, consultants, etc.) involved in project implementation.

The dominant considerations must be fitness for purpose of the completed project and safety during both the construction and operation phases. Thereafter, the normal primary project objectives are concerned with cost, time and quality. These are inter-related and may conflict.

The fact that the client does not see any return on his investment until the project is commissioned suggests that timely completion should be a prime objective.

(5) Engineering projects are normally of short duration and are completed against a demanding time-scale. Adequate staff of the right quality must therefore be appointed and given training in the appropriate techniques and procedures. All staff concerned with contract management must be familiar with the contractual procedures employed.

(6) Although the scope of the project will be agreed at sanction it is probable that conceptual design, which will determine the final layout and size of the functional units, will follow early in the engineering phase. It is recommended by the Author that the conceptual design is rigorously reviewed as this is the main opportunity both for cost saving and for ensuring that the proposals meet the client's objectives. Particular attention should be given at this stage to subsequent operation and maintenance of the project.

(7) Effective control of the project or contract will only be achieved through continual planning and replanning. Management effort should be concentrated on the present and the future: time devoted to the reporting and collection of historical data should be kept to a minimum.

In his planning, the client must take a broad view of the project and aim to co-ordinate design, construction, commissioning and subsequent operation and maintenance. Interaction of contractors, access, statutory requirements and public relations must all be considered.

A contractor will plan in more detail and aim to achieve continuous and efficient deployment of his resources. Because of the greater likelihood of change, the contractor's programme should be flexible and subject to constant review.

(8) The plan used by senior staff should clearly show the financial consequences of alternative courses of action and of indecision. It is therefore convenient to develop the plan as a time-and-money model of the project or contract which will react realistically to changes in timing, method, content and cost of work. Realism is largely dependent on the correct definition and allocation of costs and revenues as either fixed, time-related or quantity-proportional charges.

Time-related costs are significant in all types of construction work and predominate in many civil engineering projects. Adherence to the programmed time schedule for the work will therefore also control both cost and investment.

(9) Time lost at the beginning of a project can rarely be recovered: particular attention must therefore be given to the start-up of the project. Similarly, sufficient time must be allowed for mobilization by each contractor.

(10) Consideration of alternative contract strategies will frequently focus attention on deficiency of information and on the problems which will hinder the project objectives. Selection of an appropriate contract strategy at an early stage of project implementation is perhaps the most important single activity of the project management team.

(11) Appointment of a contractor on the sole criterion of lowest bid price will not necessarily lead to a harmonious contractual relationship. The lowest tender may not produce the lowest contract price.

Both parties are making their commitment at this point and should be fully aware of both the client's objectives and the contractual responsibilities.

Selective tendering followed by rigorous bid appraisal, including study of the contractor's programme and resource allocation, will do much to ensure that the contractor has not misjudged the job and that his price is realistic. The production of his own operational type of cost estimate will greatly aid the project manager in this appraisal.

The client must check that all his obligations can be honoured before award of the contract.

(12) The items in the bill of quantities or other contractual financial document should reflect the method of construction. Similarity between the tendered prices and the contractor's costs will greatly aid evaluation of change and equitable adjustment of price for inflation.

(13) Throughout the implementation period of the project the client or his representative will inspect and approve the quality of workmanship of contractors and manufacturers. Again, an adequate number of staff with relevant experience must be employed. Prior definition and agreement of acceptable standards is essential and all parties should be aware of tolerances. There is a tendency for design engineers to specify unnecessarily high standards, the achievement of which may prove difficult and/or expensive. The desired quality of workmanship must always be considered in relation to the client's other prime

objective, usually timely completion and economical cost.

(14) Clients frequently underestimate both the extent and consequence of change. The project manager should assess rigorously the cost and benefit of all design changes before they are implemented. Priority should be given to timely completion of the project.

The better organized the contractor, the more likely it is that he is working to a tight, well-resourced programme. The disruptive effect of variation may therefore be serious.

Modifications to manufacturing plant are sometimes best implemented during some future shutdown of the plant for maintenance.

(15) Involvement in prolonged bargaining over claims is a sign of failure. Evaluate and agree payment for variations and claims as the job progresses. The valuation should be based on prices, resource output and efficiencies similar to those incorporated in the contractor's tender.

(16) Projects and contracts are managed by people who are directing and communicating continuously with other human beings. Great attention must be paid to the selection and motivation of staff. Personality and ability to think ahead are as important as technical know-how.

Project and contract management staff must be given adequate authority to manage in their dynamic working environment without continual reference to head office.

For both the client and contractor, one man in each organization – the project/contract manager – must ultimately be responsible and be known to be responsible, for the realization of the project or contract. Each must be identified with, and committed to, the project.

References

1 Institution of Civil Engineers (1979) *Civil engineering procedure.* Thomas Telford, London.
2 Hayes, R. W., Perry, J. G. and Thompson, P. A. (1983) *Management contracting.* Construction Industry Research and Information Association, Report No. 100, CIRIA, London.
3 National Economic Development Office (1983) *Faster building for industry.* HMSO, London.
4 Ninos, F. E. and Wearne, S. H. (1986) 'Control of projects during construction, *Proc. Instn Civ. Engrs,* **80**, 931.
5 Barnes, N. M. L. (1978) 'Human factors in cost control.' *Proc. 5th International Cost Engineering Congress.* Danish Association of Cost Engineers, Utrecht, pp. 244–248.
6 Neil, J. M. (1982) *Construction cost estimating for project control.* Prentice-Hall, Englewood Cliffs, New Jersey.
7 National Economic Development Office (1975) *The public client and the construction industries.* HMSO, London.
8 Power, R. D. (1985) *Quality Assurance in civil engineering.* Construction Industry Research and Information Association, Report No. 109, CIRIA, London.
9 Davies, V. J., Dodd, L. A., Mills, T. R., Tietz, S. B., Woods, D. R., Barker, J. E., King, F. W., Harlow, W. A., Summersgill, I., Rust, C. E., Eye, D. and Beagley, C. (1986) 'Conference on Engineering for safety.' *Proc. Instn Civ. Engrs,* **80**, 13–119; (discussion, February 1987).
10 *New Civil Engineer* (1986) 'ICE to press for greater safety enforcement', *New Civ. Engr,* no. 718.
11 Lumsden, P. (1968) *The line of balance method.* Pergamon Press, Oxford.
12 Thompson, P. A. (1981) *Organization and economics of construction.* McGraw-Hill, Maidenhead.
13 Institution of Chemical Engineers (1979) *A new guide to capital cost estimating.* Institution of Chemical Engineers, London.
14 Perry, J. G. and Hayes, R. W. (1985) 'Risk and its management in construction projects'. *Proc. Instn Civ. Engrs,* **78**, 499–520.
15 University of Manchester Institute of Science and Technology (1980) *Severn tidal power: sensitivity and risk analysis.* Project Management Group. UMIST, Manchester.
16 Science and Engineering Research Council (1987) *Risk management in engineering construction.* SERC, Thomas Telford, London.
17 Perry, J. G. (1988) *Contract strategies for construction.* Collins, London.
18 Perry, J. G., Thompson, P. A. and Wright, M. (1982) *Target and cost-reimbursable construction contracts.* Construction Industry Research and Information Association, Report No. 85, CIRIA, London.
19 Institution of Civil Engineers (1979) *Conditions of contract,* 5th edn. ICE, London.
20 Institution of Civil Engineers (1985) *Civil engineering standard method of measurement.* Thomas Telford, London.
21 Thompson, P. A. and Willmer, G. (1985) 'Caspar – a program for engineering project appraisal and management. *Proc. Civ. Comp.,* **1**, 83.

Bibliography

Abrahamson, M. W. (1984) 'Risk management.' *Intnl. Const. Law Rev.* **1**, 241–264.
Darnell, H. et al. (1986) *Total project management.* Booklets 1 to 3, The Asset Management Group, British Institute of Management, London.
Derrington, J. A. and Barnett, M. J. N. (1986) 'Civil engineering projects – what is value for money?' *Proc. Instn Civ. Engrs,* **80**, 1589–1596.
Franks, J. (1984) *Building procurement systems.* Chartered Institute of Building, London.
Gaisford, R. W. (1986) 'Project management in the North Sea. *Intnl J. Project Mangmnt,* **4**, 1.
Harris, F. and McCaffer, R. (1977) *Modern construction management.* Crosby Lockwood Staples, London.
Harrison, F. L. (1983) *Advanced project management.* Gower, London.
Kennawry, A. (1984) 'Errors and failures in building: why they happen and what can be done to reduce them.' *Intnl Const. Law Rev.* **2**, 5779.
Pilcher, R. (1985) *Project cost control in construction.* Collins, London.