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Department of **Training**
and **Workforce Development**

INTRODUCTION TO SITE MANAGEMENT DIPLOMA OF BUILDING AND CONSTRUCTION

CPCCBBC5003A

LEARNER'S GUIDE

BUILDING AND CONSTRUCTION



BC1900

Introduction to Site Management

CPCCB5003A

Learner's guide

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Training Sector Services

Telephone: 08 6212 9789

Email: sectorcapability.ip@dtwd.wa.gov.au

Website: www.dtwd.wa.gov.au

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Government of **Western Australia**
Department of **Training**
and **Workforce Development**

1 Prospect Place West Perth WA 6005
Tel: (08) 6212 9700 Fax: (08) 9227 8393
Email: sales@dtwd.wa.gov.au
Website: www.vetinfonet.dtwd.wa.gov.au

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Introduction

This resource provides an overview of construction management at what might be described as three levels. An outline of management contracting is followed by more detailed consideration of two very practical aspects of construction management, organisation and control at site level and the use of critical path network planning and its derivatives to establish project programs. As an adjunct to the latter, the final chapter looks at resource scheduling.

The outline of management contracting looks at the essential features of contractual arrangements commonly known as *project management* and *construction management* – and how they differ from the ‘traditional’ contractual arrangement.

Consideration of practical on-site management includes site assessment and layout, site mobilisation and on-site administration and control.

Finally, this resource presents an introduction to, and overview of, critical path network planning, whose principles form the basis for most of the project planning/programming techniques in common use today.

This revised text provides an excellent overview for those who may be charged with management – at site level – of a building project, particularly in the commercial/industrial sector. As such, it is especially suitable for use in the *Diploma of Building and Construction (Building) (Builder’s Registration)* course and other courses of similar academic standard.

It is a required resource for the following Diploma unit:

- CPOCBC5003A (WA state code W9290) – *Supervise the planning of on-site medium-rise building or construction work.*

* This resource is a revision and update of the third edition (1991) of an original work, *Building Organisation 2*, published by Technical Publications Trust, a forerunner of WestOne Services (now the Department of Training and Workforce Development).



Chapter 1

Management contracting

Conventional contracts

Contractive procedures have been developed over many years to reach the forms most generally adopted for building contracts. They are based on the appointment of a main contractor after a process of tendering on prepared documents. The **lump-sum contract** is particularly suited to the tendering process.

A lump-sum contract is an agreement between the parties for completion of the work for a **fixed price**. It may or may not include a **cost-fluctuation** clause, which provides for an adjustment where cost increases occur after the project has begun.

Not all contracts are obtained in this way. Other familiar forms of contracting include:

- **Schedule of rates** – This applies when the agreement is for the execution of specific works of inexact or unknown quantities. The total value of the contract is calculated by multiplying the actual quantity of work by agreed contract rates.
- **Cost-plus** – The client agrees to pay for the actual cost of the work and administration plus an agreed percentage for profit. This form of contract can be financially risky for the client.
- **Fixed fee** – This is similar to the cost-plus contract but an agreed fee is paid in lieu of the percentage for profit.
- **Design and build** – These package deals and ‘turnkey’ contracts are other common forms of contract.

Figure 1.1 illustrates the parties involved in what can be regarded as the most common contractual arrangement employed for projects which are medium to large in size.

This text in the main refers to medium-to-large projects.

Figure 1.2 draws a comparison between the ‘traditional contractual relationship’ and the ‘fast tracking’ approach to contracting as might be employed on very large projects. The horizontal arrangement of stages involved in these two systems indicates that the ‘fast tracking’ approach might produce significant savings of time.

The tendering process has some obvious advantages but it can also have disadvantages. Notable among the problems that can arise in competitive tendering are a lack of continuity from the design to the construction stage and the sometimes brittle relationships which can exist between client, consultants and main contractor.

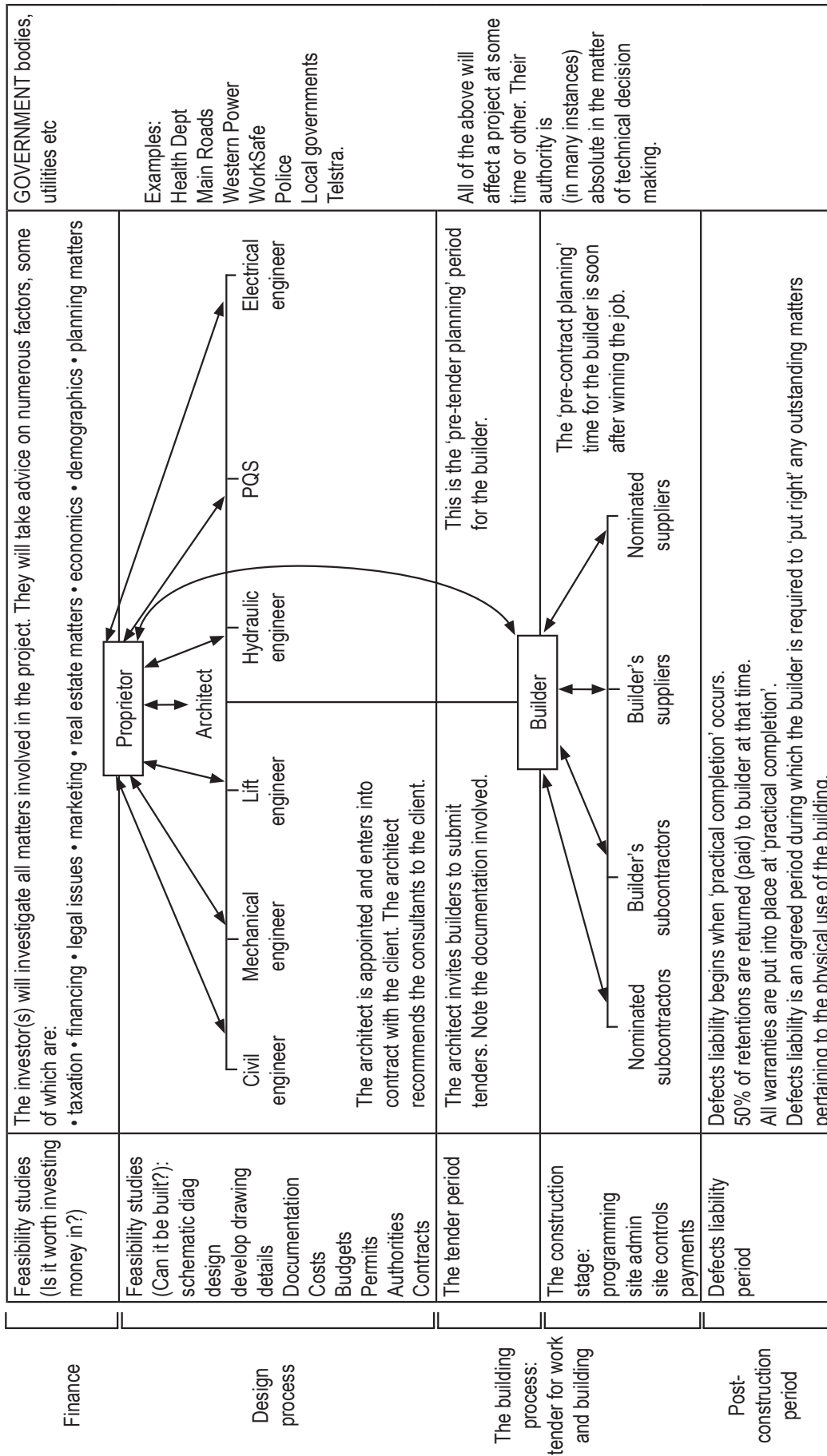
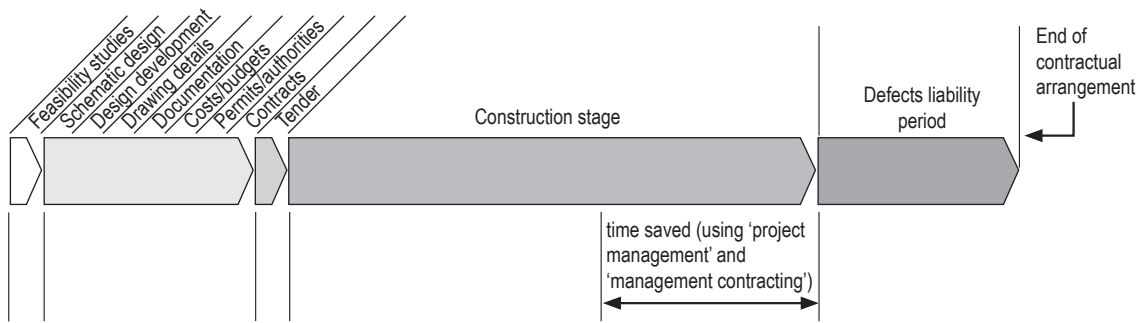
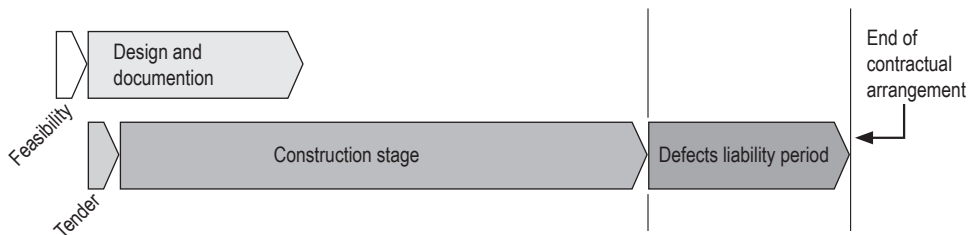


Fig 1.1 The 'traditional' (lump sum) contractual arrangement (architect-supervised project)

1. 'Traditional contractual arrangement' (see note)



2. 'Project management' and 'management contracting' (Text: pages 11–20)



As opposed to the 'traditional contractual arrangement', where all design/documentation is required to be completed *before* the project is let out to tender, 'project management' or 'management contracting' allows for only sections of design/documentation to be completed, eg footings/basement, by the time tenders are called, thus allowing work to begin significantly earlier.

Fig 1.2 Time scale comparison of differing contractual arrangements

Management contracting

Because of the size and complexities of present-day structures, greater emphasis is now being placed on the need for management expertise for major projects. An increasingly popular form of management which has developed relatively recently is **management contracting**. The concept is not confined to the construction industry but its use has increased steadily among those involved in project administration. The management contract is a growing form of construction agreement within the building industry in Western Australia.

The aim of management contracting is to bring together the common interests of all the parties in the construction process, for the ultimate benefit of the client. Management contracting tends to improve relationships and results in fewer claims being made. Many of the other forms of contract tend to place the various parties on opposite sides of the table.

Among authors of articles which refer to this method of contracting, there is still some disagreement about the precise definition of terms. In this text, reference will be made to two aspects of management contracting, namely *project management* and *construction management*.



Project management

Note: A heading numbering system is used here to help you.

1.0 Preliminaries

1.1 The project management concept:

The process of conceiving, designing and constructing projects involves a complex interface of skills, techniques and resources. Typically these centre on the areas of finance, marketing, architecture, engineering, economics and resource planning during concept and design and then constructional techniques and methods in the next stage.

The primary objective from the client's point of view is to produce a facility which optimises, within the parameters of time and cost, the following factors:

- economic return on investment
- architectural and engineering quality and design
- functional planning
- site usage
- standards and performance of services
- standards of construction and finish
- maintenance and running costs.

In order to achieve this objective, it is necessary to utilise modern management techniques and skills. Essentially, these involve the organisation, planning and control of the many skills, techniques and resources involved in production procurement.

The project management concept identifies and separates the management function required from all the other skills and functions directly concerned with the design and construction.

In this way the client, through the project manager, has the ability to control the total process, in the most efficient and effective manner. The degree to which this is achieved will depend not only on the project management concept but also on the management expertise and experience of the project manager.

1.2 The definition of project management:

Project management is the overall planning, control and coordination of a project from inception to completion aimed at meeting client requirements of completion within time and cost and to required quality standards.

2.0 Client obligations

2.1 Preliminary considerations for the client to address include:

1. clearly defining the objectives and terms of reference of the project
2. the degree of authority to be delegated to the project manager
3. the specific responsibilities and duties of the project manager
4. ensuring the project manager acts exclusively as the client's agent
5. the objectivity and impartiality of the project manager
6. the accountability and consequential liability of the project manager
7. the personality, integrity and leadership qualities of the project manager

8. the qualifications, expertise and experience of the project manager
9. fees and charges for the project management services
10. conditions for determining the project manager's services
11. form of agreement and contractual relationships with the project manager.

2.2 General functions:

The functions of a project manager can be wide and varied depending upon the project and the role determined for the project manager.

Project management services may include but are not necessarily limited to the following activities:

1. defining the client's requirements and developing the project brief
2. assessing the financial and technical viability of the project
3. advising on site location and suitability
4. advising on project financing
5. management of the overall project program and time control
6. evaluating government controls and requirements and advising upon and seeking relevant approvals
7. selection of architects and consultants and advising on their conditions of engagement
8. development of project budget, economic design evaluation and cost control
9. conceptual design and planning and the evaluation of alternative proposals
10. setting meeting procedures and times of communication for the project team
11. establishing and maintaining the various reporting procedures and mechanisms required by the client
12. preparation of contract documents
13. advice on tendering methods and procurement of building contractors
14. construction management
15. quality control management
16. valuation of work in progress and payment certification
17. construction cost control and accounting
18. management of completion and commissioning
19. property management
20. project publicity and public relations.

3.0 Project manager's obligations

3.1 Basic requirements:

The project manager should undertake the following –

1. translate the client's requirements and needs into a project brief and program of work in quantitative and qualitative terms, to accomplish the objective
2. identify and define all management and technical functions and establish their parameters
3. ensure that all systems, procedures and controls are properly established and carried out throughout the project



4. establish the responsibilities and duties of all project team members and organise and effectively control their respective functions and performance, including defining all interfaces between members so that they carry out their tasks efficiently
5. ensure that progressive review takes place in regard to the scope, cost and time of the project so that effective control is achieved
6. evaluate changes promptly and make recommendations where necessary
7. evaluate the status of the project at regular intervals, check performance, resolve problems and take corrective action to maintain the project objectives.

3.2 Defining client's requirements:

The project manager, in conjunction with the client where applicable, will do the following –

1. define those items of process, design, procurement and construction which are the responsibility of the client
2. determine the form of construction, materials and equipment required
3. evaluate existing engineering data and information applicable to the project
4. complete all investigatory work relating to the site, including surveys, soil tests etc where necessary
5. evaluate the economic feasibility of the project and the method of funding if required
6. advise on the selection of the project team and their conditions of engagement.

3.3 Conceptual design and planning:

Initial planning and design concepts are developed from the client's brief. Out of this will arise the broad parameters of time, cost, space, design and logistics which relate to the project. The project manager will prepare, or arrange to have prepared, design concept drawings and reports which will include –

1. evaluation of alternative designs
2. preliminary engineering and architectural sketch plans
3. preliminary specifications for the work
4. flow diagrams and process charts regarding planning layouts, selection of plant, storage requirements and general functions required in the finished facility
5. investigation and review of all statutory requirements, including building permits, approvals, zoning requirements and health and environmental controls
6. a detailed budget and cost plan for the project, including economic evaluation of the design proposals
7. an overall project time schedule indicating the major facets of the project and identifying all key decision points
8. line diagrams showing the management structure and lines of authority and communication in the project team and the project manager's proposed method of operation.

3.4 Budgeting and cost control:

The project manager will provide a detailed cost planning and control system to ensure that the project achieves the maximum value for money within the client's parameters.

This is achieved by –

1. constant monitoring and review of the project budget throughout design development, documentation and construction stages, to ensure that the project budget is maintained within the agreed limit
2. establishing cost control and reporting systems to achieve the above
3. carrying out value analysis, life cycle costing, cost–benefit analysis etc as required
4. preparing project cash flows.

3.5 Project accounting:

The project manager will establish accounting procedures and cost controls which will be subject to audit, covering –

- management
- planning and designing
- fees and disbursement
- purchases
- construction costs
- inspection costs
- commissioning costs
- property management costs.

3.6 Programming:

The project manager will establish in conjunction with the project team a detailed time schedule of all activities required for the design and construction showing all key dates and prepare regular updates and reports throughout the project. The program will include –

- design
- early procurement and delivery of materials, plant and equipment
- approvals
- tender dates
- construction activities
- completion and commissioning.

3.7 Reporting:

Comprehensive reporting mechanisms will be established to keep the client fully informed on all aspects of the project at regular intervals. Reports will cover –

- expenditure compared to the project budget and estimated cost at completion
- progress – compared against the program and indicating work completed and work still to be completed
- required modifications to program and budget
- design changes.



3.8 Project organisation:

Project organisation should be specifically structured to the size, complexity and scope of the project. The composition of the design team will vary but would normally include members specialising in design, costing, documentation, programming and construction.

3.9 Design and documentation:

The approved schematic concept is fully developed into a detailed design and contract documentation prepared in accordance with prevailing performance standards.

The project manager coordinates and controls this process, which includes –

- surveys
- constructional details
- specifications
- materials usage
- building and engineering design
- external works
- operational standards
- working drawings
- quantity surveying.

3.10 Construction:

The project manager should advise on the method of contracting the building works. Methods commonly in use today include –

- lump-sum contracts
- construction management
- negotiated contracts.

During the construction phase, the project manager carries out – or arranges for the construction manager to carry out – the following functions –

1. regular inspection of the quality of work to ensure that it conforms with the documentation requirements
2. valuation of the work in progress and certifying all payments
3. evaluation of all scope changes with respect to time, cost and design effects
4. monitoring safety requirements
5. advising the client on industrial relations matters
6. monitoring the project budget, controlling the cost of all variations and providing reports on the budget status at regular intervals.

3.11 Commissioning:

The project manager ensures that the project is successfully completed and then provides the following services –

1. all necessary pre-commissioning checks on all systems and services in the building
2. certification of the completion of all parts of the works

3. handing over to the client of all certificates, warranties and guarantees
4. certification of the final account
5. monitoring of the defects liability period and release of securities.

4.0 Fees and charges

Payment for project management services may be through any of the following.

- Lump sum
A total fee may be applicable where the scope of service to be provided and the facility are well defined.
- Percentage fee
A percentage of the final cost of the facility may be applicable where scope of service is reasonably defined and some innovation in the facility procurement is required.
- Combination fee
This effectively combines the lump sum and percentage fee where a facility has a portion that is relatively standard and another part that is deemed to be innovative and difficult to define in overall scope.
- Cost-plus fee
This method may be applicable to a relatively innovative or complex project where new ground has to be broken in a number of different aspects. The cost portion is based on the number of person-hours used in design, procurement and construction activities. A fee based on a percentage of the final cost of the facility is added.

It should be emphasised that no particular method of remuneration is exclusive in its area of utilisation; negotiations between the client and project manager are required, as each facility is unique.

5.0 General

The following areas of activity might be included in the project manager's brief, subject to negotiation:

- property management – advising the client on the sale or leasing or management of the facility
- project publicity and public relations – carrying out, or arranging, publicity and public relations activities on behalf of the client
- operations management – carrying out, or arranging, the preparation of operation and maintenance schedules and programmes together with likely budgets for control purposes
- inventory – preparing depreciation schedules and inventory of client fit-out items
- staff management – undertaking, or arranging, selection and training of staff for the facility.



6.0 Further points

Other issues which deserve consideration by both the client and project manager and would need clarification in the conditions of engagement include:

- responsibility/professional indemnity
- termination of commission of project manager and consequences thereof
- disputes between client and project manager
- delays in overall process – consequences thereof.

Construction management

Construction management concerns the management of the construction phase of a building project. In its traditional form, the builder is the construction manager for any project undertaken in which they have a commercial interest. With management contracting, the role's key objective is the management of the construction phase within the total project. The role is more one of management than building, though thorough knowledge in both fields is a definite advantage. Management is by way of a professional service and not as a commercial venture.

A construction manager may be appointed in any of the following ways:

- by direct negotiation with the client
- on the recommendation of the client's project management team
- by approach by the client or project manager to suitably qualified people or companies, inviting them to express an interest in fulfilling the role of the construction manager.

Once an appointment is made, the construction manager becomes part of a professional team and will be required to fulfil a number of duties and functions which could include the following:

1. provide advice to the design team on various aspects of work such as construction methods and 'buildability' during the latter part of the design development stage and throughout the documentation stages
2. prepare detailed schedules of works and construction programs to meet the established deadline. This will include ensuring adequate lead times for materials, manpower and construction sequences before start of work on the site.
3. contribute to the preparation of budgets and provide cost inputs in conjunction with the quantity surveyor for the project
4. provide the management, infrastructure, construction equipment and incidental labour in agreed ways and to agreed cost formulas
5. carry out the necessary liaison with authorities normally carried out by the building contractor on projects
6. advise on timing for calling of subcontractor tenders, call tenders at the required times, collate tender results and provide written reports advising the design team and client on the cost-effectiveness of tenders, to enable the selection of the most suitable subcontracts in relation to the budget and project timing
7. formulate subcontract agreements for the client and arrange the legal execution of those documents
8. with reference to the programs and schedules, ensure documentation is available on time to call tenders and to arrange purchase of long-lead-time items

9. analyse and report on the availability of all necessary skills and labour to be engaged and materials to be ordered, as required
10. advise upon and control all labour relationships on site, including taking responsibility for any industrial relations matters which might arise during construction
11. be a party to all decisions regarding proper insurance cover and ensure that all risks are minimised throughout the duration of the contract
12. inspect all work and maintain quality control on the site and arrange for inspections by the design team throughout the construction period
13. continually upgrade and monitor the schedules and programs and ensure proper control of these vital management aids is maintained
14. assist and advise and report on the upgrading of budgets and costs as 'real' figures become available
15. prepare written assessments in all decisions regarding the checking and payment of subcontractors' accounts and arrange the payment of accounts and carry out various agreed roles in these matters
16. report on all relevant matters to the design team and the client at regular agreed intervals
17. provide sufficient personnel to handle any problems occurring within the building for a specified period from the date of practical completion, ensuring all maintenance agreements are fully implemented and any defective work or materials are replaced or properly repaired
18. generally ensure that the client's interests are being maintained and act on the client's behalf, when and wherever necessary throughout the duration of the contract.

Client's obligations

1. Inform the construction manager in writing of the requirement for the project.
2. Nominate in writing to the construction manager a delegate who will represent them in the event of the client's absence.
3. Retain the services of a team of consultants as deemed necessary for the project.
4. State, in writing, the roles and responsibilities of the members of the project team and advise of any changes.
5. Provide and accept responsibility for all surveys and soil reports on the works site as well as information on legal limitations and location of public utility services on the site.
6. Ensure the construction manager is, without charge, provided with all documents necessary for the execution of the works.
7. Accept responsibility for the cost, accuracy and adequacy of all information made known to the construction manager by the project team.
8. Obtain any necessary approvals and pay any charges required for the works to proceed.
9. Provide necessary insurances.
10. Immediately advise the construction manager of any defaults or defects.
11. Provide necessary plant and equipment for the works where not required to be supplied by subcontractors.



12. Ensure that all communications by the client and project team are through the project manager.
13. Provide legal and auditing services necessary for the project.
14. Seek advice from the project team on industrial matters before making any decisions.

The construction manager's fee may be:

- a lump-sum fee paid by instalments
- a fee calculated as a percentage of the cost of the works *or*
- a fee paid monthly based on an hourly rate for the hours worked by employees of the construction manager.

Conclusion

- Management contracting provides improved management and coordination and a closer link between consultants and managers, as well as a fully economic and competitive price for the project.
- The difference between project management and construction management is that, in the former, the manager's role is from project inception to project completion, whereas the construction manager's role is principally in the construction stage.
- The selection of project and construction managers and members of their teams is of crucial importance to the success of the project. Each project has particular needs and it is essential that these be analysed with care so that the best possible team is selected. It does not necessarily follow that a successful team on one project will be successful on a project of a different nature.

Chapter 2

Planning

Introduction

In the building industry, as in any other form of business, planning is impossible unless every component of an organisation contributes its share to the total result. Whether they realise it or not, the work of every section is in some way concerned with the unfolding of a plan.

Each year, hundreds of millions of dollars are invested in buildings. This represents a significant slice of the capital investment of the nation.

Considerable savings have been made by the introduction of new materials and methods, in addition to fundamental changes in structural design.

Buildings have changed in design but so also have the management (skills) and methods used to construct them. The management skills required to run a successful nineteenth century building firm were insignificant compared with the skills required today to manage the complex organisation of a modern contractor capable of dealing with fierce business competition. The present size of many of our larger national contractors would not have been possible under the management methods of the past. To be concerned with change is to be concerned with the future.

In management, 'planning' is consideration of the future. It is a basic executive responsibility.

Planning is an intellectual process involving creative thinking.

Purpose of planning

Planning for a project will:

- enable the proper phasing of operations with balanced labour gangs in all trades, to ensure continuous productive work for all the operatives employed and reduce unproductive time to a minimum
- determine attendance dates and periods for all subcontractors' work
- provide information on material quantities and essential delivery dates, the quantity and capacity of the plant required and the periods it will be on site
- provide a simple and rapid method of measuring progress at any time during the contract – for the builder's information, the architect's progress certificates or the valuation of work for accounting purposes.



Benefits of planning

1. Major decisions are made in advance, while last-minute decisions are avoided.
2. Programs are realistic if based on calculations and selected methods.
3. Designers are assisted in supplying information in the correct sequence and at the right time.
4. Work is more carefully coordinated for the economical use of labour, plant and materials, so that time and money are saved.
5. Site personnel know what they need and fewer emergencies arise.
6. Material handling is minimised if storage locations are planned.
7. Careful short-term planning is essential to the pre-measuring of bonus operations and their person-hour targets.

Planning in the building industry

Planning and controlling building work are so closely linked as to be inseparable. Certainly, no project manager can properly control a project that has not been planned, for the very meaning of control is keeping site operations on course by correcting deviations from the program.

Any attempt to control without planning would be meaningless. The old method of discovering errors, mistakes or omissions after the damage has been done, and then applying pressure, is grossly inefficient.

Through planning it is possible to prevent problems arising or to minimise them, as in the case of a systematic plan for replacing a builder's mechanical plant at regular intervals, to assure a continuous availability of efficient equipment on site. In more complex situations, a builder frequently finds that the pressures of problem situations call for an extra planning effort.

Time is a central element in planning. Time spans with which planning is concerned range from relatively long to relatively short terms.

Short-term planning is concerned with the comparatively near future. Plans for the next month, or even the next six months, are short-term plans. Short-term planning is used to review work progress at regular intervals – that is:

- plan labour utilisation
- communicate requirements to subcontractors, tradesmen and suppliers
- correct problems at an early stage before a major error develops.

It is important to grasp that a long- and a short-term plan are two aspects of the same continuous process. Success in planning depends on the ability of management to achieve an integration of the two.

Short-term planning can be successful only if carried out in the context of adequate long-range planning – that is, if the time factor of the long-range plan has been taken into account in the preparation of the short-term plans. For example, the preparation of a plan for the construction of a typical floor of a multistorey building is in itself a short-term plan but it is also an essential and closely integrated part of the master plan for the construction of the complete building.

Basic steps in developing an overall plan

Planning in the construction industry often presents difficulties because of the number of 'one-off' situations.

Buildings are complex in both design and the construction techniques used; therefore, management is rarely in a position to know what would have happened if an alternative decision had been made.

Each builder must decide for themselves the methods of planning which work best for them. But it is possible to suggest various planning procedures which should prove generally useful.

Some basic steps of analytical planning are as follows:

1. Define the problem to be solved.
2. Obtain as many relevant facts as possible; organise the available information.
3. Analyse the information.
4. Select the alternative courses of action.
5. Weigh the alternatives and decide which one seems best to meet the situation.

Techniques of planning

Planning begins by asking the following questions about the work to be done: **what? where? who? how?**

The answers are then used to decide when to employ the available resources of **men, materials, machines, methods** and **money**.

Then decisions are made in the light of objectives and the best standards of **cost, profit** and **time**.

Task	Example question 1	Example question 2	Is there an alternative?
Material	What is needed?	Why that much?	Would other materials do?
Machines and work place	Where is the work to be performed?	Why there?	Can it be done anywhere else?
Method	How should the work be performed?	Why that way?	Would another way be more effective?
Men	Who is to be used?	Why them?	Could anyone else be used?
Money	What money is required?	When will it be required?	Can other arrangements be made?

Example of a planning technique



Characteristics of effective planning

Planning helps a company to remain competitive with others in the same industry. Planning may involve expansion of service departments, such as mechanical plant maintenance, for instance, or give rise to improved techniques, for example standardisation of formwork design in reinforced concrete work, and so on.

It is broadly accepted that among the main characteristics of an effective plan are that:

- it is based on clearly defined objectives
- it is simple
- it establishes standards
- it is flexible
- it is balanced
- it uses available resources to the utmost.

Planning is an executive function which helps to provide purpose and direction for the members of an organisation.

Obstacles to effective planning

We are all accustomed to planning, if only for a future social event or an annual holiday. However, planning by the individual is likely to be simpler than that required by even a small builder, to say nothing of an organisation with branches all over the world.

External forces such as laws, government regulations, trade associations and the actions of competitors may impede or influence the effectiveness of planning by commercial organisations.

Managers often do not plan as well or as thoroughly as maximum effectiveness in their work requires. This is not entirely their fault, since many factors which lead to incomplete planning are beyond their control. However, managers can improve their planning, firstly by understanding the obstacles and, secondly, by taking specific steps to minimise the influence of these obstacles.

Unforeseen and unpredictable events

In building, as in all human affairs, it is not possible to foresee with certainty all that may have serious consequences for our plans. For instance, in WA, the effects of a cyclone drifting unusually far south could seriously disrupt a Perth project's program.

Therefore, planning can only be based on what is known in the present and modified (if necessary) by what one can judge or anticipate might or will develop in the future.

People vary in their ability to see ahead, so foresight is often listed as one of the desirable qualities of the successful executive.

Mental factors

Planning requires a difficult kind of thought process – the ability to arrange a complex array of ideas and to see various possible combinations of effects. Thought requires effort and not everyone enjoys thought or effort. Planning often involves the uncomfortable contemplation of unfortunate and undesirable possibilities and arouses reflections on errors of the past. To those who are inclined to be optimistic in their outlook, planning requires that possible unfortunate occurrences also be factored in.

The executive who by nature is motivated by action may not be favourably inclined to sit at their desk and think. Further, intellectual activity is sometimes ridiculed by those who lack respect for it.

Creating is usually best achieved in a comfortable and relaxed atmosphere – although, in the building industry, strains, pressures and tensions may make it difficult to find one.

It should be realised that planning is not a ‘frill’ or luxury to be enjoyed by large companies which can absorb the costs; on the contrary, it is a prime necessity of any company which wishes to operate efficiently. The fact that some companies may operate without good planning techniques proves nothing. The end result would be improved if they did plan.

Planning is one of the most important tools of economical construction – and the search for better ways of doing things is never-ending. Today’s methods, however successful, can never be taken as wholly right. They represent simply the best efforts of the moment. Future trends may bring improvements in these methods.

Policy planning

A further division in the planning process is concerned with the operation of the business as a commercial undertaking and is referred to as policy planning. This is concerned with the overall means of achieving the aims of the business as established by company directors or principals. For a business to survive, it is important for management to try to forecast future developments and demands. The success or failure of the business depends to a large extent on the astuteness of this assessment.

The policy of an organisation should be set down in writing and include, among other things:

- the objectives of the business and the functions it will perform
- the financial structure of the organisation, including limits of working capital and the anticipated profit on this capital
- a time scale. The policy should be reviewed regularly to assess the accuracy of the forecasts and to establish whether developments are going as anticipated. Checks can also be kept on new ventures to establish whether they show signs of being profitable – if not, consideration may need to be given to withdrawing from them.
- the scope available to the business. When considering scope, management should think of the possible markets available to the business. A builder, when planning the business policy, could consider the following –
 - Should the business remain at its present size and structure?
 - Is it feasible to expand its activities within its present market?
 - Is there scope to diversify into other related and/or unrelated markets?



To be more specific in relation to markets, a building or construction company could consider, for example:

- diversifying into different forms of construction, for instance tilt-up construction
- entering into the domestic (house building) market
- building or purchasing properties with a view to becoming a property developer
- establishing a real estate agency to buy and sell properties.

Chapter 3

Pre-tender planning

Planning procedures

The previous chapter set down general guidelines for planning. In the building industry, planning procedures can vary from company to company. Some of the factors which may contribute to variations in planning procedures are as follows.

- The size and management structure of the company – size may refer to annual financial turnover or number of employees. A company with a large annual turnover may not employ a large workforce but rely on subcontract labour to perform work packages within each field of competence. This method is common in the building industry.
- The type and range of work undertaken – companies generally limit the scope of the work they undertake as a result of the company's policy plan as laid down by the board of directors or company principal. Broad subdivisions within the building industry include:
 - residential – single dwellings to multiple units
 - industrial – 'heavy' and 'light' projects
 - commercial – low- to high-rise.
- Location of the work – companies located in cities or towns and planning for projects some distance away need to ensure that planning is precise and well communicated.
- Expertise – planning procedures will be influenced by the technical and managerial expertise possessed by a company.

Planning stages for project development

The stages of planning through which a project is developed, starting at the tendering stage and finishing with the handing over to the client, will be discussed in three parts:

1. pre-tender planning
2. pre-contract planning
3. project planning.

Purpose of pre-tender planning

This is the planning performed during the preparation of an estimate as a prelude to the tender being submitted. It involves a systematic approach to anticipating or forecasting the *probable* cost of construction.

The object of pre-tender planning is to reduce or eliminate the risk of inaccurate opinions influencing decisions which affect the pricing and the estimate. By harnessing the resources and experience of the company to guide the estimator when they are



considering items of risk, or more difficult structural problems, the estimator is better able to make a realistic and accurate assessment of the work involved.

It is important that inclusiveness is practised throughout the preparation of an estimate. Decisions which will affect the cost of the job should be made by the estimating department – but always in cooperation with the other members of the builder's construction staff.

Ideally, pre-tender planning meetings should be arranged from time to time in order that more important matters can be discussed fully and the facilities of other specialist departments within the builder's organisation, as well as the expertise of professional specialist consultants if necessary, can be called upon.

The tender planning team

The estimating department

On very large projects, this may consist of a team of estimators who are coordinated and controlled by a senior estimator. It is the responsibility of the estimating team to collate all relevant information, assess risk factors involved and establish an estimated net cost of construction.

The construction staff

It is common practice for the builder to appoint a construction manager who would be responsible for the work should the tender be successful. The manager acts in an advisory capacity during the pre-tender planning to help the estimators reach major decisions affecting the use of plant, method of construction etc.

The purchasing department

In order to keep up to date with the prevailing materials supply situation and general market trend in prices, the purchasing staff should be constantly available to help and advise in the establishment of realistic prices and competitive quotes.

Specialist consultants

From time to time, it may be necessary to co-opt the assistance of specialist consultants from outside the organisation in order to establish the procedures to be adopted in specialist areas such as lift installation, air-conditioning and so on.

Planning the tender

During the preparation of the tender, the planning matters listed below should be dealt with. These stages of pre-tender planning would be carried out systematically, to provide the estimator with information as and when required:

1. the pre-tender report
2. the method statement
3. the plant schedule
4. site organisation structure
5. schedule of site on-costs
6. subcontracting arrangements
7. pre-tender program
8. estimate finance statement.

1. The pre-tender report

This should be a comprehensive document containing matters of general interest, including:

- general descriptions etc (eg directory of people involved)
- site investigation report
- local conditions in the area
- other factors (eg lodgings, accommodation).

The pre-tender report must be concise and to the point. It should follow the same sequence of operations as that used in the contract documents and the contractor's method of estimating.

So far as the builder is concerned, it should be considered an official document and should be properly presented – that is, typed in double spacing on good-quality paper with a wide margin on one side and contained in a suitable cover bearing the title. At the start it should show details of the contract, such as the names of the client, architect and quantity surveyor etc. The title page and cover should set out a description of the works, the location and correct postal address.

The report should embrace the results of a detailed site investigation and information regarding local conditions. Too much information is better than too little; nevertheless, do not provide irrelevant details or give unnecessary advice. Try to avoid any form of ambiguity. Simplicity is essential; consider each entry and be satisfied that its meaning cannot be misunderstood.

Site investigation

It is difficult during estimating to reach decisions concerning the intended methods of executing the work unless the builder is fully conversant with site conditions.

Care must be exercised when carrying out a methodical and detailed investigation into the site and local conditions. It is the ideal arrangement to organise a meeting on site with the estimator and a member of the construction staff so that answers to queries can be obtained on the spot. These matters are recorded and form part of the permanent site documents should the tender be successful. The estimator should compile a list of questions in the light of their experience – on site, they need a clear mind to observe and investigate unusual features. The more comprehensive the checklist of points for clarification, the better it will be to make those special investigations so essential to building up a really useful report.

2. Method statement

This is a schedule giving recommendations for methods to be employed for site operations – and is one of the most important matters to be considered at the pre-tender stage. The method statement is a 'communication' and is intended as a means of instruction to management at site level with regard to practices and procedures for various construction operations, together with quantities involved, plant utilisation and the programmed time which is involved.



The advantages of a method statement are:

- It describes the carrying out of particular site operations (often where special methods/equipment and/or hazards/restrictions are involved). It also provides an assessment of –
 - items of plant/equipment to be used
 - estimated duration based on known outputs.
- When finalised at the pre-contract planning stage, it helps the contractor in formulating their overall building program – in particular, operational durations.
- Plant, machinery and equipment requirements can be assessed and allocation planned.

Types of method statement

Two basic types of method statement are used in the construction industry:

- **outline method statement** – used during the pre-tender stage of a contract and referring to major operations only, outlining the overall method to be adopted, together with labour and plant required and durations involved
- **detailed method statement** – often presented at the pre-contract planning stage.

Note:

- The pre-tender stage refers to any activities which are required to be performed by the builder from the time they become involved in the concept to the time they submit a tender for consideration.
- The pre-contract stage refers to that period after the signing of the contract when the preparation and organisation of company resources is finalised before the actual start of work. As such, it is in fact a 'pre-construction' period.

Outline method statement			
Project title : A site			
Address : Anywhere St : Perth WA 6000			
Project Manager : Joe Bloggs		Architect : DR Awning, AAIA	
Activity	Method employed	Quantity/item	Duration of activity
Pour concrete to columns (all levels)	Pump (refer to plant schedule for details)	1 No.	Construction period of RC frame. Hire in item as required.
Ditto, to beams and slabs	Ditto	1 No.	Ditto
Make and fix steel reinforcement to columns	Assembly completed in nominated area. Hoist into position by tower crane.	Column steel for 50% of floor level	Construction period as per program
Ditto formwork	Ditto	Ditto	Ditto
Concrete to columns	Concrete pump	Concrete pumping to 50% of erected columns	Ditto
<p>In the above example, the brevity of the statements would suit the pre-tender requirements, ie the need is for brief statements and to avoid undue expenditure of time and money.</p> <p>There would be little merit in producing a series of detailed statements – which would cost a significant amount of money – only to find that the tender bid submitted by the company fails and the contract goes to another builder.</p> <p>The outline method statement is the basis on which a more detailed statement can be made if the company's bid proves to be successful.</p>			

Fig 3.1 Example of outline method statement

Detailed method statement						
Project: Any building		Prepared by:				
Location: Anywhere		Date:				
Version number:						
No	Operation	Quantity of material involved	Method	Sequence of operations	Plant and equipment requirements	Output
1	Clear site and excavate to basement	3500 m ²	Use wheeled FEL and 4 x 10-tonne trucks to load and cart away to tip, as required.	1 Clear site. 2 Excavate to basement.	1 x Terex TL260 FEL with 2.5 m ³ bucket for rock and 2.8 m ³ bucket for earth 4 x 10-tonne capacity tipping trucks	50 m ³ /hr for FEL
8	Hoist steel reinforcing bars from ground floor storage area to required floor slab level	1 No. Bundle of steel reinforcing bar	Container for reinforcing bars with slings and shackles	Hoist from ground level to required floor level.	JASO J-140N tower crane 58.85 m jib, with 2200 kg lifting capacity at 58.85 m Container for steel bars, including slings/shackles	To satisfy supply requirements of steel fixing
<p>In this example, the information is detailed in that it can be used by site staff to assist in the programming of the works.</p> <p>The operations shown above are random samples taken from a method statement.</p> <p>Detailed method statements are devised at the pre-contract planning stage, being developed from the outline method statement (see previous diagram). It might be presumed that the site staff for the project could develop this format.</p>						

Fig 3.2 Example of extract from detailed method statement

3. Plant schedule

After the presentation of the method statement, a summary of plant requirements should be drawn up in the form of a schedule of mechanical equipment intended for use on the project. This summary must show the type of equipment required, all ancillary equipment and the anticipated period of use.

Plant schedule							
Project: Any building							
Location: Anywhere							
Plant item	Output	Dates		Working days required	Ancillary equipment	Rate per hour	Operation/ comments
		On site	Off site				
Terex TL260 front-end loader with two No. buckets – 1 No. as 2.5 m ³ and 1 No. as 2.8 m ³	20 m ³ /hr for rock. 50 m ³ /hr for earth.	12/06/2012	07/07/2012	9 days	Light material bucket with bolt-on cutting edge for use during site clearance	To be finalised	5-day working week. Weekend/ after hrs work is prohibited.
JASO J-140N hammer head tower crane – max jib reach of 58.85 m, 2200 kg lifting capacity at maximum jib reach	N/A	From commencement to completion of project	As stated	Project period	Additional items, eg kibbles etc for walls, columns etc, to be ordered in as required	Company-owned unit	Agreement with adjacent owners has been made concerning jib reaching over properties.
<p>The plant schedule will complement the method statement to the extent that additional information concerning the individual plant items is given in this document.</p> <p>The format applicable to this schedule can be 'outline' or 'detailed', as is the case with method statements.</p> <p>Dependent upon the size and complexity of the project and the amount of plant/equipment required, it could be that the detailed method statement will contain enough information concerning plant/equipment items, which would render the plant schedule superfluous.</p> <p>As with the method statement, this schedule would be most useful at the pre-tender stage.</p> <p>It should, as with the method statement, be derived from information gleaned from the site investigation report.</p>							

Fig 3.3 Example of plant schedule



Consideration must be given to the capabilities, capacities, limitations and outputs of different plant available.

Take excavation, for example. The first step is to decide which item of plant is most useful. The choice of plant will then be influenced, for example, by the type of excavation, the nature of the soil, the volume of soil involved and the distance it must be transported.

4 & 5. Site organisation and site on-costs

These are the site overheads that will have to be charged to the project. They are, in fact, items which cannot be priced in the course of the normal productive work and will include:

- site staff required for administration
- temporary roads and hoardings
- site huts
- offices and stores
- temporary services.

Site supervisory or technical staff will be calculated in relation to their administrative time. Initially, site accommodation requirements are based on a site organisation chart. Industrial awards may determine minimum accommodation standards.

Following is an example of a site staff requirement chart which could be used to determine the extent of site administration salaries and accommodation requirements, so the ongoing costs of that particular item can be estimated.

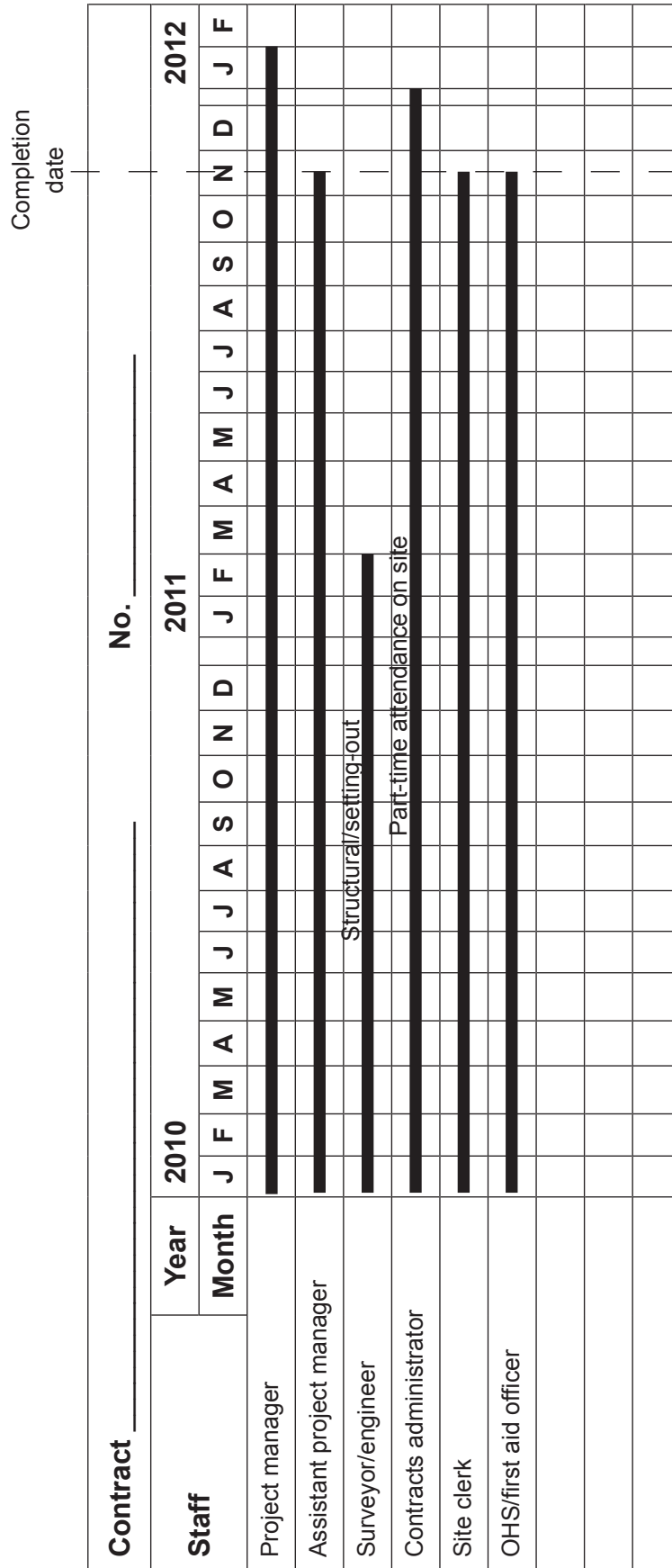


Fig 3.4 Example of site staff requirement chart



6. Subcontracting arrangements

Below is an example of a chart used to estimate subcontract labour requirements for a project.

Subcontractor requirements															
Contract _____															
Contract no. _____															
Subcontractors	Year														
	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Carpenters		4	4	6	8										
Bricklayers				8	8										
Steel fixers			6	6	6										
Labourers				8	8										
Plumbers															
Electrical															
Plasterers															
Tilers															
Total		4	10	28	30										

Fig 3.5 Example of subcontract labour requirements chart

7. Pre-tender program

The pre-tender program is an important reference in relation to estimating the cost of the project initially, as it outlines the main operations involved on major subcontract areas of work.

Once the construction methods and resource requirements have been determined, a pre-tender program can be produced. This program is used to help minimise problems and help coordinate planning schedules to try to ensure completion of the project within the stipulated period. It can be used at a later stage as a guide for preparing a more detailed master plan.

Figure 3.6 below is an example of a pre-tender estimate timetable, which is prepared to ensure that the tender for the project is finished by the closing date. Figure 3.7 is an example of a pre-tender program.

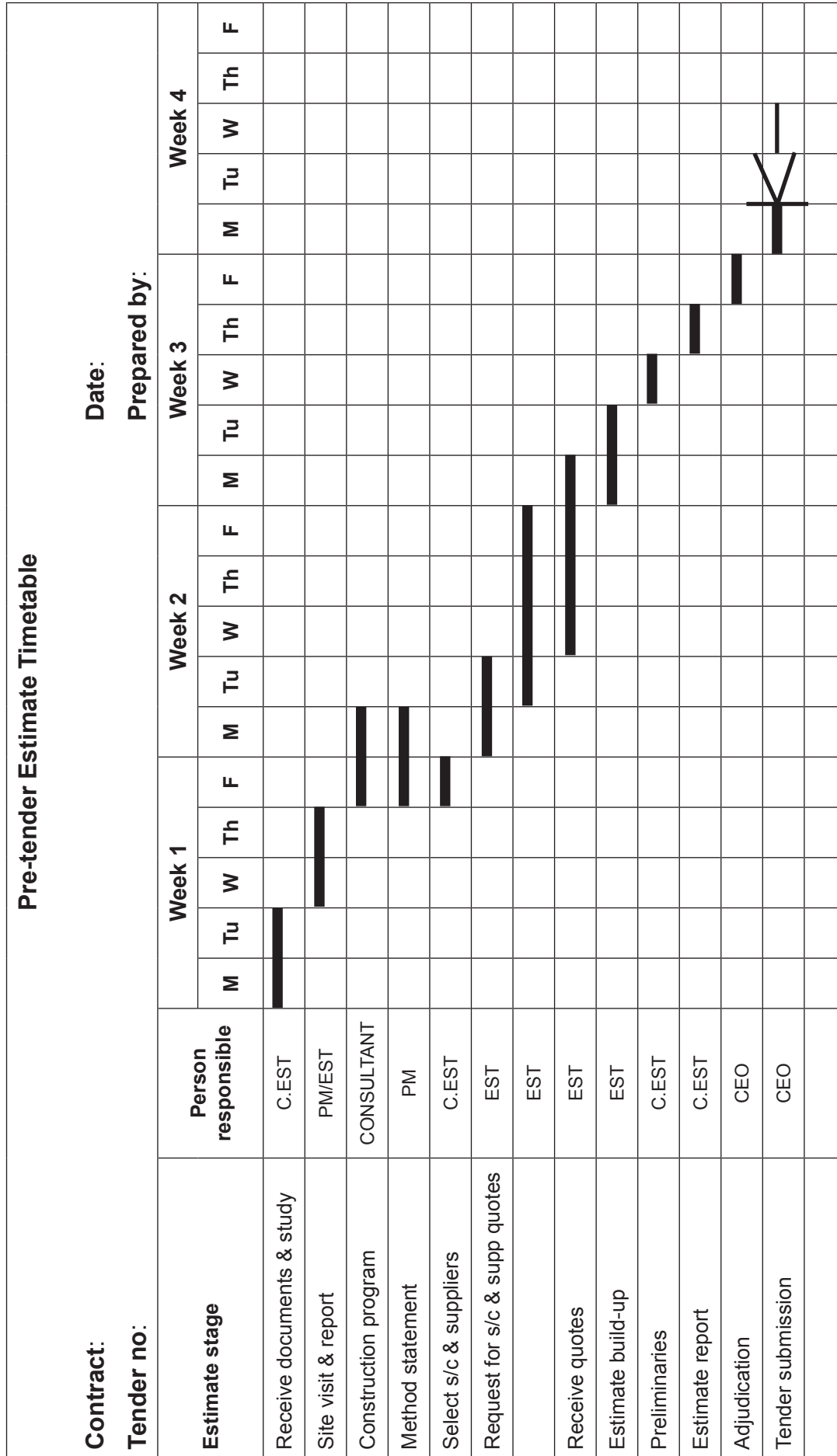


Fig 3.6 Example of pre-tender estimate timetable

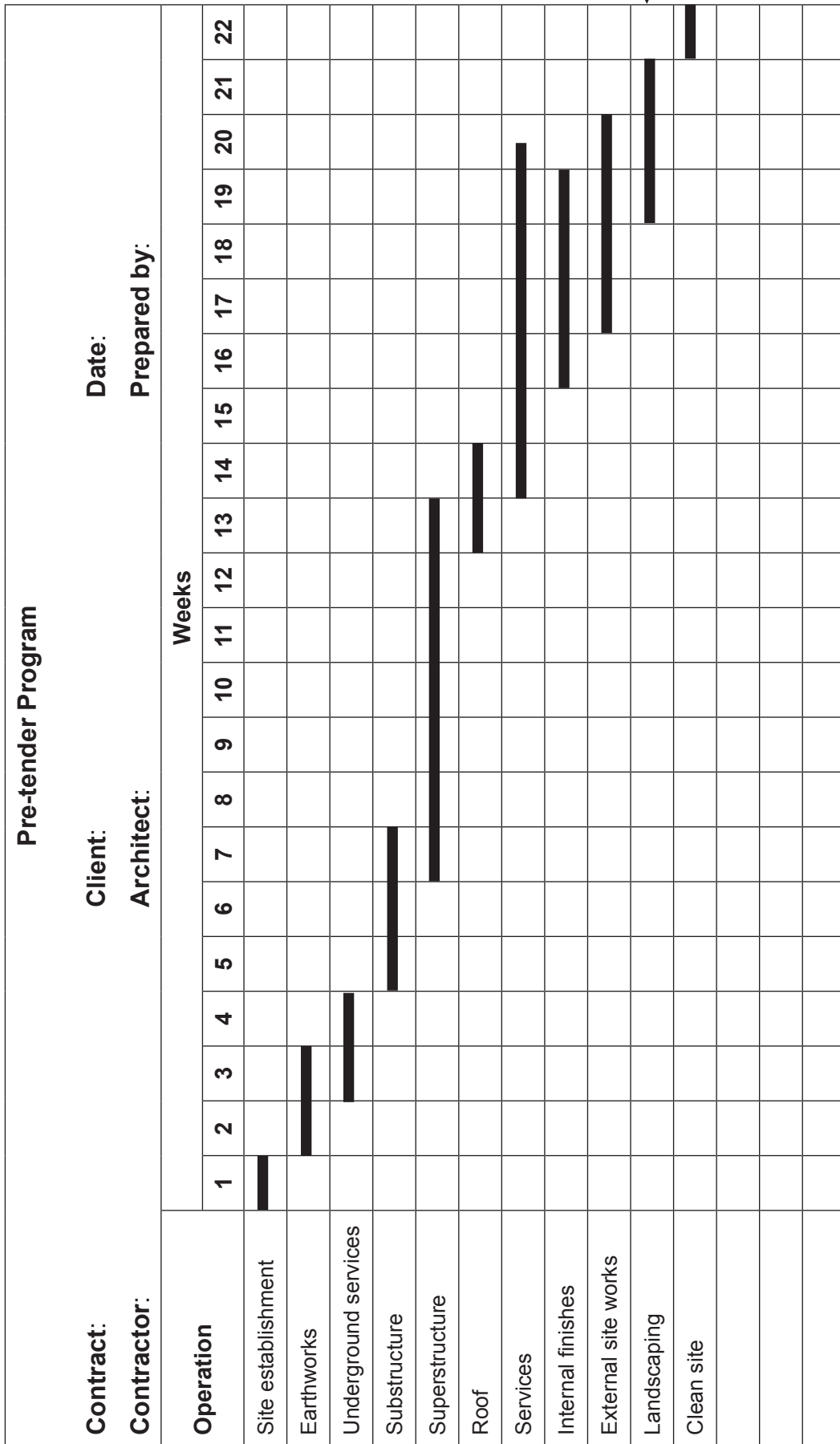


Fig 3.7 Example of a pre-tender program



8. Estimate finance statement

This statement is a simplified summary and breakdown of the total costs anticipated for the project – and involves the following:

- preliminaries and site overheads
- labour costs
- material costs
- mechanical plant and transport costs
- sums to be included for nominated subcontractors and suppliers
- sums to be included for the builder's own subcontractors
- provisions and contingencies.

Final decisions

When the estimator has completed pricing the bill of quantities, the basis of the tender is ready for the final decisions to be made on such items as profit margins and risk factors etc. The estimator will then have the estimated cost of the work based on a selected contract scheme together with a program and estimation of the contract period.

In many companies, it is the practice for a person at board director level to be responsible for finalising tenders. Although it may not be necessary for this person to know details, they will need to know the broad principles of the scheme on which the estimate of cost has been prepared.

When the tender is finally completed, it is submitted. Later, if the contractor is successful in securing the contract, the tender program will form the basis for preparing the contract program.

Chapter 4

Pre-contract planning

Types of information

In many instances, a contractor tendering in competition will not be required to carry the effort beyond the pre-tender planning stage, as only one tenderer can be successful.

Once the main contract has been signed by the proprietor/client and the contractor, the successful tenderer can proceed to plan the work in greater detail with increased consideration of the amount of work to be undertaken, the methods to be adopted and the timing of its execution. This calls for close cooperation on the part of those principally involved.

As a general guide, the contractor needs the following types of information:

1. an overall program for the project showing key operations and their logical sequence
2. the anticipated duration of each operation
3. the estimated subcontract component required to complete each operation as planned
4. the type of plant required to achieve the output in the time allocated
5. the materials required for each operation and the delivery times
6. details of specialist work, which will need to be coordinated with the progress of the contractor's own work
7. a timeframe in which outstanding information documentation, samples etc must be provided to ensure continuity of all operations.

The time span available for undertaking pre-construction work varies widely, depending on the complexity and magnitude of the project and the urgency with respect to starting work on site. Not all of the information listed above is always available at the outset of a contract; therefore the need for teamwork on the part of those involved in the contract is important.

Request for information (Original)		No: _____
<p>To: _____</p> <p>_____</p> <p>Attention: _____ Date: _____</p> <p>Project: _____</p>		
<p>The following information is requested by the dates indicated to prevent delay to the contract works program.</p>		
Description	Date required	
<p>Purpose</p> <p>These forms are to be used in lieu of verbal requests and in addition to requests recorded in site meeting minutes.</p> <p>The original copy is to be signed by site staff and issued to the architect.</p>		

Fig 4.1 Example of a request for information form

Procedures

It is important that, upon being awarded a contract, a company finalises the site management team so the staff who will control the work on site have as much input as possible in determining the program for the work. Inadequate planning at this stage inevitably results in delays later in the project.

Meetings with the architect and consultants

A basis for good communication should be established as early as possible. This is best achieved by arranging a series of meetings at which the participants in the contract can discuss future procedures. The requirements from, and responsibilities of, each participant should be clearly established at these meetings. The extent of information required needs to be clarified. A checklist can be prepared to help establish what information is available and what information is still required to set the project in motion.

Where it is considered that insufficient information is available to start the site work, a formal approach should be made to the architect, outlining the information required, with a request for the details to be provided in sufficient time to prevent unnecessary delays to the project.

There are some other important procedures which need to be either started or reviewed at the pre-construction stage.

Registration of drawings

On major contracts, specialist drawings and details are numerous. These drawings and details are often amended to supersede previous drawings. It is therefore essential that all drawings and details received are systematically filed and recorded. Superseded drawings should be removed from the file as a precaution against an incorrect drawing or detail being used. A *drawing register* is used to record this information and, in addition to showing the project title and number, should record the following for each drawing:

- title of drawing
- drawing reference number
- source
- scale
- date received
- number of copies received
- date of distribution
- to whom distributed
- details of amendments.

(The drawing register may later prove to be a useful document when the final account is being prepared.)

Drawing register										Contract no.	
Contract	Drawing no.	Title or description	Main scale	Received from	Original		Amendments				Distribution
					No.	Date	A	B	C	D	

Fig 4.2 Example of a drawing register

Transmittal note <input type="checkbox"/>	
Memorandum <input type="checkbox"/>	
From: _____	
To: _____	Project: _____
Attn: _____	Job no: _____
Date: _____	
Description/memo	
	D/no.
	Qty
PURPOSE	
To keep a record of the distribution of plans, contract documents etc	
forward or picked up by subcontractors etc.	
FOR YOUR:	
<input type="checkbox"/> ACTION	<input type="checkbox"/> APPROVAL
<input type="checkbox"/> COMMENT	<input type="checkbox"/> INFORMATION
<input type="checkbox"/> AS REQUESTED	<input type="checkbox"/> Delivered by: _____

Fig 4.3 Example of transmittal note



Further documentation

Bill of quantities

When a priced bill of quantities has been completed as part of a successful tender, it can form an important part of the planning process. The bill of quantities represents an analysis of each and every operation in the project. To the project manager and members of the planning team, it constitutes a schedule which sets out such information as the types and amounts of materials required, labour, plant and equipment requirements and costs, specialist subcontractor and supplier involvement, provisional sum items and site supervision and overhead requirements and costs. This information can then be broken down into more detail in order to calculate or review the time period for each operation.

It must be remembered that bills of quantities are measured net and make no allowance for merchantable sizes or waste with regard to materials.

Method statement

The pre-contract period also provides an opportunity to re-examine the method statement to determine whether further detailing of the document is required or whether cheaper and/or better alternative methods are available. Any changes to the original method statement should be recorded for future reference.

Resource schedules

Another essential task to be undertaken is the presentation or reviewing of resource requirements. Subcontract labour and plant schedules have been discussed in the previous chapter but now need to be considered in detail to ensure that a balanced program is forthcoming for the duration of the contract.

Labour requirement schedule

With complex projects, it is important at the pre-contract stage to try to determine the approximate subcontract labour requirements for the various stages of the project. Where it appears that an unrealistic number of people is to be employed on site during any particular phase of the project, steps can be taken to provide a more evenly balanced labour force throughout the contract period. This aspect will be explained more fully later in the text. Figure 4.4 illustrates an extension to the labour requirements chart shown previously (Figure 3.5).

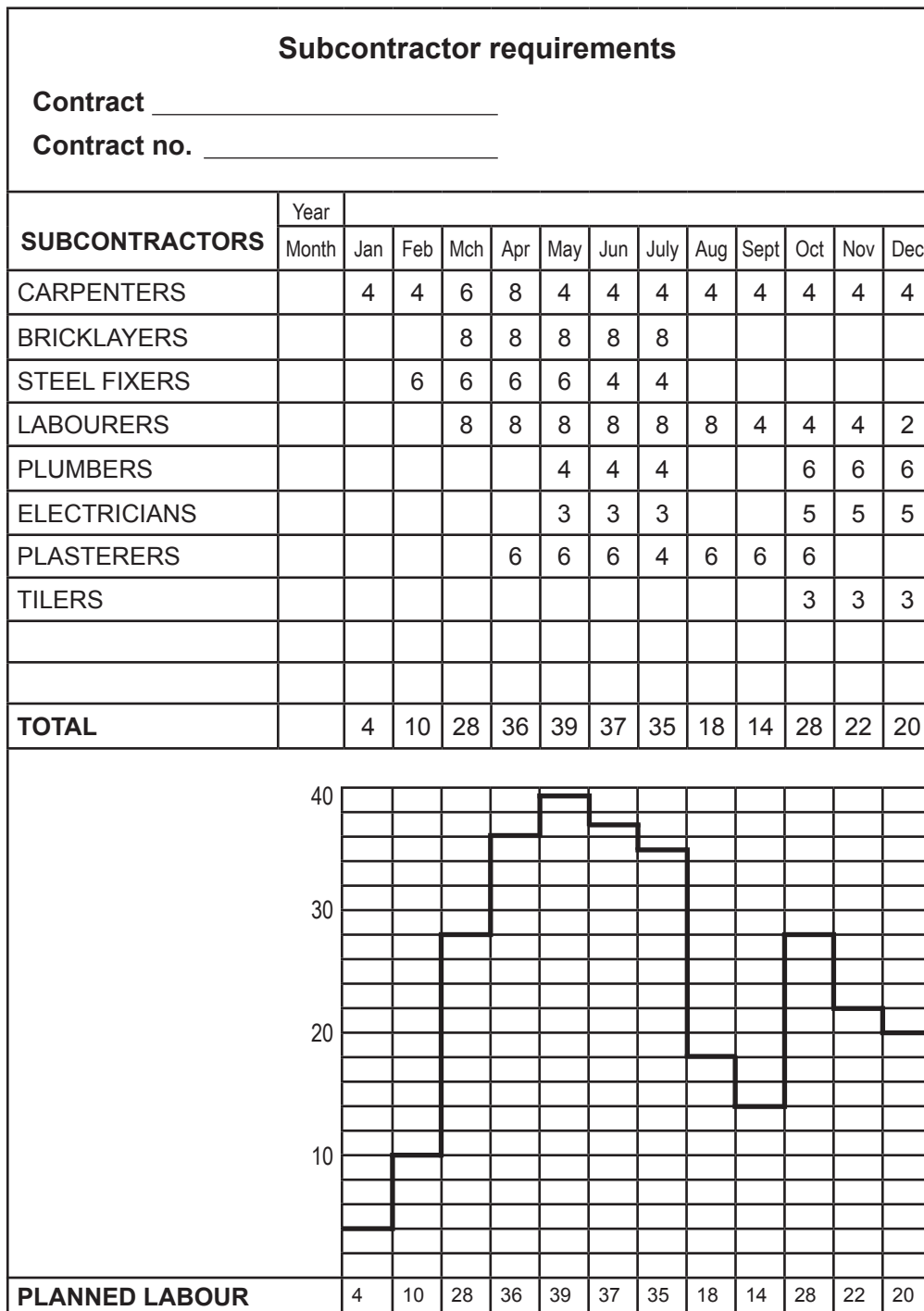


Fig 4.4 Example of labour requirement chart and histogram

It is possible to use the construction program as an alternative means of establishing the labour requirement. The number of workers required for each activity is placed above the respective bar, a vertical calculation is made and the totals inserted at the bottom of each column.

A histogram (bar chart) or a frequency polygon (line graph) is often prepared as part of the schedule to provide a graphical representation for use when reporting the results to others.

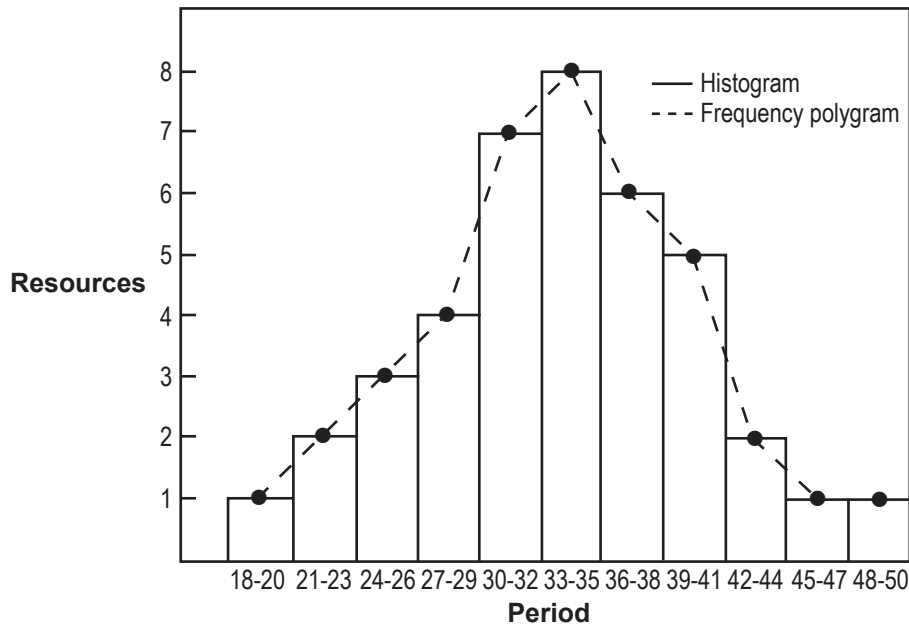


Fig 4.5 Example of histogram and frequency polygon

Plant schedules

If changes are made to the subcontractor labour schedule, it is also possible that changes will be required to the plant schedule to maximise plant utilisation on site. Plant requirements must be phased to suit the order and sequence of the master program.

Master construction program

To prevent problems in general coordination and delays, a master program is prepared which outlines to those involved:

- what is to happen
- when it is planned to happen
- by whom it will be carried out.

The program should be a simple but comprehensive view of the project, embracing the information from prepared charts and schedules, and include all key operations. The bar chart is probably the most common of the alternatives used to prepare a program of this type.

The extent of the information to be shown on the master program will depend on the size and complexity of the project. To ensure that the program contains sufficient detail for the smooth performance of the project, the following information may be included:

- starting date and duration of each activity
- logical sequence of activities and their relationships
- key dates or milestones
- appropriate allowances for holiday periods
- resource allocation required for each activity
- lead-in times and delivery dates for plant and materials
- dates when drawings and information must be available
- subcontract and specialist work
- provision for monitoring and recording progress.

MASTER PROGRAM

PREPARED BY: _____
DATE: _____

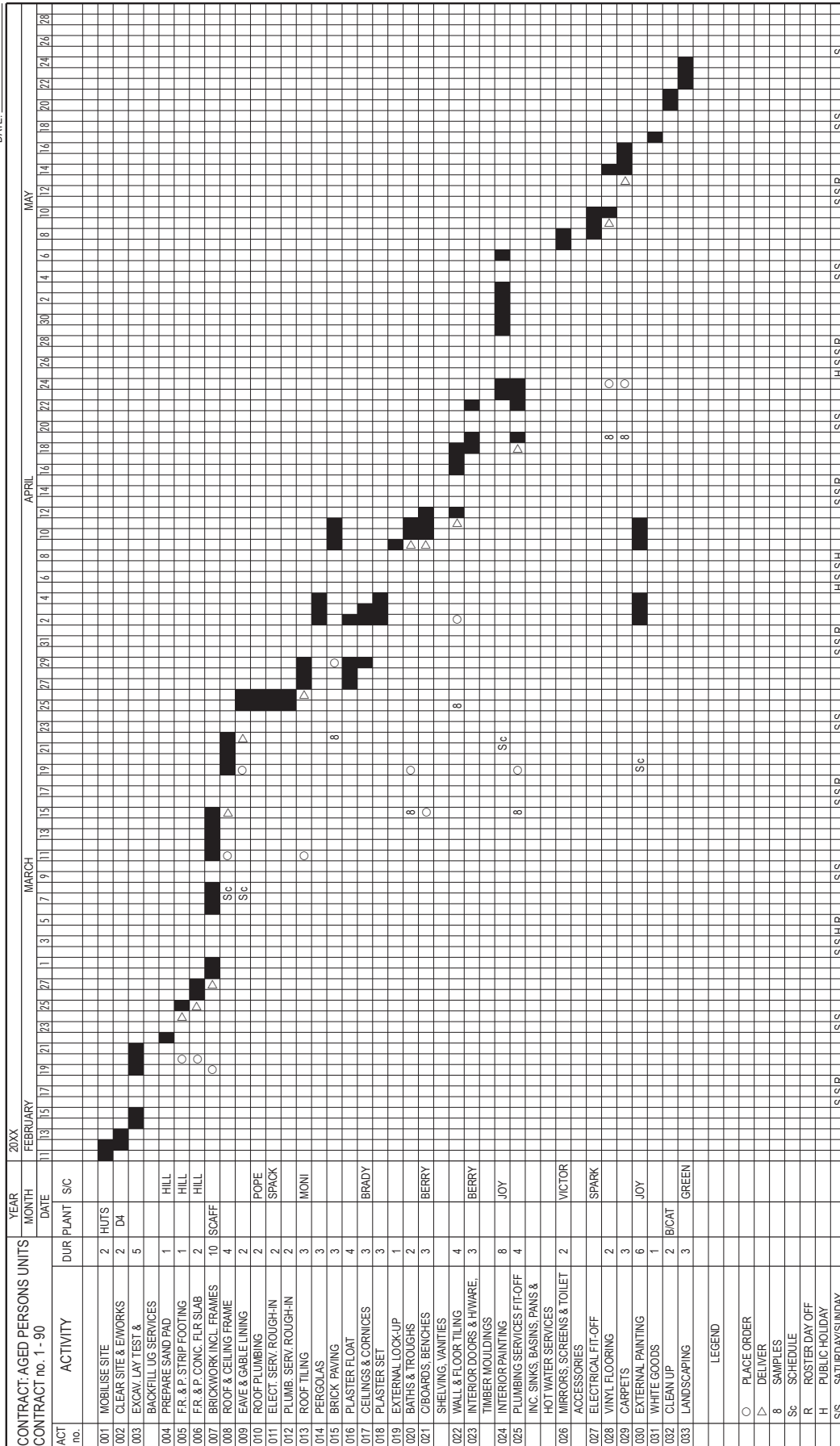


Fig 4.6 Example of simple master program

Other arrangements

As well as the preparation of statements, schedules and charts, other arrangements also need consideration before work can start on site.

Consideration must be given to matters such as local authority regulations, insurance, scaffolding and a wide range of site issues, including site accommodation, storage and security, temporary services, access roads, work areas and site drainage, as well as any other matters considered applicable to the particular project.

Some of these will be discussed in more detail on following pages.

Site layout planning

Physical characteristics of the site often affect the method and sequence adopted in the construction program; therefore, the program and site layout are sometimes prepared in conjunction with each other. A site investigation should be undertaken to establish where accommodation, storage, access roads, plant etc would be best situated. Confined sites make it difficult to position some things on site. A confined site may make it difficult to position some plant convenient to work. This may result in an alternative and perhaps less economical method having to be used. Limited access may also restrict the maximum size of plant which can be brought on site.

Sites with tall buildings surrounding them may restrict the type of plant that can be used; for example, a derricking jib crane may have to be used instead of a horizontal jib crane. This could be an added financial burden if the builder owned a horizontal jib crane and then had to buy or hire the other type of crane.

Sloping sites can also render certain types of plant unsuitable, particularly where a level base is required to 'set up' on – for example, for a rail-mounted tower crane.

The builder must consider the nature of the structure being built in relation to the site, to decide where best to place equipment and materials. Plant should be positioned so that it creates as little obstruction as possible while in use and can be dismantled and/or removed with a minimum of inconvenience. The same applies to accommodation.

Authorities

It is necessary to be aware of, and to comply with, the various service authority regulations. The number of authorities which will be involved depends on the type of project. For example, some matters which may need to be considered include crossovers and footpath maintenance, gantry and hoarding requirements, restrictions on placing materials on verges, disposal of water from sites, street parking availability, loading and unloading restrictions etc. The above matters would involve the local authority and possibly the police and roads authority such as Main Roads in WA.

Site layout

The purpose of planning an efficient site layout is to enable the flow of materials and work on site to be as free as possible from obstruction. The flow should be orderly and involve the minimum movement of operators and materials and minimum handling of materials during the progress of the project.



Site layout drawing

Before a site layout drawing is prepared, a list should be compiled of all accommodation and plant and material storage areas required. The method statement would be consulted at this stage.

A detailed site drawing can then be prepared showing the position of the project on site, together with access services, the location of facilities and plant and obstructions.

A common method for preparing site layouts is to use the block plan supplied by the architect. Sometimes an overlay of clear plastic is used on which the sketch of a tentative layout can be easily erased if found to be unsuitable.

Site layouts may be developed around five facets:

1. the movement of personnel, plant and materials
2. accommodation for –
 - administrators
 - operators
 - welfare (first aid, toilets etc)
3. work activity areas, for example –
 - repair and cleaning areas for formwork
 - steel reinforcing storage/work area
4. site access – vehicle deliveries etc
5. control of site work activities.

Particular considerations

Particular aspects to be considered include the following.

Location of accommodation – Administration offices are the information and control centre of the site and should be situated so as to facilitate checking, supervision and security on site.

Ready-made and equipped mobile accommodation is available to meet a range of requirements and can be established on site very quickly and reasonably economically. Alternatives include using existing buildings on site, which may or may not require demolition at a later date – or a building adjacent to the site. Completed sections of a project may also sometimes be used for site accommodation or storage.

Toilet and mess facilities – The extent of such facilities for site occupants will depend on the location (local or remote) and the number of operatives involved.

Parking facilities – It is preferable that these are located close to site offices. Local authorities would probably be consulted here.

Subcontractor accommodation – Subcontractors may provide their own accommodation and stores or may make arrangements to utilise the main contractor's accommodation.

Accommodation for client's agents – Where required, the tender documents will usually indicate the extent and type of accommodation and furnishing needed for (occasional use by) the architect, quantity surveyor and/or other specialist consultants.

Site clerk's accommodation – This is best situated near the entry to the site so the clerk can check and inspect deliveries and direct them to specified areas.

Typical accommodation stipulations and location factors

The size of accommodation and type of fitting out will vary from project to project, depending on the extent of the building works and duration of the contract.

The following is a typical example of an extract from contract documents relating to the establishment of site accommodation.

Contractor's site office

The contractor will need to provide temporary site office accommodation, complete with telephones and other facilities for the safe keeping and efficient use of contract documents.

Workers' amenities

The contractor must provide, keep clean and maintain, adequate temporary sanitary accommodation for the use of the workers employed on the works. Such sanitary accommodation shall conform with the requirements of the local authority and Health Department.

The contractor must provide all necessary sheds and statutory amenities for workers – ie drinking water and facilities for messing, changing, storage of equipment, first aid etc.

Besides the amount and type of accommodation required, consideration also needs to be given to the most strategic position available on site to locate it. Some influencing factors are:

- the utilisation of natural light
- the fact that the project manager and assistant project manager will prefer to be located where they can view the site works
- the need to locate offices away from dust and noise, as far as possible
- the site clerk's need to maintain an effective check on all movements of materials etc onto and away from the site.

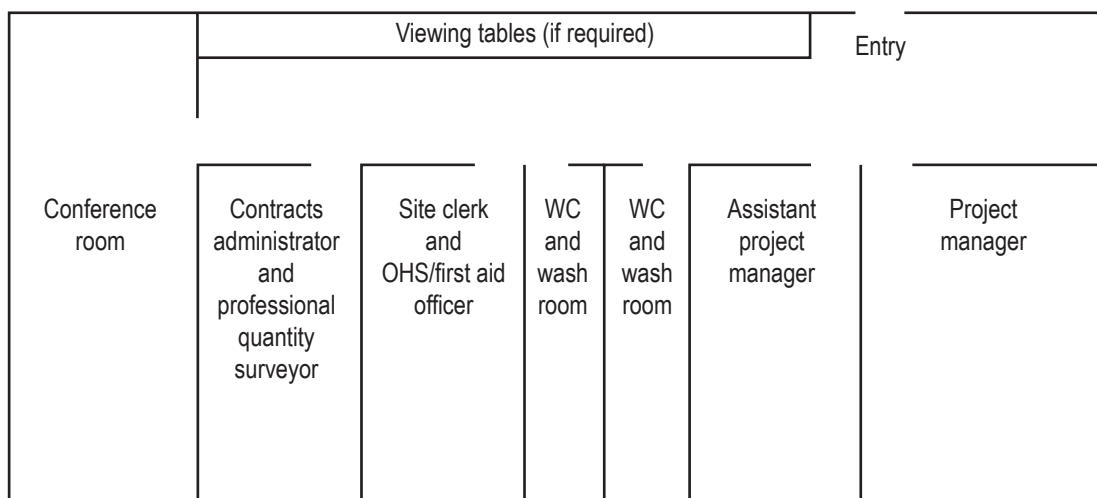


Fig 4.7 Example of layout of staff office accommodation for a medium/large project



Location of services

Often the site report prepared for the pre-tender phase will outline the extent and location of existing services on site which may be utilised for temporary services during the construction stage of a successful tender.

The bill of quantities will indicate what temporary services are required for the execution of the work under the contract and to be made available to the builder's own personnel and nominated (and general) subcontractors. Once the work is completed, it is a normal requirement that all temporary services be disconnected and all traces removed from the site.

The following temporary services are generally provided by the builder:

- **water** in adequate supply, including payment for any costs incurred in providing the water used until practical completion
- **electricity** to the site, including, where necessary, the builder's temporary pole and power board. Where a 'mains' supply is not available, a generator may need to be provided. Consideration should also be given to the provision on site of lighting for safety and security purposes.
- **telephones** for the site offices as required. Locations where normal telephone services are not available may require the installation of a radio telephone as a means of communication.

Temporary access and roads

The provision of temporary roads and crossovers for the movement of plant and materials is often a crucial matter. Where paved areas for roads and parking form part of the contract, they are often advanced in the program so as to be available for use during the contract and are then upgraded prior to the handing over of the project.

Storage on site

Storage involves the occupation of space by materials or goods. In an effort to prevent site congestion, it is often wise to keep to a minimum the quantity of materials stored on site. Because of circumstances, it is not always possible to do this. Some storage of materials will always be essential to ensure the project is not unnecessarily delayed.

Factors which may influence or make it necessary for a contractor to store materials include the following.

- Economic buying of materials – a builder may buy in large (bulk) quantities to reduce material costs. This requires a coordinated effort by the site and the company's purchasing department.
- Changes in production programs – a revision of the initially planned sequence of operations may require materials ordered and supplied for the initial planning to be stored until required.
- Late delivery from suppliers – in order to prevent last-minute delays, the builder may order materials early and store them until they are required.
- Limited period of availability of some materials – manufacture of some products may take place only at a certain period of the year to cater for the time of greatest demand. Once stocks are depleted, no further manufacture takes place until the same period in the following year. If a regular supply of a material in this category is required, bulk buying and storing will be essential.

To avoid high storage costs, close cooperation and coordination are required between the departments or staff responsible for purchasing and construction.

Signs

The architect's sign board will be an item addressed in the contract documents. Other signs should be prepared and strategically positioned around the site to indicate entry, exit, directions and safety requirements for the project.

Hoarding and protection of the public

Adequate protection for the public must be provided in the form of hoardings, gantries, fans, dust barriers, security gates and safety lighting, as may be applicable. The local authority will lay down requirements regarding this aspect and the architect may specify certain requirements also.

As a public relations exercise, particularly on major projects, consideration could be given to viewing areas and information boards.

Other considerations

- Work areas will be required for activities such as:
 - the making, repair and cleaning of formwork
 - assembly of steel reinforcement
 - the manufacture of small, pre-cast items such as small beams or spacer blocks.
- Space must be left around the building for scaffolding and for the movement of plant and material.
- Special storage facilities for inflammable materials such as oil, paint and gas containers must be provided.
- Security compounds and protection of electrical installations may be essential.
- Space for waste disposal containers etc could be required.
- Protection of adjoining properties could be an important consideration.
- Protection of trees etc on site may have to be kept in mind.

Conclusion

The design of the site layout in relation to access, storage, site handling and control will have a considerable influence on the effectiveness of site management.



Chapter 5

Project planning

Once the pre-contract planning phase is completed, it can be assumed that all necessary permits and insurances have been obtained and all preparatory planning and documentation are sufficiently advanced to enable the site management team to take possession of the site and start the construction phase of the contract.

Site management structure

The on-site structure within an organisation is influenced by the size, type and complexity of a project. On a large project, the builder will appoint a project manager whose responsibility it is to see that the project is managed satisfactorily on site in terms of budgeted costs, specified quality and contracted time. The project manager would be a staff member of the organisation and made responsible for the total conduct of the site and any other associated aspects. Various subordinate staff assist the project manager (as illustrated in Figure 5.1 overleaf).

Each of the subordinate staff is allocated specific duties for which they are responsible, through the chain of command, to the project manager, who, in turn, is responsible to the construction manager of the organisation.

Role and duties of project manager

The task of the project manager is to 'establish' the project and then ensure that it continues to progress, at least at the level predicted, so as to complete it on time. To achieve this, the project manager requires a sound knowledge of site management and the ability to perform these duties efficiently.

Many decisions will need to be made in the course of a project and the requirements of these decisions must be communicated clearly to those concerned. The project manager must ensure that accurate records are kept of all decisions made. These records form a basis for future reference and planning and also provide evidence in the event of disputes. The project manager must ensure that company policies are adhered to. Their role requires planning, coordinating, controlling and reviewing the day-to-day site activities. Their duties will include:

- liaising with the client, specialist consultants, subcontractors, statutory bodies, suppliers, trade unions and owners of adjacent properties and others
- attending and conducting meetings to discuss aspects requiring clarification
- receiving instructions from the architect and implementing variations
- maintaining the site in a safe working condition
- acting as an arbitrator in disputes arising between subcontractors and others associated with site activity
- generally controlling, through delegation, the various resources associated with the project, for example labour, materials, machines and money, as well as aspects like method, space and time.

Note: This is typical of a simple site staff structure – but each site needs a staff structure applicable to its specific circumstances. There is no ‘set formula’.

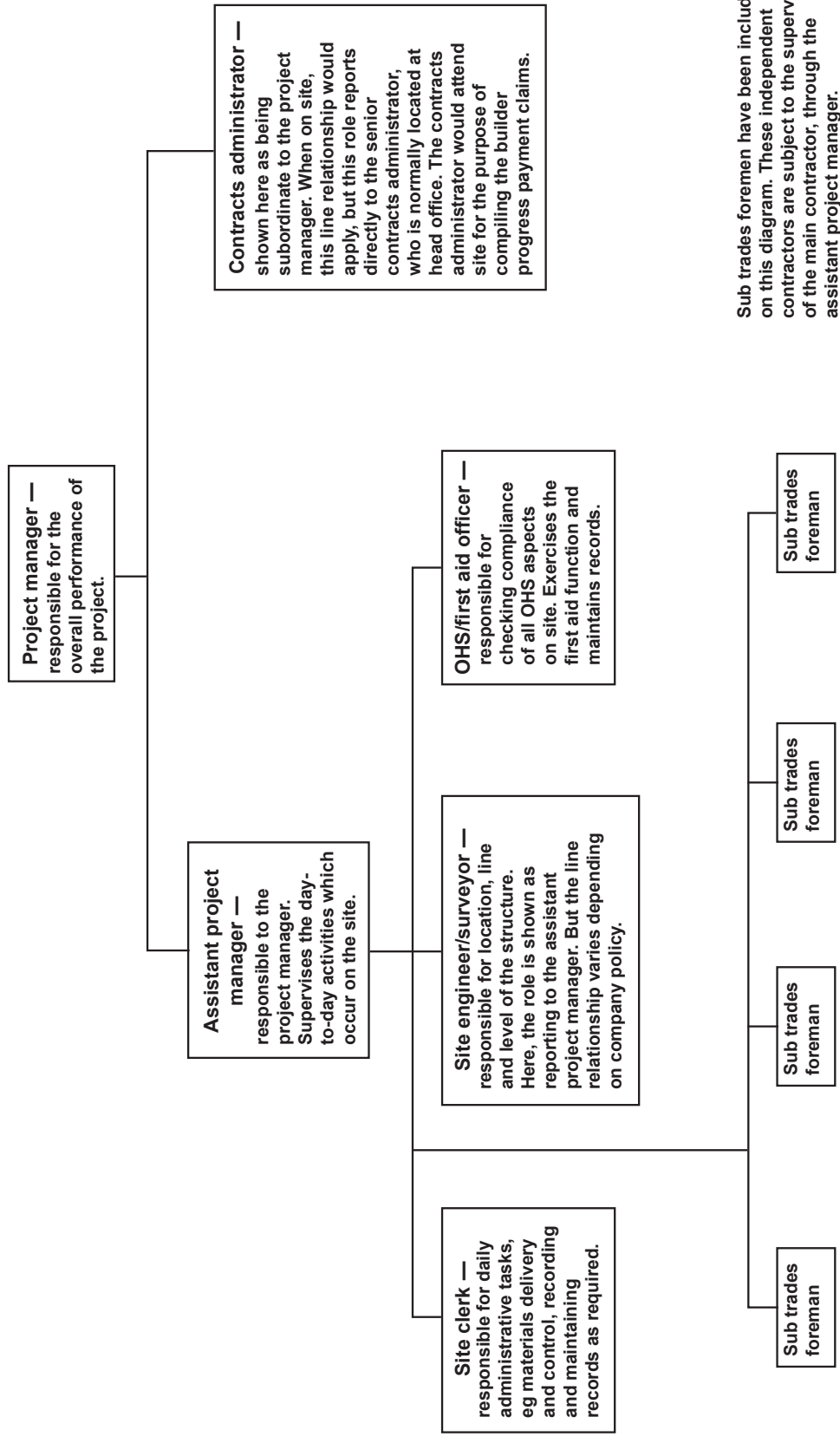


Fig 5.1 Example of site staff organisation structure

Site organisation and administration

As indicated earlier in this chapter, the on-site staff structure will be determined by the size, type and complexity of a particular project. The builder's site staff will often include personnel such as the project manager, assistant project manager, site clerk, OHS/first aid person etc. Each on-site position involves duties and responsibilities which must be performed efficiently if the project is to proceed economically and to plan.

It is therefore important to develop and maintain a means of communication between all those involved in the project. One method used to achieve this is conducting regular meetings to collate relevant information and plan future progress and to communicate this information to the personnel involved in performing the planned work.

Meetings

Meetings should be conducted on a regular basis, at least once a month and generally no more than once a week. Meeting dates should be flexible so as to cope with busy and slow periods during the construction program. Meetings should not be conducted just for the sake of having a meeting; there should be an agenda of items for discussion. Each meeting should be productive, with information being conveyed to, or received from, those in attendance. A main object of such meetings is to utilise each person's expertise, so that effective planning can be achieved through group discussion and cooperation.

Careful thought and preparation should precede all meetings. As mentioned previously, a meeting should not be called unnecessarily, as some items can be discussed in private.

When a meeting is in session, it should be *controlled* by a chairperson. Discussions should be 'through' the chairperson and not be allowed to become discussions between individuals attending the meeting. Diversion from topics under discussion and 'rambling on' should be avoided, as they prolong meetings and achieve nothing.

Initiating meetings and basic rules

To achieve meaningful meetings, it is essential that a format be established and adhered to. Briefly the format could be established as follows.

1. Plan

The meeting should have precise objectives. It is important to establish what is to be achieved. The agenda should list the topics to be addressed and say whether each is for information only, discussion or a decision.

The chairperson should have all available information ready for the topics to be discussed.

2. Inform

Everyone required at the meeting must be advised and provided with an agenda prior to the meeting so that they have ample time to study its content and establish why they are required and what information they may be expected to provide.



3. Prepare

Develop a time plan for each topic for discussion and look for logical connections between topics. A discussion may follow these stages:

- present the topic for discussion
- provide all available information
- allow discussion on the topic
- make a decision.

4. Structure and control

The meeting should be structured in stages, so that backtracking is avoided.

5. Summarise and record

It is necessary to record, in the minutes of the meeting, a summary of key points arising from the discussions and the decisions made, together with the names of those made responsible for future actions.

Types of meeting

The two types of meeting which are usually held on site are:

- the architect's site meetings
- the builder's site meetings.

The architect's site meetings

An architect's site meeting is held on site as and when deemed necessary by the architect. The need for a meeting is dictated by the needs of the project.

It is quite usual for these meetings to be held once a month, often at those stages of the project where, for a variety of reasons, problems and questions have arisen which require answers, hence the need for meetings chaired by the architect.

Attendees will be those needed to make a contribution to the matters being dealt with, prominent among whom will be the professional quantity surveyor (PQS). Also invited, when needed, would be the specialist consultants, for example a structural/civil engineer, electrical engineer, mechanical engineer, lift engineer and/or hydraulics engineer.

The builder will, of course, be represented at such meetings; the project manager usually fulfils this role, together with those members of the builder's site staff as may be required.

Subcontractors (both nominated, or 'separate contractors' as they are referred to in the AIA/MBA joint contract, MWP – 2008, and those subcontractors selected by the builder) will make significant contributions at these meetings, as will those suppliers (again, both nominated and 'builder-selected') whose input is needed.

Statutory authorities will be invited if needed. It could be that an authority will make a critical contribution to some important matter; in certain instances, only a statutory authority will possess the authority to give a decision.

The decisions arrived at during the course of the meeting are carefully recorded in the minutes, which are taken as the meeting progresses.

As is the case with many formal meetings, resolutions passed by the meeting will be regarded as being binding on those parties who have been identified as having a task to fulfil.

However, the legal standing of such resolutions is debatable. They may or may not be admissible at law in some future action.

For the builder, the possibility of dispute arising some time later during the project, for example the application of liquidated and ascertained damages against the builder due to a delay in completion, is an incentive to exercise the utmost attention to matters raised and resolutions agreed at such meetings.

In summation, past experience indicates that, given the contractual and managerial relationships which exist between the parties involved in the traditional contractual arrangement, the architect's site meeting is an effective means of dealing with issues which inevitably arise during the course of the project.

The builder's site meetings

A builder's site meeting may be no less formal than those held by the architect. The degree of formality depends on the circumstances prevailing at the time.

On large, commercial-type projects, the meeting may be conducted in a manner which mirrors that of the architect's site meeting; on the other hand, an ad hoc meeting may be held in the 'fresh air', for example next to the cement shed, due perhaps to some emergency which has unexpectedly arisen.

These meetings will probably focus on a narrower range of issues than an architect's site meeting, in that the builder will call – mainly – subcontractors and suppliers to the meeting.

The presence of specialist consultants would be unlikely at these meetings. Statutory authorities may be invited, and their attendance may be indispensable to the success of the meeting, but the essential thrust of such meetings is progress and the resources required to maintain or improve it.

These meetings will be called as required. On large projects, when activity is at a peak, and ignoring emergencies and the like, meetings may be scheduled on a weekly basis, with longer intervals scheduled when activity lessens. While 'monthly planning meetings' may feature on large projects, the frequency of meetings will generally be – as stated above – dictated by site demands.

Smaller projects may only require meetings to be held at intervals greater than one week, though formal 'monthly planning meetings' are probably less likely to be scheduled.

The above relates to meetings which – essentially – are about progress. But the timing of others will be dictated by safety and health (OSH) issues.

While the proprietor/client, together with the architect and specialist consultants, have statutory obligations with regards to OSH, there are far more stringent requirements of the builder.



In the maintenance of an adequate OSH regime, a builder will need to allow for (among other considerations) whatever meetings are necessary, for example in the matter of 'job safety analysis'. In such instances, the builder may be called upon to meet with subcontractors on a daily basis, dependent on the form of the construction and the degree of OSH control required by that form.

Documentation

Of the many and varied tasks required on site for the wellbeing and smooth running of any construction firm, regardless of its or the contract's size, perhaps one of the most important and exacting is keeping up-to-date and accurate records of what is happening on the site.

Important records should not be left in an office where they may be viewed by all who enter. Important records should be kept under lock and key.

Let us now consider some of the important documents and records which are necessary.

Job site diary/daily record

Of all the records which must be kept in the site office, the one which will possibly have the most far-reaching consequences is the daily job diary. The diary should be written up daily on the site, preferably in such a way that it cannot easily be erased or smudged. If handwritten, it should be clear and legible to those who will want to examine such records. This is the task of the project manager.

It is beneficial to make entries in the diary at the end of each working day while the events which took place are still fresh in the mind. Some project managers prefer to make entries as soon as possible after they occur.

It is important that, at the beginning of the job, a pattern be set and adhered to if at all possible. There will be times when the pattern must unavoidably change owing to circumstances beyond control but a return to the 'system' should be made as soon as practicable.

If a system is established early in the project, there is less likelihood of the diary being forgotten and the day's activities not entered. Making daily entries can become a bore and frustration, especially under pressure of work. Nevertheless, the discipline should be maintained and accurate entries made. It may prove well worth it if, several months after work has finished, you need to establish what activities occurred on a particular day and who was responsible.

An accurate diary should be kept on site to enable authorised parties to see at a glance the entire case history of the work so far. Such a document records the events on site for the whole of the works from beginning to end and is a major source of job information. It may subsequently be used as the basis on which claims can be negotiated and may be produced during litigation if a dispute arises from any cause during the job. As such, it then becomes an important reference document.

The diary format is of little consequence and it may be that the contractor will stipulate that their own printed form be filled in. An ordinary single-page-per-day diary available from any stationery shop may be adequate for the number of entries to be made on smaller projects. While a nominated person will usually have to fill in the daily attendance sheets for the workers on large sites, the numbers of those on site by trades should still be noted in the job diary.

If duplicate copies of the day's entry must be kept, a duplicate manifold book will adequately fill the bill. In such cases, the original will be sent back to the main office, along with time sheets, progress reports and any other information to be forwarded, and the duplicate kept on site.

Contents of a diary

Every diary, whether in printed form or simply in a duplicate book, should record most of the following items:

- the personnel on site each day – hours worked and work engaged on
- sub-trade labour force divided into trades – hours worked and work engaged on
- an estimate of site progress for each day, stating types and approximate quantities of materials used where applicable
- any movement of subcontract labour to or from the site during the day
- any shortage of resources or stoppages, stating causes
- weather conditions, with special emphasis on any disrupting element such as excess wind, extremes of temperatures, rain etc
- visitors to the site, including reason for visit and record of comments or instructions, eg from architect, consultant, client, building surveyor
- power or other service shutdowns
- record of discussions held with architect or specialist consultant/s and any instructions given (note that only the architect has the authority to issue formal instructions)
- dates on which information was requested from the architect and when the information was received, including record of any delays in receiving vital information from the architect or client
- notes on general progress of the work, mentioning areas where the building has advanced rapidly
- any further comments which have a bearing on the works in hand
- any accidents which occurred on site, with action taken and cause (note the requirements of WorkSafe/legislation).



Weekly site report

A weekly site report, which summarises resources used etc over the period, may be produced as a complementary record to the daily site diary.

		Weekly site report (Original copies to be returned weekly by mail with progress reports)		138800	
CONTRACT: _____			CONTRACT no: _____		
Weather and lost time: _____			Date: _____		
Visitors to site: _____					
Important instructions received: _____ (Name the instructing party)					
No. of workers on site:					
SUBCONTRACTORS:					
DEMOLITION		PLUMBER		PLASTERER, FIBRO	
EXCAVATOR		ROOFER, METAL		TILER, VITREOUS	
REINFORCING FIXER		ROOFER, A/CEMENT		TILER, VINYL	
CONCRETOR		ELECTRICIAN		PAVIOR	
DRAINER		MECHANICAL		PAINTER	
STRUCTURAL STEEL		GLAZIER		CLEANER, BRICK	
BRICKLAYER		PLASTERER, HAND		CLEANER	
CARPENTER		SPRINKLERS			
FORMWORKER		SUSP. CEILINGS			
Other trades: _____					
Number of tests taken: _____ Number of items delivered: _____ Number of items used: _____					
PLANT ON SITE (MECHANICAL)	HOURS WORKED	DOWNTIME	PLANT HIRED FROM (COMPANY)		
SITE REPORT (PROGRESS/DELAYS)					
Project manager's signature: _____					

Fig 5.2 Example of weekly site report page

General recording and regular returns from the site

Site clerical work must be done properly. Adequate information should be available at or from the site to assist management in its obligations to workers, suppliers, subcontractors etc and also to control the operations in terms of time, cost and progress effectively.

Forms and site clerical routines should, in most cases, provide data that is of immediate value to site management and will assist head office to meet its obligations without further duplication of information.

Clerical records and returns are mainly designed to provide:

- a clear indication of the activity of the subcontractors
- a correct record of the flow and stock of materials
- a record of the movement and use of plant and equipment
- a brief history of events on site and a report of information and instructions received (eg site diary).

Materials records

The four basic site records of materials take the form of:

1. records of goods received against goods ordered
2. weekly or daily returns of materials received
3. monthly stocktaking of materials on site
4. memoranda of goods returned to supplier.

These records and returns are for the purposes of:

- checking invoices and making payments
- the programming of deliveries of outstanding materials
- control of the quantities and cost of materials used.

A useful materials record available to a project manager is the goods received sheet. This record should show them what has been received.

Figures 5.3 and 5.4 below show examples of a goods received sheet and a goods returned memorandum.

SUPPLIER'S COPY

GOODS RETURNED

No 843

PROJECT:

DATE:

REFER: Mr

PLEASE RECEIVE THE UNDERMENTIONED GOODS

REASON FOR RETURN:

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

YOUR DELIVERY NOTE No. _____ **DATED** _____

RECEIVED ON BEHALF OF THE ABOVE SUPPLIER

NOTE:

Fig 5.4 Example of a goods returned memorandum



Plant records

The three basic site records relating to plant and equipment are:

- an inventory of plant and equipment on site, which is checked regularly
- memoranda of plant or equipment returned
- a weekly record of performance times and plant breakdowns.

These records and returns provide a means of checking the efficiency of plant and equipment and provide a form of cost control in the matter of plant costs/expenses.

Site instructions

Instructions from the builder (project manager) to site operatives can be prepared in a variety of ways, including:

- drawings or sketches of the work to be performed
- written statements of methods to be used
- procedural instructions for steps to be taken in assembling or erecting various components
- diagrams of the layout of the site or workplace
- lists of materials or equipment to use
- job information sheets.

Architect's site instructions

In the 'line relationships' which apply in the traditional contractual arrangement (see previous chapter), the architect – as the principal consultant – is the sole representative of the proprietor/client and is the 'leader and coordinator' of the design team, which is made up of specialist consultants.

Given the above arrangement, *all* site instructions emanating from either the proprietor or the specialist consultants' design team *must* be issued through the architect.

Whatever contractual arrangement might exist between the proprietor/client and the architect/specialist consultants, the builder (invariably) contracts to accept instructions from the architect *only*.

Various people who visit the site may well express a desire for some aspect of the construction or finishings to be altered or some such. The builder will obviously pay attention to opinions or desires voiced by the proprietor/client or a specialist consultant, but the contractual relationship which exists between the builder and architect will take precedence – that is, the builder must await an official instruction from the architect. This applies equally to instructions received from statutory authorities. In the case of the supply authorities, such instructions are quite often issued directly to the subcontractor involved. It is standard procedure then for the subcontractor to immediately inform the builder of the instruction. The builder would then immediately inform the architect of the situation – and await an instruction from the architect.

Instruction from the architect to the builder may be given orally. It is then incumbent upon the builder to ensure that written confirmation is received from the architect before action is taken to carry out works involved with the instruction. Relying solely on the spoken word can lead to serious misunderstanding between the parties.

A drawing, details or other documentation/information issued by the architect may be a copy of a drawing or the like prepared by a specialist consultant and then passed on to the builder in the form of an architect's instruction. A copy of a direction received from a statutory authority likewise may be issued to the builder in the form of an architect's instruction. Changes required by the proprietor/client will be given to the builder directly by the architect.

The essence of the traditional contractual arrangement is that *all* information, from whatever source, must be channelled through the architect and then issued to the builder by the architect.

As noted above, when a builder receives an instruction from the architect, it should always be in writing, signed and dated. Where action is required, the instruction should begin with a title, for example 'Ceiling change', and, ideally, also be accompanied by a sketch to clarify the written instruction.

If a price for the work is wanted, that request should be included with the instruction – for example, 'price before commencing'. Or the instruction may read: 'Delete item 161 (B) of the bill of quantities. A contract variation will be issued forthwith.'

When an instruction is issued, it should be treated as urgent by the builder and attended to as soon as possible.

PENN & SCALES, ARCHITECTS 2 Board St, Perth WA 6000	CONT. VAR DOCUM. NO.	
	INSTRUCTION DOCUM. NO.	
	OP. CTR. NO.	
	CONTR. NO.	
SITE INSTRUCTION	IR No. 505	
TO:	DATE	
	BUDGET CODE	
	APPROX VALUE	
	S/C NAME	
	ADJ. ADV. NO	
DESCRIPTION		ACTION BY
<input type="checkbox"/> Submit quotation of costs. Do not proceed without approval. <input type="checkbox"/> Proceed with the work. Submit quotation of costs later. <input type="checkbox"/> Instruction only. Does not involve a contract variation.	Instruction issued by:	Date:
	Instruction issued by:	Date:

Fig 5.5 Typical site instruction form used by project architect

Variation orders

Provision is made in many forms of building contract for 'variation without vitiation'. All variations must, however, be authorised by the architect and should be recorded in writing in the form of a *variation order*, prepared and signed by the architect.

It is important to follow established procedure in dealing with variation orders.

It is essential that all works related to variation orders or claims by the builder be measured on site by the builder's project manager or other appointed person – and the professional quantity surveyor, ideally – at the time of execution and all relevant information recorded, as 'evidence' of such works may be immediately 'covered' or become inaccessible.

Hence, variations must be noted, measured, evaluated, claimed, verified, authorised and passed for payment, all with due concern for formality, punctuality, legality and time. Clarity is the essence in recording variations. Dates of issue, execution and measurement should be recorded.

Variations may be defined as any of the following:

- increase or decrease in, or omission from, the works
- change in the character or quality of any material or work
- change in level, line, position or dimensions of any part of the works
- execution of additional work.

General conditions relating to variations are:

- Variations shall be within the general scope of the agreement and such that they are capable of being executed under the agreement.
- The contract sum shall be subject to any appropriate adjustment and the date for practical completion shall take into account any extra time or reduction of time.
- All such variations shall be authorised in writing by the architect before work is commenced unless the architect is of the opinion that the matter is one of such urgency that the builder should proceed.

A claim competently documented by the builder will facilitate the authorisation of particular work as a variation.

Figures 5.6 and 5.7 respectively illustrate a typical variation order issued by an architect and the type of form used by a builder to request that certain work be authorised as a variation.

WOOD & MASON BUILDERS 5 Brick Street Perth WA 6001 Telephone: (08) 7010 5421								
Date:								
INSTRUCTION: EXECUTION: MEASURED: ISSUED:								
CONTRACT <u>People's Village</u>								
VARIATION ORDER No. <u>13</u>								
Description	Ref	Unit	Qty	Rate	Deductions		Additions	
					\$	c	\$	c
Prepare consolidated sand base and lay Sahara Dune solid standard brick paving to courtyard area indicated.								
ADDITIONS								
Clean sand fill, consolidated and graded to fall.	8.C	m ³	5.5	6.85			37	68
Std. 230 x 110 dry jointed stretcher bond brick paving.	23.D	m ²	18	13.50			243	00
Disc cutting to edges abutting courtyard walls.	23.F	m	14	4.20			58	80
							339	48
The foregoing will result in a net <u>Addition of \$339.48</u> to the contract amount.								
Yours faithfully P Wood MANAGER Date								

Fig 5.6 Example of a variation order illustrating adjustments

Illustrated below is a variation request form as would be used by a builder where they considered that certain work was a variation but no variation order had been issued. It would be signed by the project manager and issued to the architect.

VARIATION REQUEST		No. _____
ORIGINAL		
TO: _____		

ATTENTION: _____		DATE: _____
PROJECT: _____		
<p>THE FOLLOWING VARIATION IS SUBMITTED FOR YOUR ATTENTION. WE REQUEST THAT AN OFFICIAL VARIATION ORDER BE ISSUED FOR THIS WORK.</p>		
Drawing/other references	Description	
		Signature: _____

Fig 5.7 Typical form for variation request from builder to architect

Architect's certificates

Certificates are used where the contract is not merely to do work in accordance with the specification but to do it also to the eventual approval or satisfaction of the building owner and the immediate satisfaction of the architect.

There are generally three types of certificate and each will be described.

1. Progress or interim certificates

These are issued during the course of the work, for example monthly, and are provided for in most building contracts.

The object of this system of progress certificates and payments is to enable the contractor to have money in hand to pay subcontractors and get on with the work.

Progress certificates certify that work has been carried out and/or materials supplied.

They are not binding as to the *quality* or *amount* of the work; they are provisional and subject to adjustment at the end of the contract.

A progress certificate, once issued, creates due debt – that is, the employer is in debt to the contractor for the work done to date as specified in the progress payment schedule and the contractor can demand payment. In certain circumstances, the proprietor may be able to withhold money due on the progress certificate, for example for set off or counterclaim for defective work or liquidated damages.

Items payable in a certificate

These are the gross value to date of:

- completed work, including that of nominated subcontractors
- materials delivered to site but not fixed
- a proportion of the preliminary time
- extras completed
- rise-and-fall adjustment if applicable.

Subtracted from the total of these are:

- retention
- amounts previously paid.

Interim certificates are always prepared on an approximate basis. Determining an exact amount to be paid would be a lengthy process and just not worth the time. Overvaluation should be avoided.

Submission date

The date for submission of a progress claim can vary from contract to contract. On some major contracts, there is a monetary restriction on progress claims – a claim must exceed a certain dollar value before it will be accepted. It is advisable, in awarding a subcontract, to include in the subcontract documents the date by which the subcontractor is to present a claim, so it can be included in the builder's claim to the client. The practice on large projects is to agree to the percentage of the work finished with the professional quantity surveyor prior to submission of the claim to the architect. Progress claims are usually submitted once per month.

Retention

This is a sum of money retained on the client's behalf as a safeguard against default by the builder. The retention fund is built up gradually by making deductions from the amounts due to the builder in a succession of certificates. To deduct the total retention from the first payment could place a financial burden on the builder, so, to avoid this, the total of the fund is reached in progressive stages.

The contract, therefore, must make two stipulations with regard to retention:

1. the total, or limit, of the retention funds, for example \$20 000
2. the amount to be deducted from each certificate *until the limit is reached*.

Once the limit of the retention fund is reached, no further monies are kept back from the builder. The retention monies are deposited into a bank account, the joint signatories to which are the client and the builder. Monies therefore cannot be withdrawn from the account without the signatures of both the builder and client.

As an alternative to the retention system, a builder may lodge with the architect a written statement to the effect that their bank will guarantee payment to the total amount contracted for retention in the event of default by the builder. Naturally, the statement must be issued by the bank, not the builder, and must guarantee payment directly to the architect or the architect's client.

If a builder is successful in obtaining such a bank guarantee, deductions for retention are not made from interim certificates.

2. Certificate of practical completion

This certificate is issued once the building works have reached the practical completion stage.

Practical completion is usually defined in a contract as the stage at which the works are ready for use and/or occupation by the proprietor.

The building agreement usually fixes a date as the date for practical completion and will often provide for payment of liquidated damages in the event the builder fails to bring the works to practical completion by that date.

The significance of the issuing of this certificate is:

- the builder is ordinarily by the terms of the contract entitled to the release of part of the retention fund
- the date of practical completion will also be made by the contract the start of the defects liability period
- it changes the liability for damage to, and insurance of, the work to the proprietor
- the date of practical completion signifies the end of the contractor's liability for liquidated damages.

There are two exceptional circumstances when building works can be deemed practically complete without notice or the issuing of a certificate of practical completion from the architect.



These are where:

- the architect fails to respond to a notice from the contractor within the stipulated period – or a reasonable time if none is set down
- the proprietor prematurely occupies or uses the works.

3. Certificate of final completion

The role of the final certificate, which is issued after completion of the contract, is two-fold:

- to notify the amount finally owing to the contractor, including release of the balance of the retention fund
- to certify that the works have been completed in accordance with the terms of the contract to the reasonable satisfaction of the architect.

Final certificates are normally binding and conclusive.

PROGRESS PAYMENT SCHEDULE				
Builder J Bloggs				
Proprietor W Smith				
Contact no. 387			Project Office block	
Claim no. 3			Contract sum \$286 000	
Date _____ Location of project _____				
ITEM	VALUE	% COMPLETE	CLAIM	VALUE
Builder's preliminaries	\$20 000	% 100	\$20 000	
Excavator	\$10 000	% 100	\$10 000	
Follow BOQ set out } 	Site works	% 50	\$ 5 000	
	Concretor	% 30	\$ 6 000	
	Structural steel	% 40	\$ 8 000	
	Bricklayer	% 10	\$ 3 000	
			Value:	\$ 52 000
PC adjustments	\$10 000	% 5	\$ 500	
Contingency adjustments	\$20 000	% 10	\$ 2 000	
Prov. sum adjustments	\$30 000	% 10	\$ 3 000	
Prov. quantities adjust(s)	\$20 000	% 20	\$ 4 000	\$ 9 500
			<u>VALUE OF WORK COMPLETED:</u>	<u>\$ 61 500</u>
Add variations as per schedule attached				\$ 5 000
Add rise and fall as per calculations attached				\$ 2 000
			<u>TOTAL</u>	<u>\$ 68 500</u>
			Less retention 10%	\$ 6 850
			<u>TOTAL</u>	<u>\$ 61 650</u>
			<u>Less previous progress payments</u>	<u>\$ 40 000</u>
			<u>THIS CLAIM</u>	<u>\$ 21 650</u>
			<u>ADJUSTED CONTRACT BALANCE</u>	<u>\$231 350</u>
<i>(NB: All figures used are illustrative only.)</i>				
\$286 000	Contract sum			
<u>7 000</u>	Adjustments			
293 000	Contract sum + additions			
<u>61 650</u>	Value of payments			
<u>\$231 350</u>	Adjusted contract balance			

Fig 5.8 Example of a progress payment schedule



Chapter 6

Project control and reporting

For progress to be achieved in any project, a plan must be devised for participants to follow. A check of the estimated goals against actual performance will indicate the measure of control achieved. What types of control are used is a decision of management but a system of control needs to be established in relevant areas and selected personnel made responsible for maintaining control procedures. Effective control is essential to ensure that all stages of the overall plan are monitored; necessary changes can be made with a minimum of inconvenience while still maintaining control over the original objectives. Yet, in the construction industry, with all the possible variations, control is often difficult to ensure.

The administration and implementation of policy control at site level is the duty of the project manager and support staff.

It is necessary to maintain adequate control over all aspects of the operation of a project. Control in various major areas is considered below.

Subcontractor control

If the site plan is well organised, it should allow for continuity of work for both nominated and general subcontractors. Monitoring of the plan should be such that it enables adequate warning when a delay is approaching so that subcontractors may make alternative arrangements for their labour team. Likewise, sufficient advance notice should be given to subcontractors of their expected date of arrival on site. Adequate facilities should exist for the subcontractor to discuss problems which will inevitably occur. This can be either by a direct approach to the project manager or at builder–subcontractor planning meetings.

Quality control

If so stated in the contract form being used for the project, the builder will put in place a quality assurance system.

Reference to the contract documents, particularly the specifications, will establish the quality of work expected by the designer and client.

It is the project manager's responsibility to ensure that the required standards are maintained and faulty work rejected. When materials and components are received on site, and before accepting them, an appointed person should check the quantity and quality and, where necessary, return damaged or unsatisfactory goods to the supplier.

The architect or other specialist consultants will reject any substandard work or materials, thereby incurring extra expense to the builder in correcting faulty work etc.

Quality control applies to both the builder's own work and that of the subcontractors, as all work has to be approved prior to payment.



Materials control

Initially, it is the responsibility of the purchasing officer at head office to ensure that materials are ordered on time and that stock levels are maintained on site. Where the project manager assumes responsibility for materials control at site level, quantities may be extracted from drawings/specifications and checked against the BOQ and requisitions made at required intervals, or orders are called forward from the supplies on general orders which may have been lodged at the pre-contract stage. It is important that suppliers are given advance notice of the dates supplies are required on site.

The supplies received should be recorded on the appropriate forms and advice forwarded to head office at regular intervals (see previous chapter on project planning). Control in the form of recording is also necessary in the return, or transfer, of materials from the site.

Plant and equipment control (site)

It is important that plant and equipment are on site and in position to be used when required. Steps should be taken to ensure they are available for use by all parties involved so as to avoid costly duplication. A possible method of controlling this is to provide a plant-booking board or book so that those needing to use particular plant know when it is available and can plan their work accordingly. Control is further required to ensure that the right type of plant is acquired, used economically, maintained regularly and removed from the site when it is no longer needed.

Waste control

Briefly, this relates to the economical use of materials, labour, plant and equipment. It requires control over materials so that waste is minimised, control over labour so that there is a minimum of unproductive time and control over plant and equipment to ensure that it is used to the maximum extent possible while on site.

Cost/budget control

Cost control is the process of controlling the expenditure on a project from inception to completion. This is most important to ensure that the actual cost of the project does not exceed the estimated cost. This requires that all costs of resources are recorded and checked for accuracy. The cost control of a project is the responsibility of the project manager, as the person on site who is most familiar with details of the work across the board. In order to achieve cost control, the estimated budget should be available to the project manager prior to work beginning on site.

Cost control serves the following functions:

1. It draws attention to any operation which is proving to be uneconomical. If a specific operation is being performed inefficiently, its cost control issues a warning to management so that immediate action can be taken to correct the problem.
2. It provides feedback to the head office estimator who was responsible for establishing the estimated cost for the tender and who may elect to use this information for future estimates of a similar nature.

3. It may provide data for the valuation of variations which may occur during the contract. Maintaining accurate cost records helps the builder prepare claims for revised rates in the matter of variation orders.

The first of the three functions above is the most important, as it serves as a cost-monitoring and warning system with regards to viability of the project at any given time. The other two functions tend to make historic use of collected information.

The system of cost control should be simple, easy to install and not costly to operate. The system should be reconcilable with company documentation for other purposes such as progress claims, plant hire and return of goods.

Consideration must also be given to the amount of detail required in reports; for example, the company directors may not need to know every detail of cost involved, whereas the project manager or construction manager may require all the information possible.

Common tools for monitoring costs include operational cost sheets, period cost records and summaries, and graphical reports.

Figure 6.1 illustrates a budget graph. The estimated progressive expenditure is marked on the graph, so the total estimated costs at any stage of the project can be seen. The actual expenditure for each monitored period is calculated, marked on the graph and compared with the estimated costs to assess whether the anticipated result is being achieved for each stage of construction.

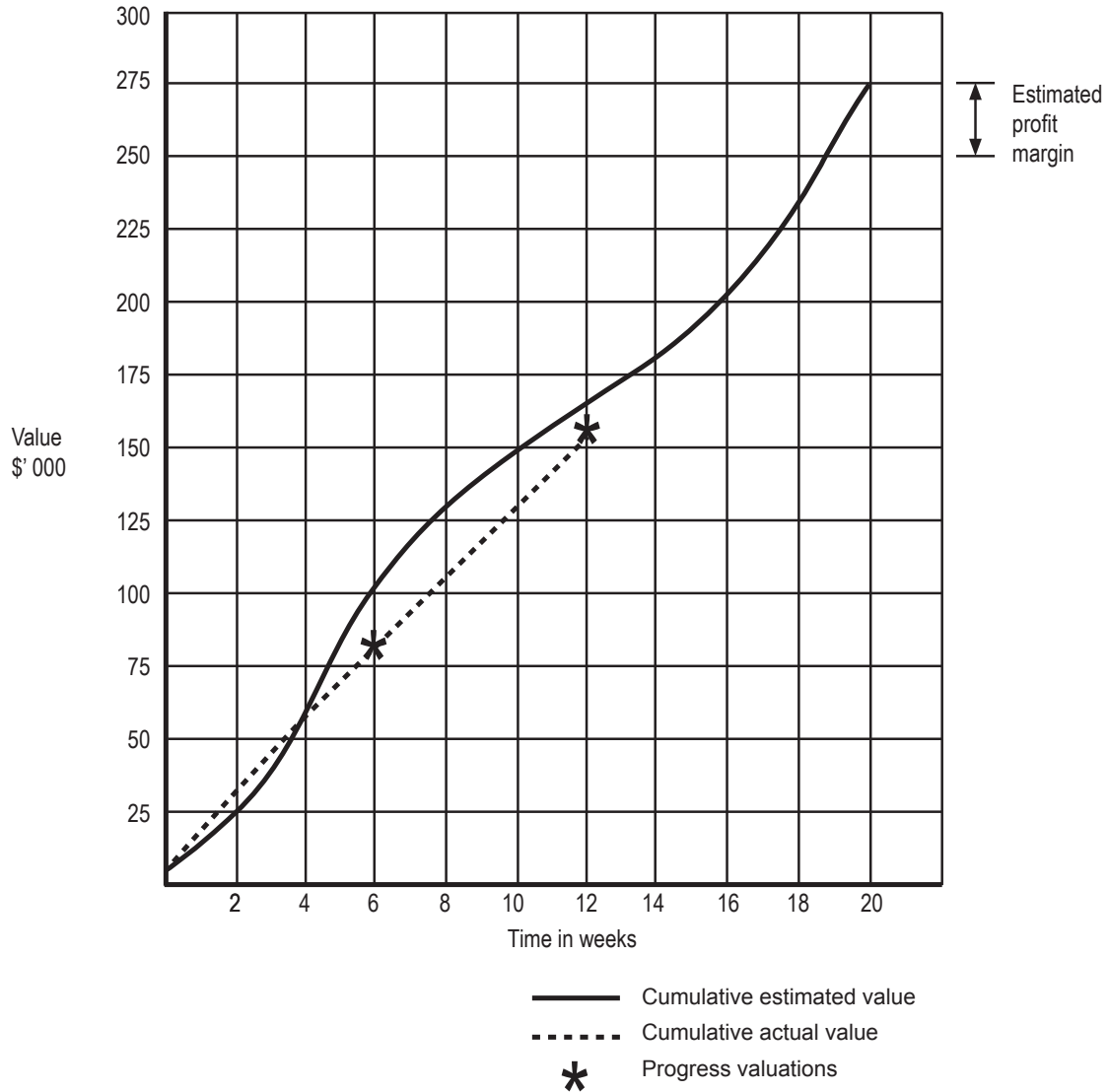


Fig 6.1 Example of budget graph

Illustrated below is another type of cost-versus-time graph which can be used as a cost-controlling system. The presentation allows for 'activity float'. The word 'float' is the term used to describe the tolerance associated with some of the activities within a project – which allows them to be moved around within a specific time span without affecting the finishing time of the project. Float is discussed in detail later in this resource.

The two curves represent the extremes of time between which cost can be incurred – one if each activity in the project begins at its earliest start time and the other if each activity starts at its latest start time. The value of the work performed should always lie somewhere between the two cost curves. Should the value-to-date point fall outside the latest cost curve, the indication is that claims are beyond schedule and work must be accelerated if the original target is to be maintained.

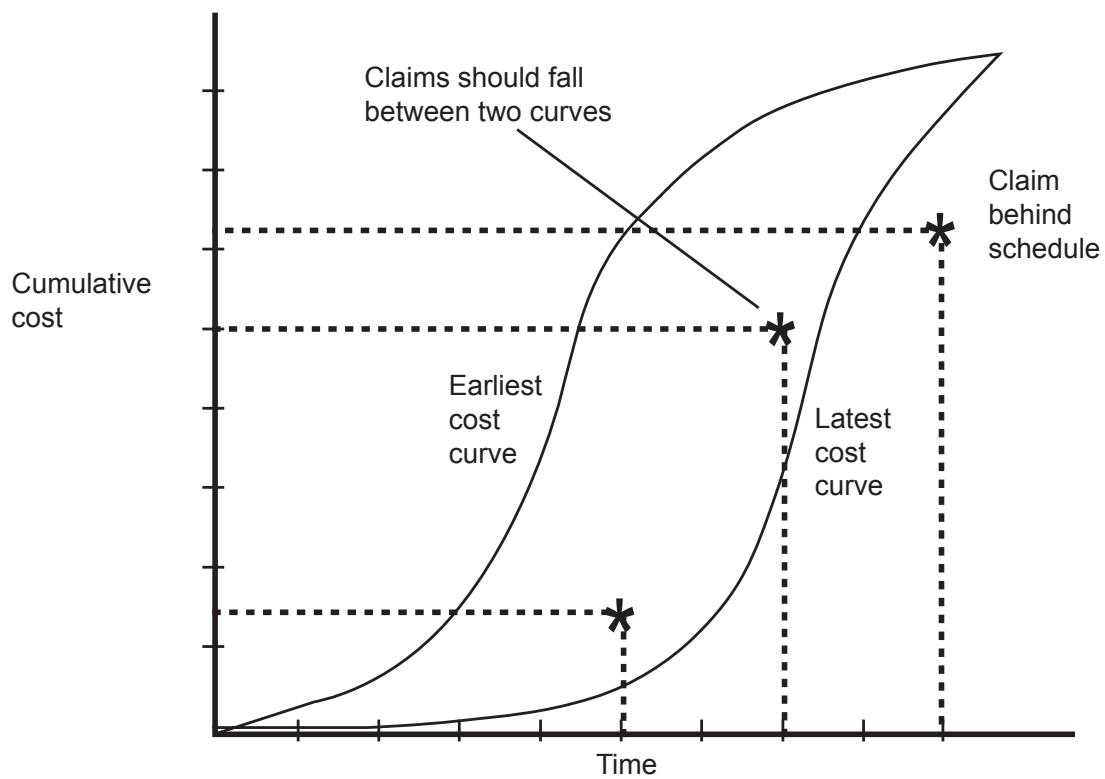


Fig 6.2 Cost-versus-time graph (the 'S' curves)

Progress control

For the benefit of overall programming to be maintained after work has begun on site, progress must be controlled and the work ahead kept under constant review. Progress control should, wherever possible, be integrated with other control systems such as those for cost, resources and quality.

In Chapter 4, reference was made to the preparation of a master program to provide management with a broad view of the contract as a whole. The master program can be used as a management-control tool to check actual progress against the anticipated progress at the time of preparing or updating the program. As the master program does not always show sufficient detail for day-to-day purposes, short-term programs are often prepared by the project manager. Breaking the program operations into finer detail means that it can be used more effectively as a control document.

The aim of short-term programs is to check progress frequently against the dates for operations envisaged in the master program. They also allow modification and new ideas to be incorporated into the program. The period involved will depend upon circumstances but is often between four and six weeks. It may be shorter or longer as the need dictates.

The monitoring of progress is the quantifying and communicating of the work performances on site. As stated earlier, before progress can be monitored, it is necessary to have planned and programmed the expected performance, against which a comparison can be made. Whatever technique is used to monitor progress, it should suit the purpose and also instigate corrective procedures. Bar charts and graphs are probably the most common method used as a visual presentation for monitoring progress. It is important that a date cursor be included to highlight the time of monitoring. Illustrated in Figure 6.3 is the use of a bar chart for monitoring progress.

Figure 6.4 illustrates a more comprehensive chart which combines a variety of information. Besides time scheduling of the activities, it shows the stage of completion of each activity, a curve indicating scheduled and actual progress as a percentage, the labour situation, information on claims, delivery schedules for resources and what percentage each activity represents of the total project. Further information could also be included on such a chart.

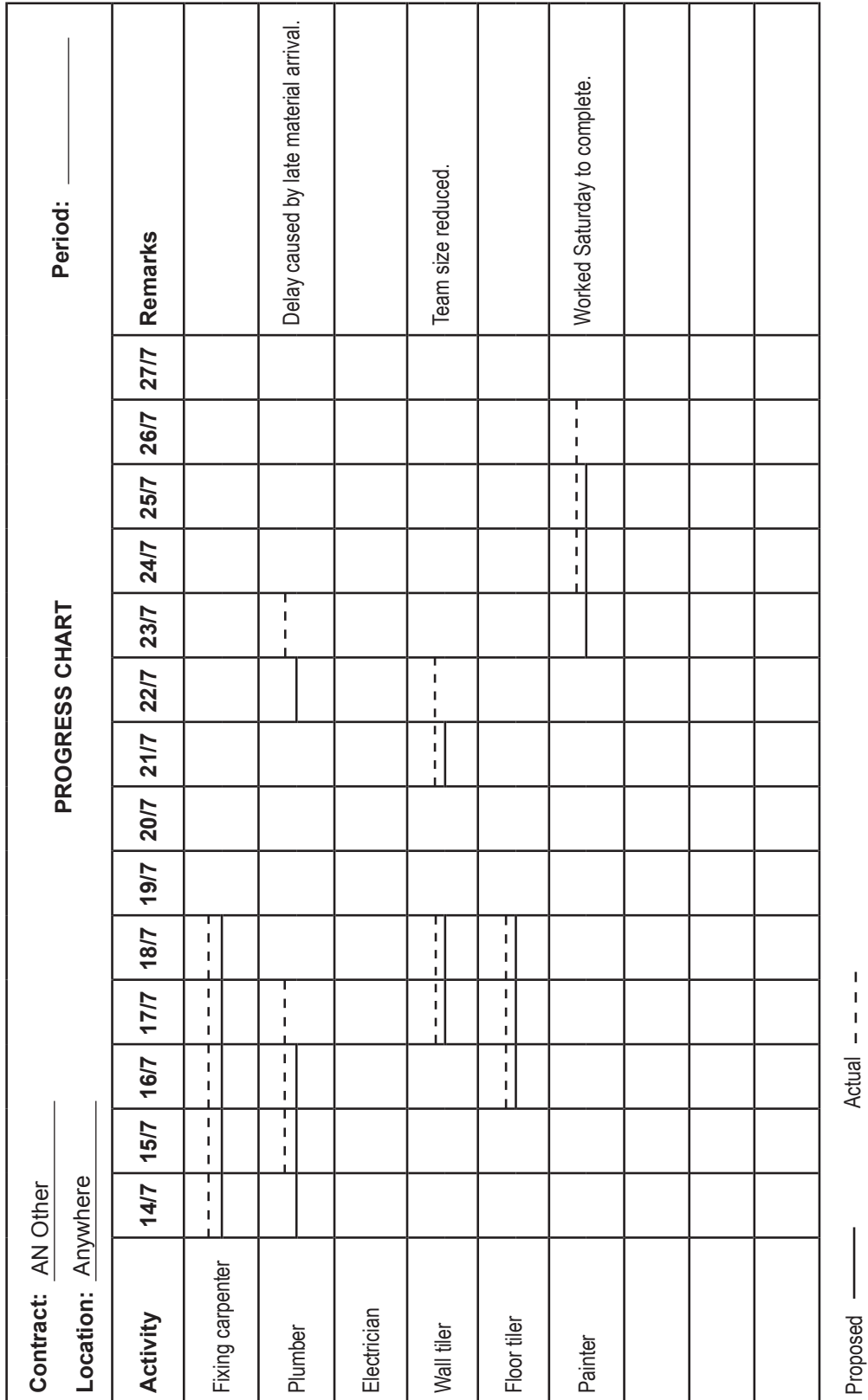


Fig 6.3 Example of a progress chart



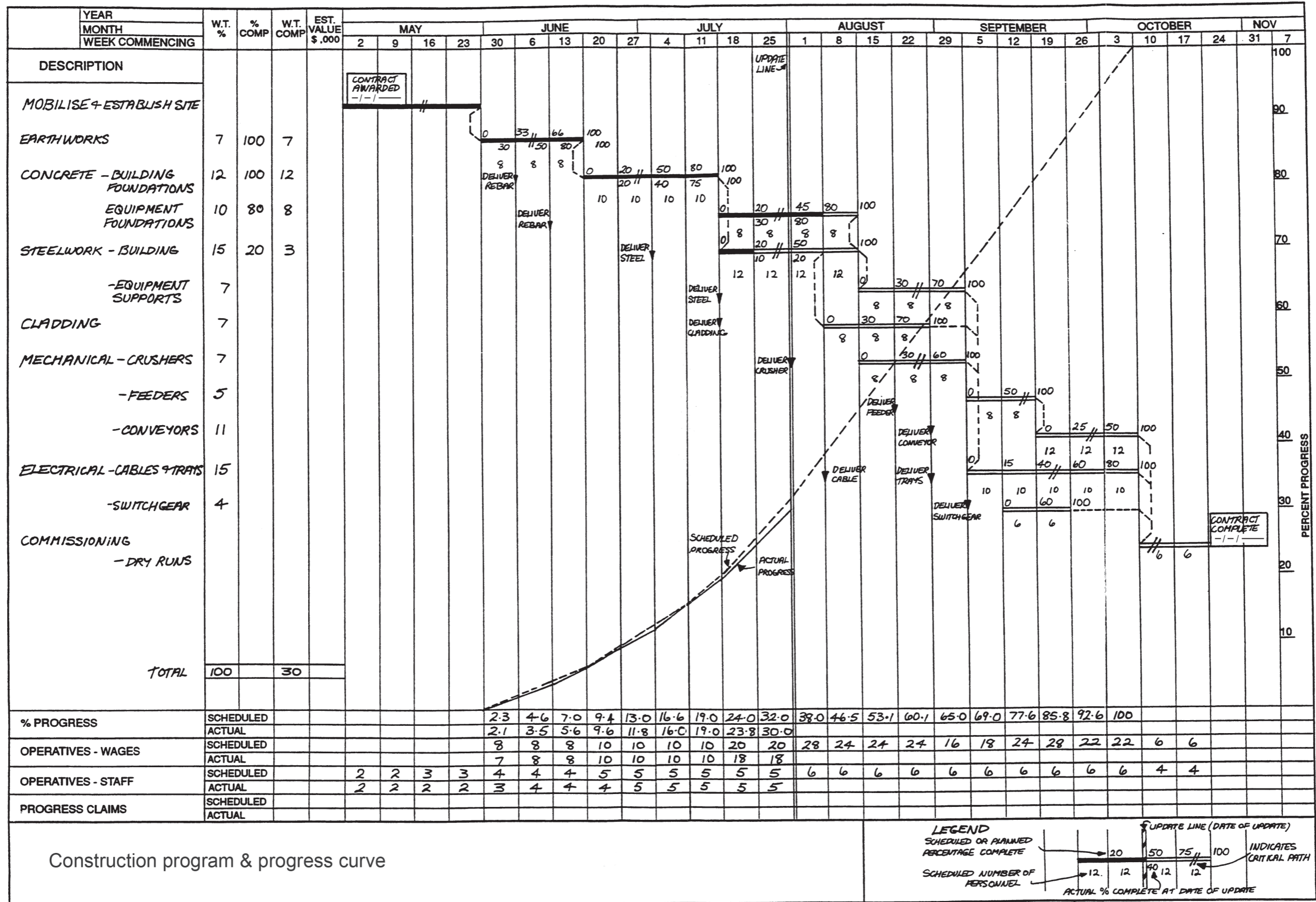


Fig 6.4 Example of construction program and progress curve



Progress reports

Progress reporting is part of the progress control system. Progress on the site should be recorded and reported to senior management on a regular basis. The frequency of the reports should be determined at the beginning of a contract and inspections planned to coincide with reporting requirements. Progress reports will contain the following information:

- name of project
- report number
- date of report
- general comments
- work in progress
- work completed since last report
- work which was scheduled to start but has not
- contract status at time of report.

An example is given at the end of this chapter to illustrate a presentation format for a progress report.

Conclusion

This chapter has not attempted to cover all aspects of control, nor to provide solutions. Each company must assess what controls it considers necessary and implement a system of control and recording which satisfies its needs.

Control at site level is concerned with ensuring that project budgets, cost programs, supplies and labour have achieved the targets set and that quality requirements satisfy the standards specified in the contract documents.

For control to be effective, the time between initial action and feedback must be as short as possible, so remedial action can be taken if required.

Control methods vary from firm to firm and from site to site but principles are similar and techniques should be as simple as possible to ensure that they are clear and concise in the information they convey.

Example of a progress report

City Views Stage 'B'

Construction progress report no. 7

Date:

General

Progress of the works has been recorded to the finish of work on Thursday, 20 September 20##, and shows the project three (3) days behind the updated construction program.

Current projected completion is 4 April 20##.

The most critical activity in progress is the cleaning down and making good of external brickwork and concrete. This activity must regain schedule and, if possible, improve on program, as some critical external ground works are controlled by this activity.

Other areas of concern are the plasterboard ceiling and bulkheads, which are holding program at the moment but must continue to do so until all floors are complete.

Glazing kitchen sashes is in progress with only two days float available and should maintain this status.

Kitchen cupboards to floors 2, 3 and 4, where scheduled to be fixed, have not started. The float available has now been reduced to five days.

As the current update program is a tight one, made to minimise the delays experienced to date, we should ensure that works generally start as scheduled and the float available is jealously guarded and used when necessary.

Works in progress		
Activity	Floor/s	Float available
<i>Rectification works</i>		
Exhaust air plenum	1–5	7
Supply air plenum	11	10
Clean and make good external brickwork	14	– 3
Sanitary fixtures	1–6	20
Distribution boards		40
Glazing kitchen sashes		2
Glazing full height		17
Glazing toughened		14
Plasterboard ceilings and bulkheads	11	0

Work completed last period	
Activity	Floor/s
Check pressurisation shaft and make good	
Clean and make good external brickwork and concrete pent-house	
Hot and cold pipework rough-in to penthouse	
Electrical rough-in penthouse	
Final sub-circuits	14 and penthouse
Bathroom cupboards	2-4
Floor and wall tiling	2-4

Work scheduled that has not started		
Activity	Floor	Float available
Rectification works to supply air plenum	10	10
Rectification works to supply air plenum	12	15
Clean and make good external brickwork and concrete	13	- 2
Unit switchboards	1	14
Unit switchboards	2	18
a/c ductwork and fan coil units	14	17
Kitchen cupboards	2	5
Kitchen cupboards	3	9
Kitchen cupboards	4	13
Wardrobes, linen press etc	2	13
Wardrobes, linen press etc	3	17
Clean-up and make good to penetrations in lift lobby	2	27
Clean-up and make good to penetrations in lift lobby	3	30

Contract status		
Contractual completion date		29 March 20##
Ahead/(behind) schedule		(– 3) days
Contingency period (updated)		12 days
Contingency period remaining		12 days
Projected completion date		4 April 20##
Total contract period updated (working days)		207 days
Elapsed time to 20 September		94 days – 45%
Delays to date:	industrial	16 days 1.5 hours
	inclement weather	4 days 5 hours
	Total	20 days 6.5 hours

Note: Does not include delays experienced since 31 August.

Delays approved – nil

End of report

Chapter 7

Introduction to programming

Introduction to critical path analysis/networks

In previous chapters, the need for planning has been discussed. The need to achieve benefits from planning, characteristics, basic steps, techniques and obstacles to proper planning have been considered with respect to the building industry. As building projects have increased in size and complexity, and come to comprise more separate operations and activities, the need to produce programs which will provide for coordinated action and effective communication among members of the building team has become more essential. Time, as well as cost, is an important factor in project control; therefore, if a project is to proceed efficiently and on time, it must be carefully planned and scheduled in advance.

The *critical path network* (CPN) is a technique which has been developed to perform this planning and scheduling function.

A network is essentially a model of the logic and calculation employed when planning a project. It displays a series of operations which must be followed in order to complete a project.

Historical background

Because of the increasing complexities of construction procedures, tighter time schedule requirements, rising costs and intense competition which developed in the 1950s and has continued since, it became necessary to develop a system of programming that would cope with the new technology confronting both governments and managements in commerce and industry. Earlier, the most common form of visual presentation of a construction program in use was the bar or Gantt chart. A major weakness in this form of presentation was its inability to readily display the interrelationships and interdependencies among the various phases of the work to be performed. It was necessary to develop a more efficient system which would offset the weakness of the Gantt chart. This was achieved through the development and introduction of *network analysis*.

It is claimed that network analysis originated in the United States from two separate spheres at approximately the same time, in the latter half of the 1950s. One of the techniques developed was referred to as the *critical path method* (CPM) and the other as the *program evaluation research task* (PERT) – which has since become known as the *program evaluation review technique*.

The CPM, alternatively referred to as *critical path scheduling* (CPS) and *critical path analysis* (CPA), had its origin when American companies Dupont Engineering Services and Remington Rand combined their resources to settle on a graphical network diagram which was a departure from the traditionally accepted method of planning represented by the Gantt chart. Their new technique allowed scheduling to be carried



out using simple arithmetic. From these calculations, it was possible to establish a critical path through the network diagram.

By 1958, PERT was developed for the United States Navy, to provide a method of program evaluation for the Polaris missile project. Because of the complexity of the program, conventional methods of planning and program evaluation were of little use and any delays could have had serious consequences for defence policies. Some 3000 contractors and agencies were employed in the development of the Polaris missile. The mathematical process developed for PERT made allowance for probable errors in the estimation of durations to be examined.

The basis of both the CPM and PERT is the network diagram. CPM assumes that the duration of each activity can be established with reasonable accuracy, while PERT allows for significant variation in the duration of each activity.

Types of network

There are three basic methods of preparing a network diagram:

1. 'activity-on-the-arrow' (arrow diagram), in which arrows represent activities and nodes represent events
2. 'activity-on-the-node' (precedence diagram), in which nodes represent activities and arrows represent their dependencies
3. PERT – a method of network analysis which enables the uncertainty associated with the estimation of activity *durations* to be taken into consideration.

The same logical steps are used to present any of the three types of network. Once the basic principles of network planning are understood, it will become a simple matter to comprehend network systems in general.

In this text, the arrow and precedence methods will be discussed.

Advantages of network analysis

When the potential of planning with the aid of networks is fully utilised, it allows many ideas to be considered, enabling designers, planners, builders and administration staff to review available resources and select, from alternative proposals, the method best suited to a particular project.

Some of the advantages – and disadvantages – of network planning are summarised below. The number of advantages clearly indicates the assistance the system offers when adopted as a part of management planning.

Advantages

- The allocation of times to activities is more accurate when using network planning than is the case with the Gantt chart method.
- It shows the relationships and interdependencies between activities – the way some activities depend upon or influence others.
- It enables resource and time restraints to be included in the plan before its evaluation.
- Possible bottlenecks during the construction period can be foreseen.

- It enables closer control of complex projects, since any deviation from the schedule is quickly noticed.
- Critical activities can be highlighted.
- It provides a means to test and select alternative solutions before any particular option is implemented.
- It allows for greater detail when planning and scheduling. By dividing the project into small activities, it assists in the estimation of their durations, leading to more accurate target dates.
- Modifications of policy can be included easily and the implications assessed quickly.
- It provides a more accurate and effective basis for the preparation of Gantt charts, resulting in improved control.

Disadvantages

- It is a tedious and exacting task if attempted manually. Depending upon what is required, the number of activities that can be efficiently handled without the aid of a computer is not very high.
- Staff will require special training to prepare and read networks.
- The network is generally used only by management staff and project coordinators and controllers on the project site. As a rule, subcontractors have no specific interest in the complete network; therefore, it is usual to provide a detailed Gantt chart for their use, as it is generally accepted that Gantt charts are easier to read and understand.

Principles of programming

In preparing a project network, the project planner or members of the planning team must apply the following principles.

The construction program, whether master or secondary, must be:

- realistic and capable of being achieved
- unambiguous
- based on available information
- appropriate in degree of detail for the particular project
- coordinated with any other programs for the project.

It must show:

- all significant activities – which should be clearly defined
- the work of specialists
- consistent forms of visual expression for clarity and easy identification
- a unique reference number.

The above will provide ease of monitoring performance.



It must reflect:

- sound construction methods
- availability and economical use of resources
- holidays and other calendar irregularities
- seasonal influences.

Administering the network

The management of a project can be considered in three stages:

1. planning
2. scheduling
3. controlling.

Planning

This involves the definition of:

- what should happen
- when it should happen
- by whom it is to be carried out.

The 'pre-tender planning' may be used as a foundation in the preparation of a more detailed master plan. The right decisions, together with careful examination of all aspects of the work at this stage, will most certainly result in the saving of money and time in the construction period. A plan is in fact a map of the future.

Scheduling

This is the fitting out of the building program to either a bar chart or a network, taking into consideration the interrelationship of operations and any fixed dates which have been superimposed on the schedule.

It is worth noting that planning by the critical path analysis method enables two decisions: one concerning relationships, the other concerning time. These can be separated. Other planning methods, such as the time and progress schedules and bar chart or Gantt chart, require these decisions to be made simultaneously. This separation constitutes one of the advantages of using critical path analysis when planning.

Controlling

Continued control involves the highlighting, for management action, of anything which is likely to jeopardise the progress of the project. The essential features of management control are:

- A plan is formulated.
- All interested parties are provided with a copy of the plan.
- When implemented, the plan must be supervised.
- The work progress is constantly evaluated to determine the effect of changes caused by varying productivity, mistakes, the weather or by the client.
- Any deviation from the contract agreement must be promptly reported by the builder's project manager for processing.

- All variations or deviations from the contract are analysed before final decisions are made, to ensure that:
 - the contract will be completed in the specified time
 - all resources are being used economically and to their fullest extent
 - there will be minimal disruption caused to the project
 - existing contract conditions can be fulfilled – failing which negotiations with the architect (acting on behalf of the client) will be necessary.



Chapter 8

Introduction to arrow diagrams

To develop a network, it is obviously important to understand the principles involved and the terminology used.

Fundamentally, a network is a project graph. It represents a plan, clearly displaying the series of operations in a logical sequence and also indicating the interrelationships and interdependencies of the operations with one another.

Network components

Activities are elements of work entailed in a project. They are operations which consume time and other resources such as labour, plant etc. The symbol used to represent an activity is an arrow, the arrowhead indicating the flow of the network.

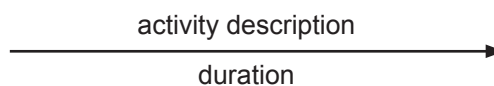


Fig 8.1

The length and orientation of arrows are of no significance. Length bears no relationship to time; it indicates the direction of the workflow only.

A *node* represents an event, which is the point at which an activity or group of activities starts or finishes. The symbol used to represent a node is a circle.

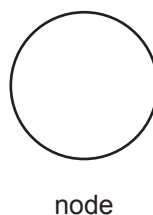


Fig 8.2

A *milestone* is an event selected for its importance in a project. It may be either the start or finish of an activity and is a useful means of reporting progress to senior management, as well as for creating a sense of awareness within the project team. A different-shaped symbol, such as a hexagon, is often used for the node concerned, to highlight the event's importance. Milestones form a series of goals within the network.

Basic conventions and rules of logic

Conventions

Two conventions are adopted in preparing arrow diagrams.

1. The network flows basically from left to right. The arrowhead on the activity line indicates the direction of operations for the network.
2. Head nodes have a higher number than tail nodes. Activities must begin and end at a node. The preceding node is the tail node and the succeeding node is the head node for each activity. The tail node is often referred to as the 'i' node and the head as the 'j' node. Each node in the network is given a number in ascending order and each activity must have a unique identity.

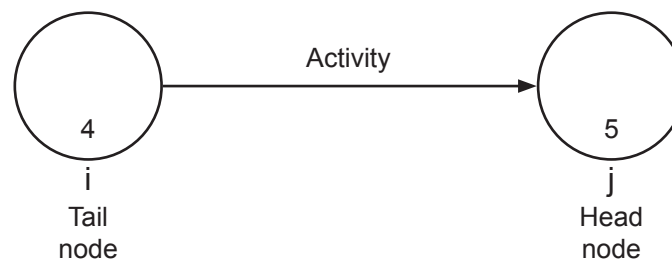


Fig 8.3

Numbers used need not necessarily be arranged in normal sequence (ie 1, 2, 3 etc) but may be arranged in any ascending order, for example 5, 10, 15. The latter allows modifications to be made to the network while still maintaining an ascending sequence of numbers.

In fact, when constructing an arrow diagram, it is safe practice to 'gap' the numbers in the nodes, for example, 0–2–4–6–8 etc. Leaving gaps allows additional activities/arrows to be included later – if they have been 'missed out' – without the need for what might be a confusing means of identifying the arrows to be inserted. For the present, consecutive numbering will generally be used here. (See Figures 8.7 and 8.10 and the examples of service station networks in Chapter 10 for 'gap numbering'.)

The dependency rule

The following two basic rules govern the construction and analysis of network diagrams.

1. An activity cannot begin until its preceding event has finished.
2. An event is not completed until all activities entering it have been completed.

This applies equally to either a single chain of activities (eg Figure 8.4) or where a group of activities is involved (eg Figures 8.5 and 8.6).

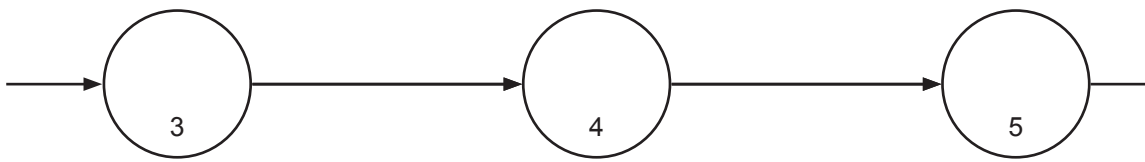


Fig 8.4

Thus, in Figure 8.4, Activity 4–5 cannot be started until Activity 3–4 has been completed.

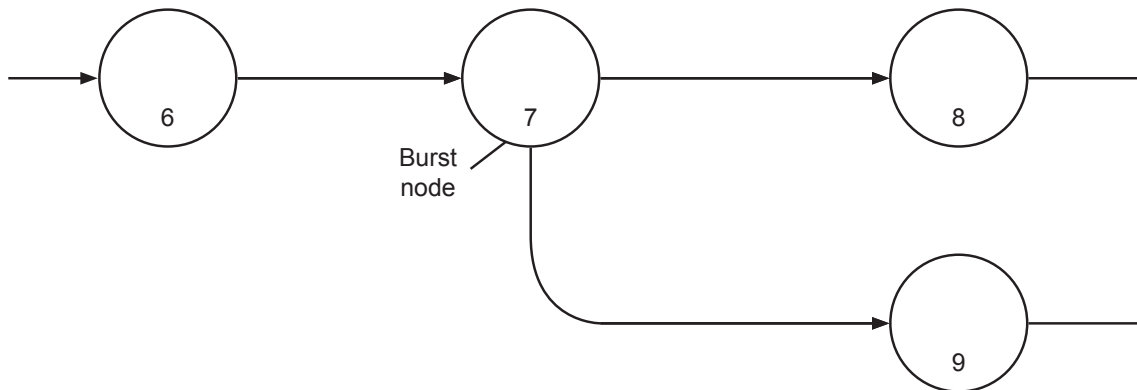


Fig 8.5

In Figure 8.5, Activities 7–8 and 7–9 cannot start until Activity 6–7 has been completed. A node from which two or more activities generate is known as a 'burst' node and the diagram is said to contain a 'burst'.

In Figure 8.6, Activity 17–18 cannot begin until Activities 15–17 and 16–17 have both been completed. A node into which two or more activities terminate is known as a 'merge' node and the diagram is said to contain a 'merge'.

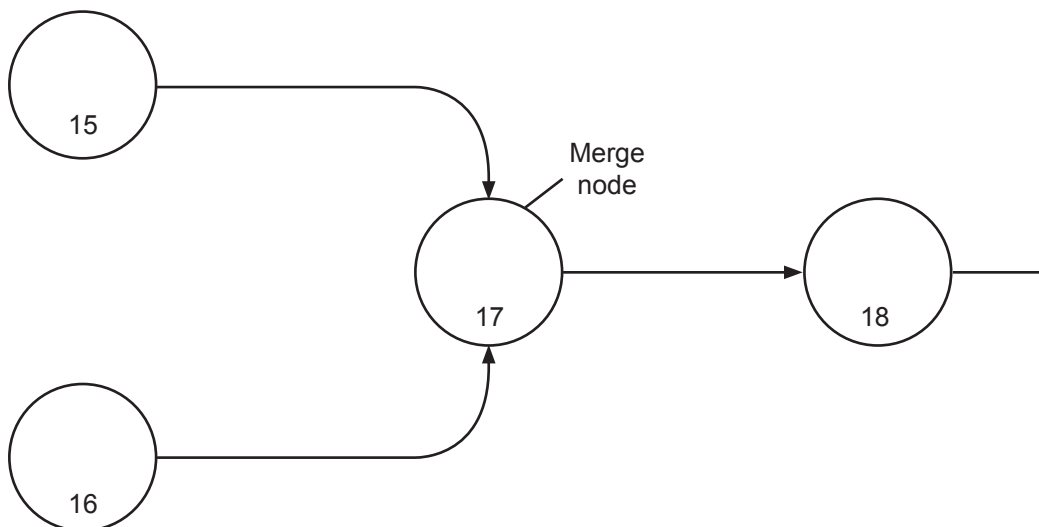


Fig 8.6

Activities 30–35 and 30–40 in Figure 8.7 cannot begin until Activities 20–30 and 25–30 have both been completed. Where two or more activities must be completed before two or more activities can start, the diagram is said to contain a ‘cross’.

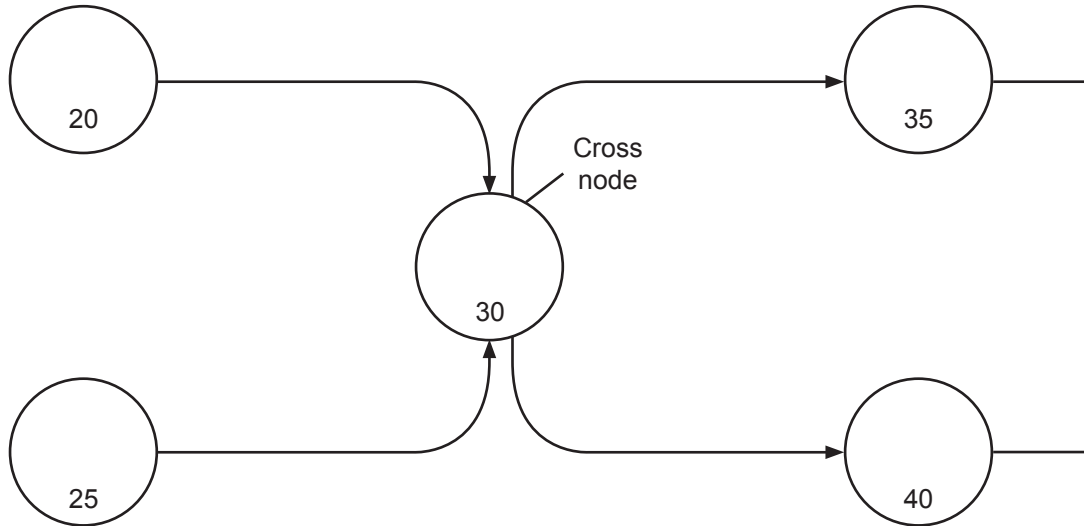


Fig 8.7

In Figure 8.8, Activities 13–14 and 13–15 are dependent on Activity 12–13 being completed. Activity 15–17 is not dependent on Activity 13–14 being completed but is dependent on Activity 13–15 being completed.

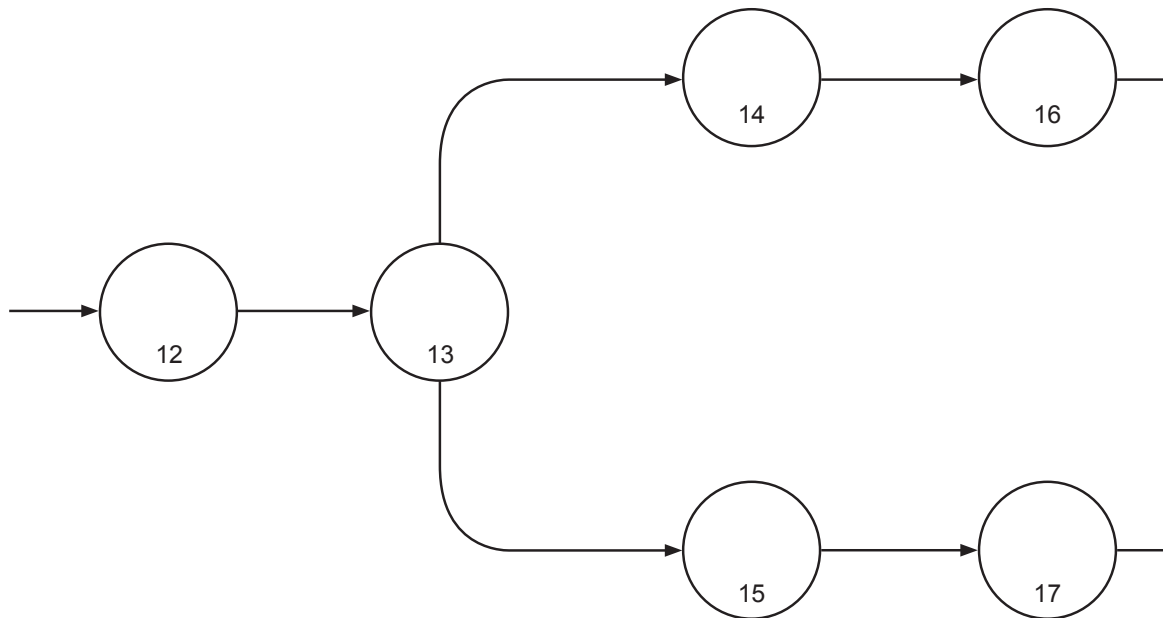


Fig 8.8

The *duration* is the estimated time required to complete an activity. When calculating the duration of a project, add the duration of an activity to the time at which its start event was achieved. The unit of time in which duration is measured should be consistent throughout the network.

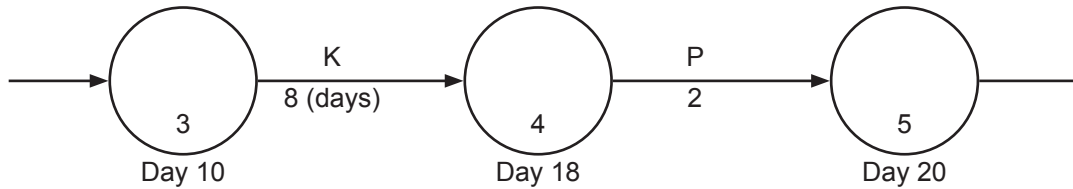


Fig 8.9

In Figure 8.9, Event 3 was achieved on Day 10; the duration of 'K' is 8 days and the duration of 'P' is 2 days. Event 4 can therefore be achieved on Day 18 and Event 5 by Day 20.

Figure 8.10 shows that, even though Activity 20–25 could be completed by Day 15, Activity 25–30 cannot begin until Day 25 – that is, until both Activities 15–25 and 20–25 have been completed.

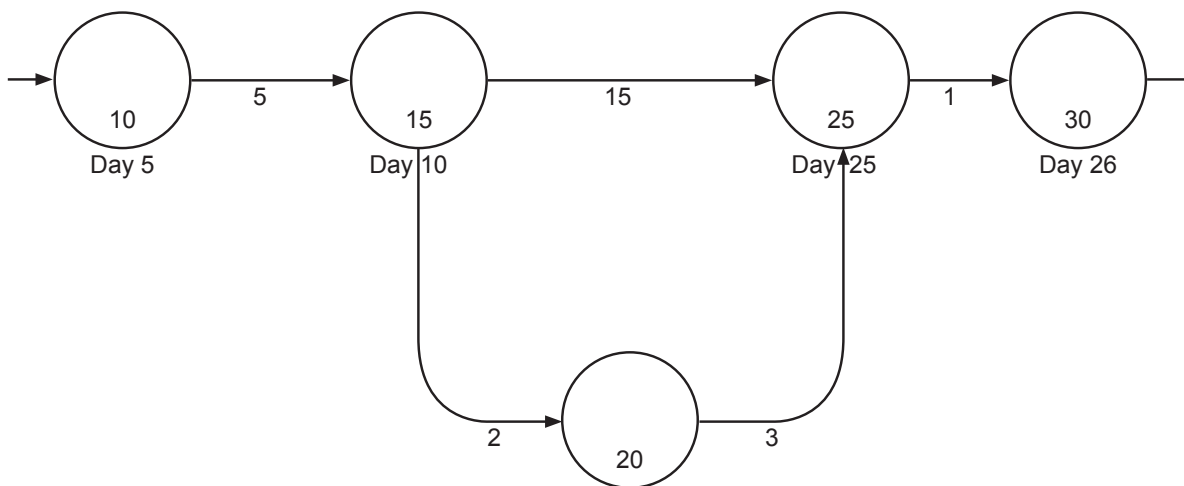


Fig 8.10

At this point, it should be repeated that the length and orientation of an activity line are of no real consequence; it is the accuracy of the duration determined for an activity that is important. The duration chosen for each activity should be realistic and capable of being achieved by the average worker. The duration indicated for an activity is not necessarily the time between the tail ('i') and head ('j') nodes. This statement will be expanded upon later in the resource.

Parallel activities

When two or more activities connect between the same tail and head nodes, and therefore have identical activity identification, the activities are said to be *parallel*, as shown below in Figure 8.11.

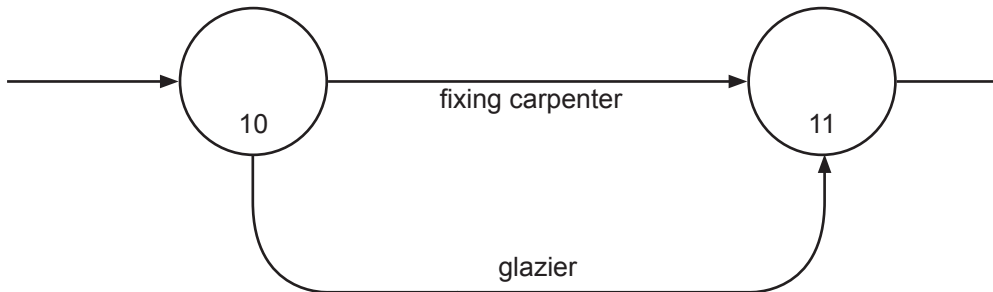


Fig 8.11

It can be seen that the 'fixing carpenter' and 'glazier' are shown as separate activities with the same activity identification. It is undesirable to include parallel activities in network logic, as it results in confusion when referring to, or analysing, the network. When computers are used to prepare a network, they may reject any attempt to enter more than one activity with the same identity number. A means of avoiding inclusion of parallel activities in network logic is to introduce *dummy activities*.

A dummy activity represents no actual operation and uses no resources – but can be used to give a distinct identity to another activity. The symbol used to represent a dummy activity is a broken line and an arrowhead to indicate the direction of travel.

Dummy activities have two main applications – one known as a *distinguished restraint* and the other as a *logic restraint*.

Distinguished restraints are used only to maintain the unique numbering system and represent no consumption of time or resources. In Figure 8.11 above, two activities have the same identification number. In order to correct such a situation, a dummy would be added, as shown in Figure 8.12, so as to maintain a unique numbering system.

In this instance the dummy has been placed before the activity – but it could just as correctly have been positioned after the activity. When it comes to analysing the network, it may be found that placing the dummy in front of the activity facilitates a more accurate analysis.

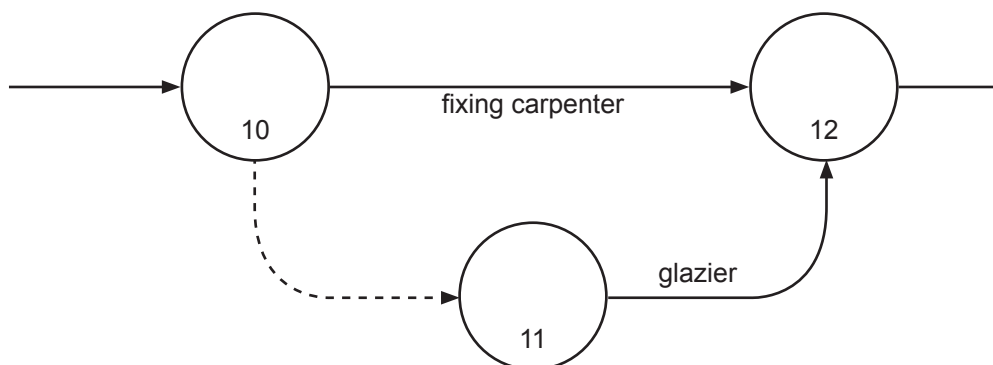


Fig 8.12 Dummy – distinguishing restraint

Logic restraints are used to ensure that logic of the network is maintained where this cannot be achieved using activity arrows.

As an example, in Figure 8.13, if Activities 13–15 and 14–16 are dependent on Activity 11–13, and Activity 14–16 is also dependent on activity 12–14, then the logic is drawn as shown.

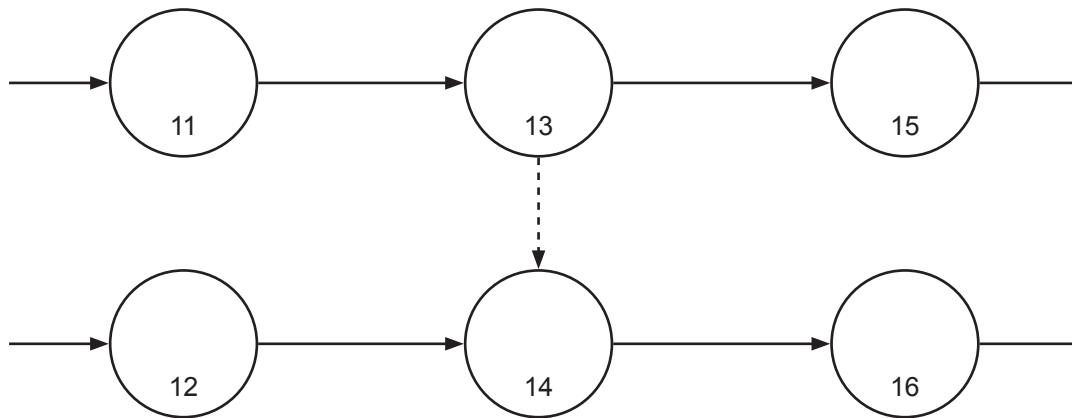


Fig 8.13 Dummy – logic restraint

Care should be taken to ensure that the direction of the logic restraint is correct. If the dummy arrow pointed in the opposite direction, the logic would change to read Activities 13–15 and 14–16 are dependent on Activity 12–14, and Activity 13–15 is also dependent on Activity 11–13.

The use of dummy activities in arrow diagram networks is largely indispensable.

A *dangle* is a break in the path of a network where an activity does not connect to the end of the network. Dangles can be created where a project which is underway has all completed activity arrows removed from the diagram, leaving a series of unconnected activities, or where an activity has been added as an afterthought and has not been tied back into the network, as shown in Figure 8.14. Dangles should either be tied back into the network or specified as starting or finishing events.

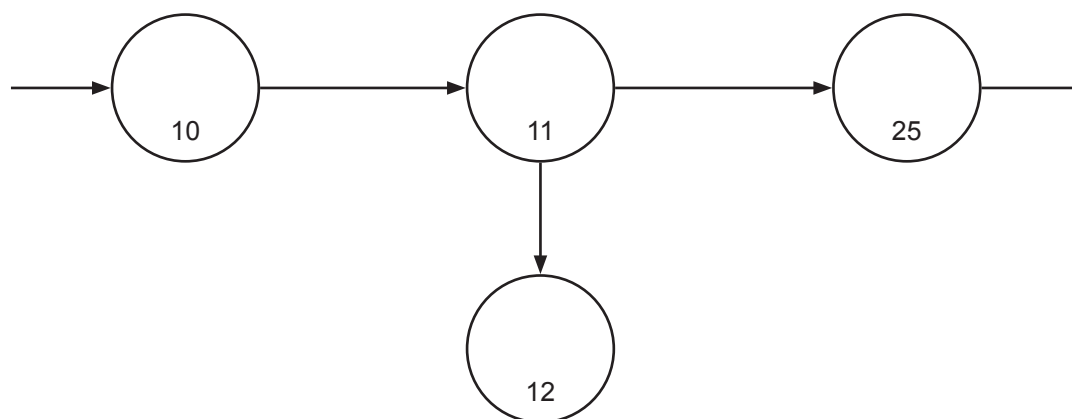


Fig 8.14 Dangle

A basic rule to follow is that, except for the first and last events, all nodes must have at least one activity entering and one activity leaving the node.

Figure 8.14 is simply solved by introducing a dummy activity between Nodes 12 and 25.

Looping is an error in network logic which results in an activity imposing a restraint on a preceding activity.

Figure 8.15 suggests that the network's activities proceed in sequence from Node 1 to Node 2 and then from Node 2 to Node 3, which is correct logic. The following step of diverting Node 3 back to Node 1 creates an impossible situation, as it incorrectly indicates that Activity 1–2 is dependent on Activity 3–1 being completed – a dog chasing its own tail situation.

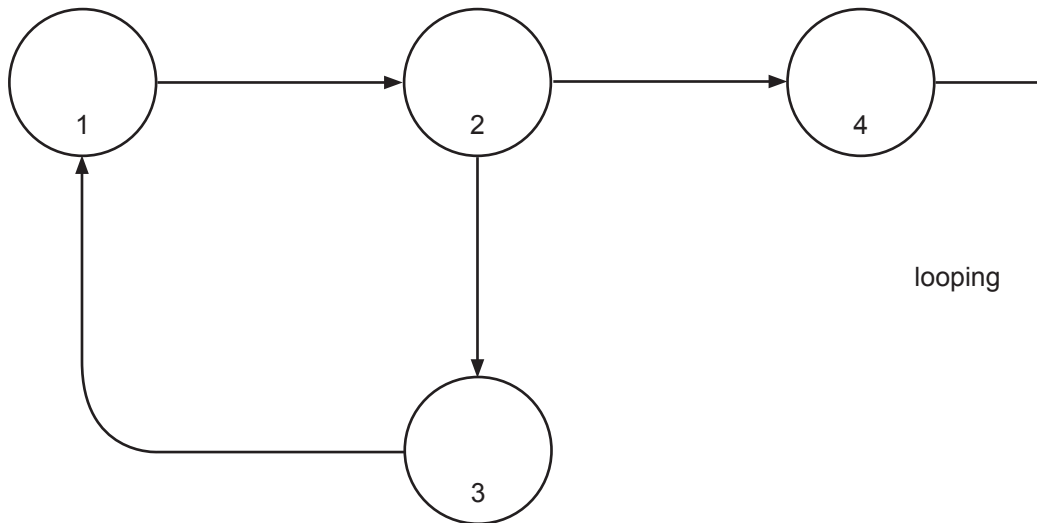


Fig 8.15 Looping

Network preparation and management

Reference was made in the previous chapter to the stages to be considered in the management of a project, namely:

- planning
- scheduling
- controlling.

These stages will now be further considered in the context of critical path networks.

Planning

Planning a network involves the determination of the number of activities involved and their organisation into a logical sequence. The logic being set down should be carefully examined to ensure that it does not contain false logic or built-in prejudices which would prevent the best solution from being achieved. The level of detail required should be practical, yet sufficient to enable sound planning. To reduce a project's duration to a minimum, in planning a network, it is desirable that:

- something is happening all the time
- as many activities as possible occur as soon as possible
- as many activities as possible occur at the same time.

In developing an arrow diagram, three questions should be asked about each operation:

1. What activity must immediately precede this activity?
2. What activity can immediately follow this activity?
3. What activities can take place concurrently with this activity?

Network planning should be based on what is physically possible, taking into account likely variables such as priorities on the use of resources and prevailing climatic conditions.

Practical example:

Set out and prepare the excavations and formwork to a stage where the job is ready for the pouring of a concrete strip footing.

The planning determines that the following activities are necessary:

- set out
- excavate trenches
- order materials
- construct the formwork
- erect the formwork.

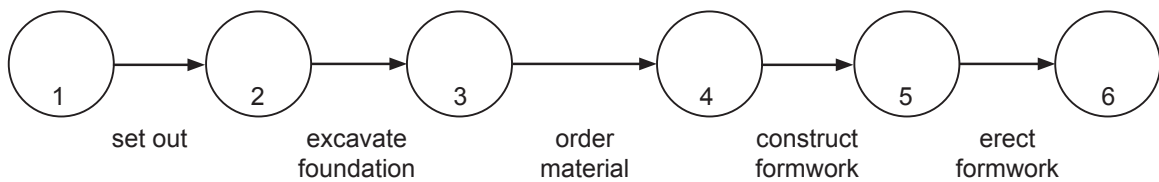


Fig 8.16 'Straight line' sequence of activities

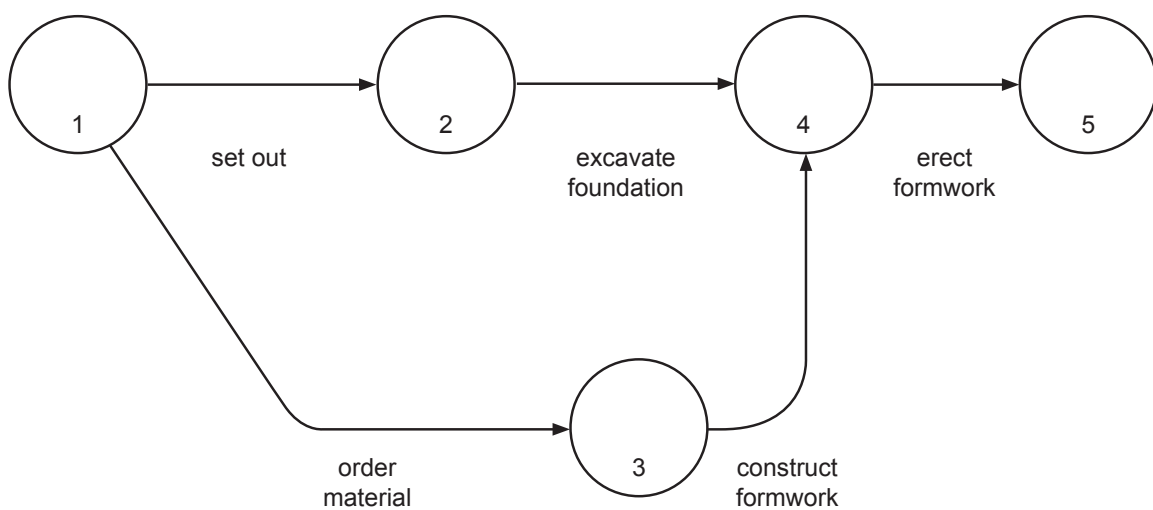


Fig 8.17 Alternative sequence including concurrent activities

Figure 8.16 illustrates a situation in which one activity simply follows another – where just one activity was planned to happen at a time.

But this method is not logical in practice. As noted above, it is desirable to have as many activities as possible occurring as soon as possible, to reduce project duration. Where activities can be performed concurrently, without inconveniencing others, a network should be planned in this way. Figure 8.17 represents the network being planned with this principle in mind. To reduce the duration required to complete this task, the activities of ordering materials and constructing formwork have been planned to coincide with the activities of setting out and excavating foundations. If the planning is correct, it will enable the formwork to be erected as soon as the excavations are completed.

Scheduling

Scheduling is the fitting of the planned network to a time-track, taking into consideration the interrelationship of operations and any fixed dates which may have been imposed on the schedule. It is important that time estimates are realistic.

There are three fundamentals which should be adhered to when scheduling for a network.

1. Durations must be measured in the same unit throughout the network – that is days, weeks or hours. Don't mix the units, for example:
 - a) set out – 1 day
 - b) order materials – 4 hours.
2. Consistency of position should be maintained when indicating durations – that is, either place the duration above the activity line throughout or place it below throughout.



Fig 8.18

3. Each activity should be considered as a separate entity; that is, it should not be influenced *initially* by project target dates. The duration of an activity should be estimated, based on assumptions of a normal work week and normal resources availability.

Controlling

Controlling entails monitoring the network to determine whether it is proceeding as planned. The actual performance can be compared with the planned performance. Problem areas within the work can be detected and remedial action started to rectify the situation.

The critical path

The critical path is the *path* or *paths* through a planned sequence of activities of a network which indicates the shortest possible time in which the project can be completed.

As there is no tolerance allowed along this path, it is critical that each activity be completed in the specified time. Any circumstances which create delays, and which cannot be swiftly rectified, will automatically extend the completion date of the project.

The basic method used to determine the critical path through a network will be explained using the sequence of activities for the preparation of a concrete strip footing that was discussed under 'Planning' earlier in this chapter.

A study of the network (Figure 8.19) shows that there are two paths through the network:

- Path 1 involving activities 1–2, 2–4, 4–5
- Path 2 involving activities 1–3, 3–4, 4–5.

Totalling the durations on each path establishes that it requires four days to complete the activities on Path 1 and three days to complete the activities on Path 2.

Path 1 is therefore the critical path through this network, as it represents the shortest time in which the work can be completed – that is, while it's the path occupying the longest passage of time, it leads to the earliest possible time by which all activities can be completed.

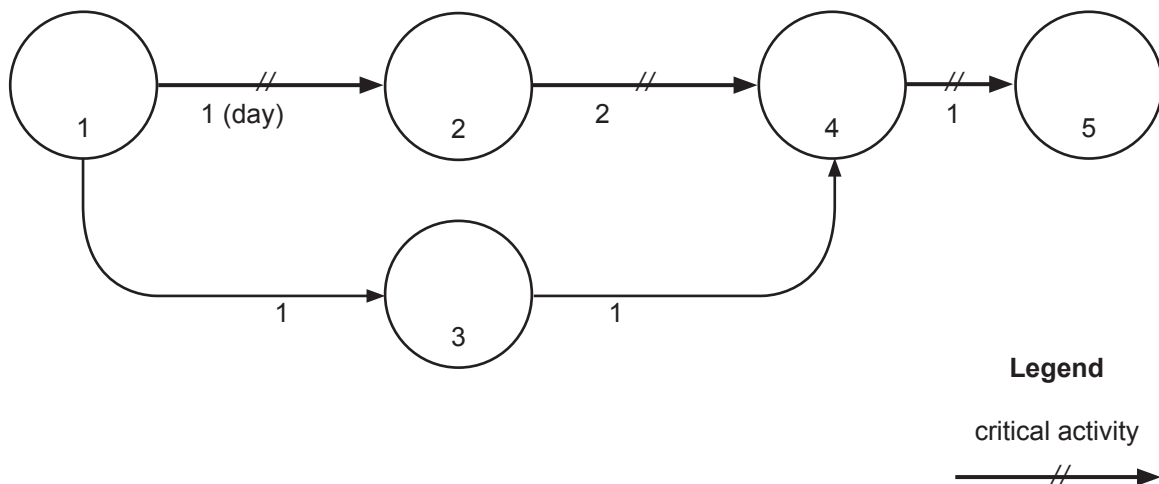


Fig 8.19 Critical path

Once established, this path should be illustrated in such a manner in the network diagram that it is easily identified. For example, it can be shown with parallel lines across the activities and/or thickened arrow lines (as shown in Figure 8.19). The critical path must be obvious to whoever is studying the diagram. Whatever the method used to indicate the critical path, a legend should be used to clarify its meaning.

Further examples of establishing the critical path

The following two examples further illustrate the method of establishing the critical path through a network.

In the following two diagrams, two additional points arise.

1. There can be more than one critical path in a network, as illustrated in Figure 18.20.
2. A dummy activity may form part of the critical path, as shown in Figure 18.21.
It should also be noted that a dummy activity has zero duration unless otherwise specified.

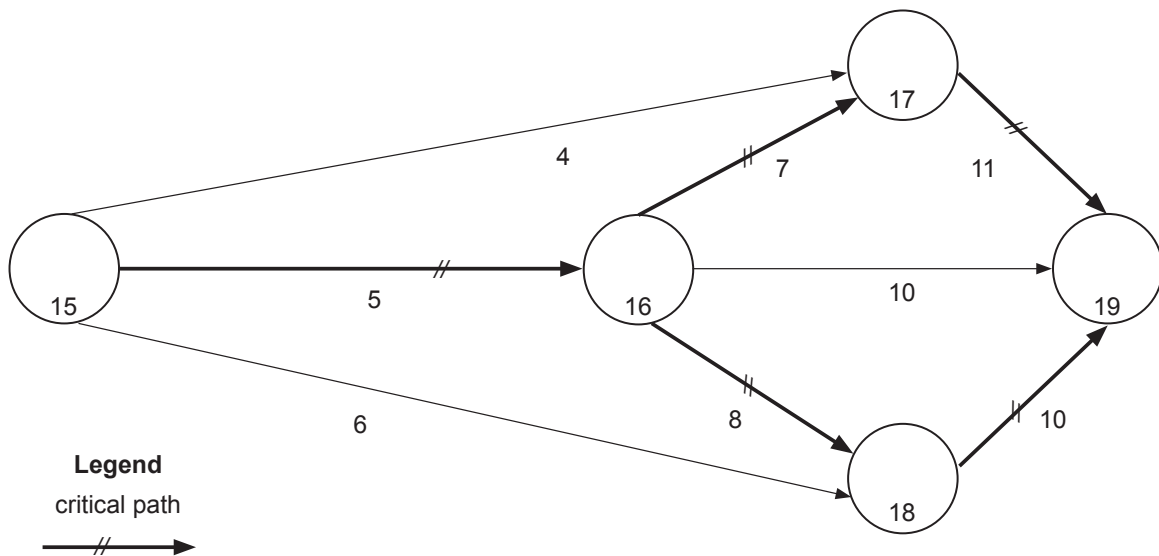


Fig 8.20

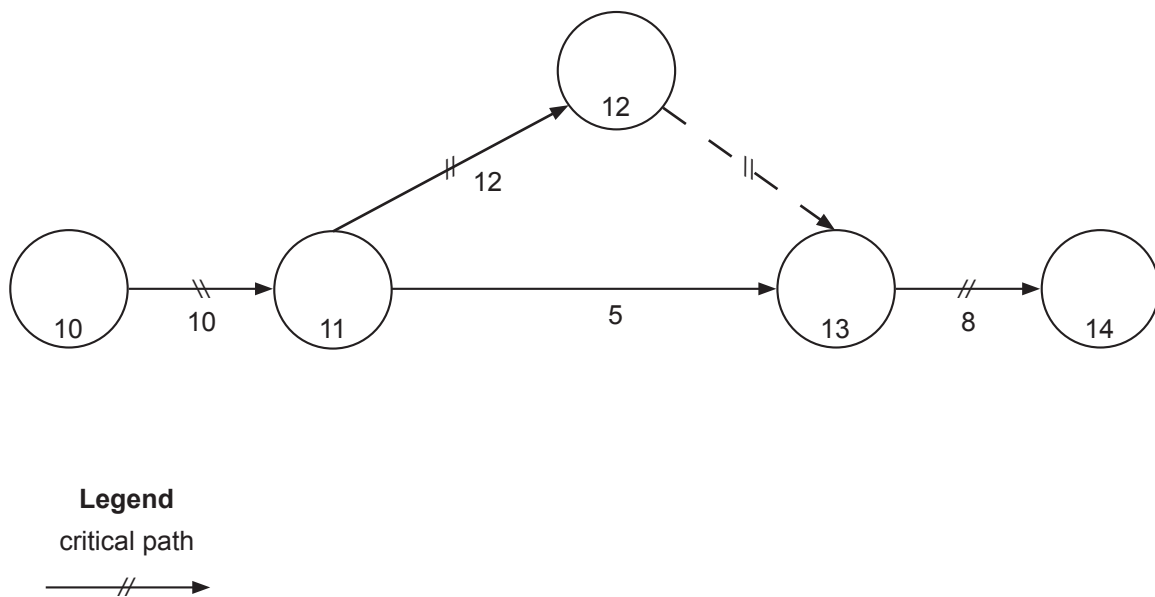


Fig 8.21

The node

Earlier in this chapter, the node was defined as being the point at which an activity or group of activities starts or finishes. The circle is the symbol used to represent a node in a network diagram. To this point, the only information shown as contained in the node has been a node identification number.

To establish an easier means of monitoring and analysing a network, further information needs to be provided. This information and the method of presentation will now be discussed. The methods of presenting information for each node are many and varied. To maintain consistency, the following procedure will be adopted.

The circular node will be divided into four parts by means of two diagonal lines and information inserted into various sections of the node, as follows:

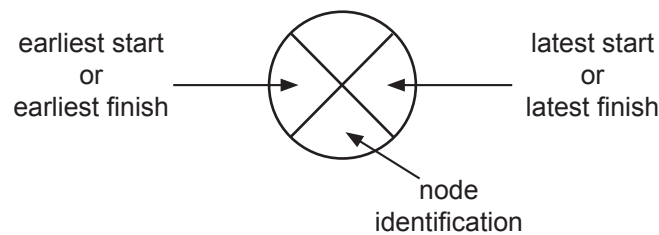


Fig 8.22

- The *earliest start time* is the earliest possible time at which an activity can start and is indicated by the earliest time of the tail event.
- The *latest start time* is the latest possible time at which an activity can start without affecting either the total project time or the logic of the network.
- The *earliest finish time* is that point of time before which an activity cannot be completed.
- The *latest finish time* is that point of time after which an activity cannot be completed without affecting the total project time or the logic of the network.

Each of these four definitions will be elaborated on in the following pages.

Network computations

Once a logical sequence of activities has been established and the duration for each activity estimated, other essential project information can be computed. Various scheduling computations can be established from the network once the duration for each activity has been noted on the network.

This information is determined by conducting a forward pass computation (ie calculating from left to right) and a backward pass computation (ie calculating from right to left) through the network.

The forward pass computation

The purpose of the forward pass is to establish the earliest starting and finishing times in the project, based on the lapsed working days, keeping in mind the dependency rule. The following rules apply when using the forward pass.

1. The earliest time of occurrence of the initial node is taken as zero.
2. Each activity begins as soon as its preceding node occurs.
3. The earliest finishing time for an activity is equal to the earliest starting time for the activity plus the duration for the activity in question.
4. The earliest time of occurrence of an event is the latest of the earliest finishing times of the activities merging at the node in question.
5. These times are noted in the left-hand space in the node, as indicated in Figure 8.22.

Calculating earliest starts and finishes

The earliest start time of an activity is established by adding the previous activity's duration to the earliest finishing time noted in the previous node, calculating from left to right across the network.

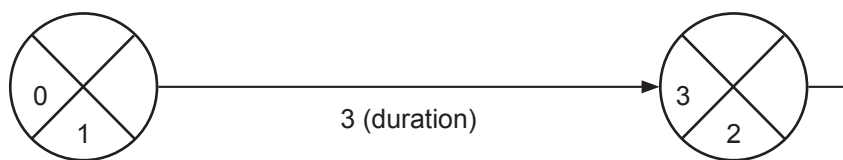


Fig 8.23

In the above figure, taking the earliest start time for the project as zero, the duration of the first activity is then added to this to calculate the earliest finishing time. This earliest finishing time in turn will become the earliest start time for the next activity.

Where two or more activities meet at a common node, the greatest time (the highest number) represents the earliest start time for the next activity.

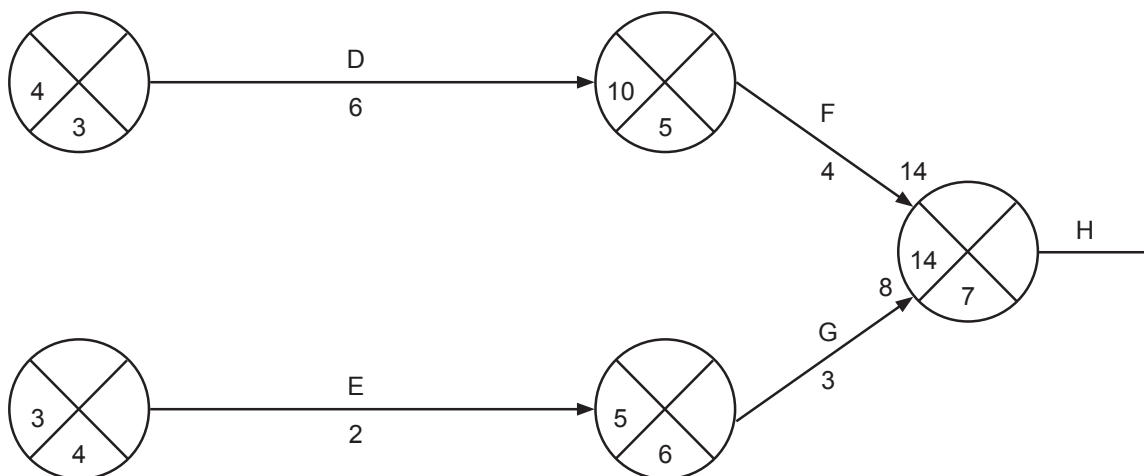


Fig 8.24

Figure 8.24 shows Activities 5–7 (F) and 6–7 (G) both terminating at Node 7. The time required to reach Node 7 along the paths including Activities D and F is 14 days and the path through Activities E and G requires 8 days. As both F and G must be completed before H is commenced, the earliest H can begin is Day 14 (ie the greater of the two durations).

The backward pass computation

The purpose of the backward pass is to establish the latest allowable starting and finishing times for each activity so as to permit the project to be completed at the earliest expected time computed in the forward pass.

The backward pass begins with the planned project completion date and works backwards to determine the latest date (or day) on which each activity can begin or terminate without affecting the final completion date of the project.

The following rules apply when using the backward pass.

1. The latest allowable time of occurrence of the terminal of the network is set equal to the earliest time of occurrence computed in the forward pass.
2. A node occurs as soon as the preceding activity finishes.
3. The latest allowable starting time for an activity is the latest allowable time of occurrence for the succeeding event, minus the duration of the activity in question.
4. The latest allowable time for the occurrence of a node is the earliest of the latest allowable starting times of activities diverging from the event in question.

Calculating latest starts and finishes

The latest start time is calculated by subtracting the duration from the latest finishing time noted in the head node of the activity concerned. Start from the terminal node and calculate from right to left.

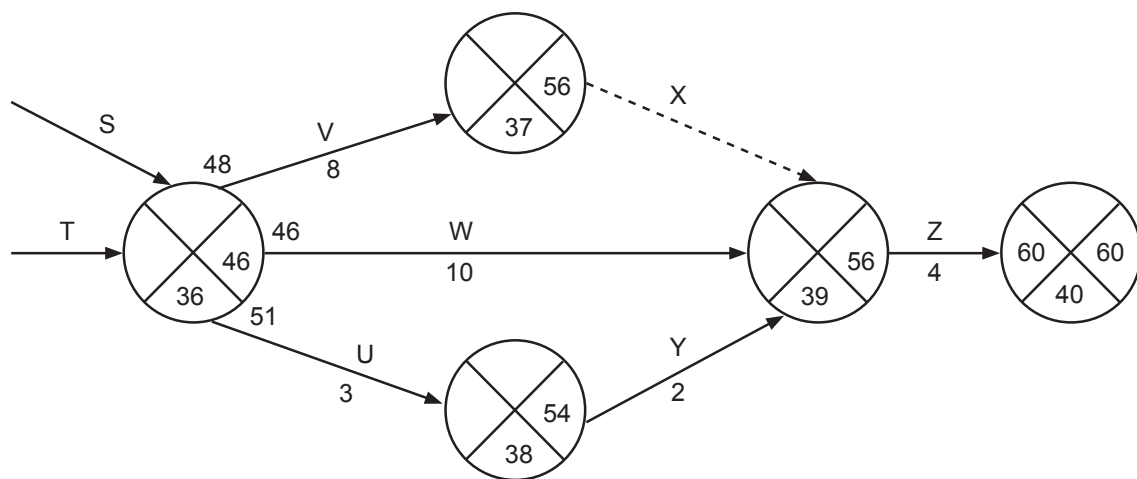


Fig 8.25



Figure 18.25 illustrates the point that the figures contained in both sides of the terminal node (Node 40) should be identical. To calculate the latest possible start time for Activity Z, the duration of four days is subtracted from the figure in the right-hand space of the terminal node (ie $60 - 4 = 56$). This is the figure to be placed in the right-hand space of Node 39 and it represents the latest start time for Activity Z and latest finishing time for Activities W, X and Y.

Two further points arise in Figure 8.25.

1. Where a dummy activity is incorporated in a network, for example Activity X, the latest time in the right-hand space of the tail node is identical to the latest time in the head node of that activity – that is: $56 - 0$ (duration of the dummy activity) = 56.
2. Where more than one activity emanates from the same node, for example Node 36, the activity with the lowest value determines the figure which is placed in the space representing latest start/latest finish. In Figure 8.25:

$$U = 54 - 3 = 51$$

$$V = 56 - 8 = 48$$

$$W = 56 - 10 = 46.$$

Therefore 46 is the figure to be placed in Node 36.

If either of the other figures were to be used, the latest start/finish time in Node 39 would be extended when the longest duration of Activity W was added (ie $48 + 10 = 58$ or $51 + 10 = 61$). This would cause the project to fall behind schedule and be in danger of not being completed on time.

Here is the general rule to be used where multiple activities are involved.

On the forward pass, the highest figure is the one used in the appropriate node.

On the backward pass, the lowest figure is the one used in the node.

Summary

The completed simple network diagram in Figure 8.26 combines the principles discussed in this chapter for establishing the critical path (CP) through a network.

It also illustrates the inclusion, in the appropriate positions in the nodes, of the early starts/early finishes and late starts/late finishes calculated using the forward pass and backward pass techniques.

Points to note

1. Nodes which are connected by the activities that comprise the critical path have identical numbers in their left-hand and right-hand sections. Care must be exercised, however, as, in some instances, activities connecting nodes with identical numbers do *not* form part of the critical path. If the duration for the activity does not occupy the total time between the connected nodes, it is not a critical activity.

For example, Activity 1–3 has five days in which it can be completed – that is, it starts at 0 and following activities cannot commence before day five. The estimated duration for the activity is two days, leaving three additional days to complete the activity without affecting the remainder of the network. *Critical activities have no tolerance.*

2. There is no set pattern for the positioning of activities and nodes – provided the planning logic is feasible, the durations allocated are realistic and the position of nodes is not congested. The actual layout of the network is the responsibility of the designer. It is preferable to have only one activity connecting the final node.

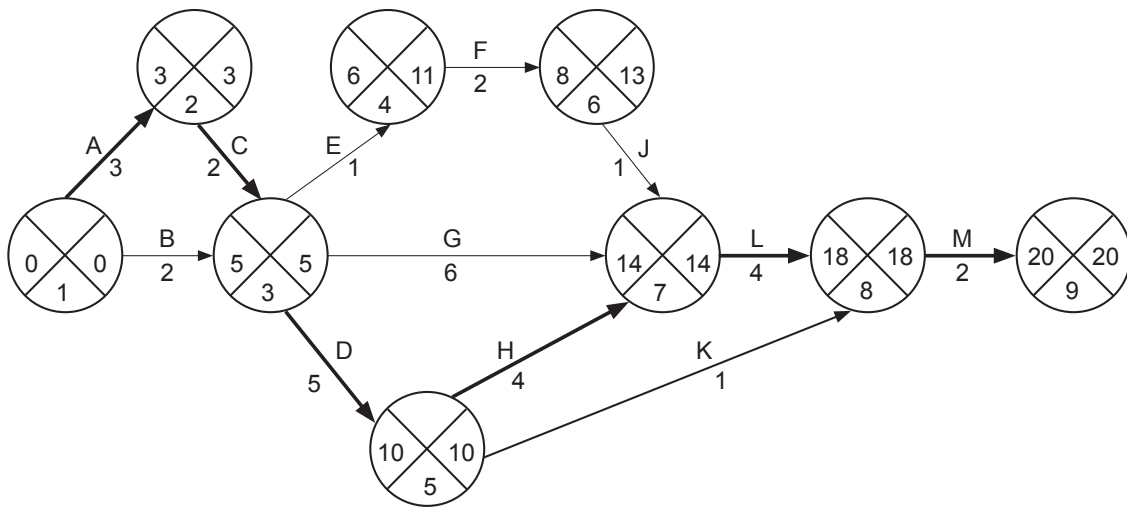


Fig 8.26



Chapter 9

Critical path networks

The previous chapter dealt with basic network terminology, the method of establishing node information, together with the manner of presentation, and also the method of determining the critical path or paths through a network.

In defining the term 'duration', it was stated that the duration of an activity is not necessarily the total time which elapses between the head and tail nodes. The following example is used to illustrate this statement.

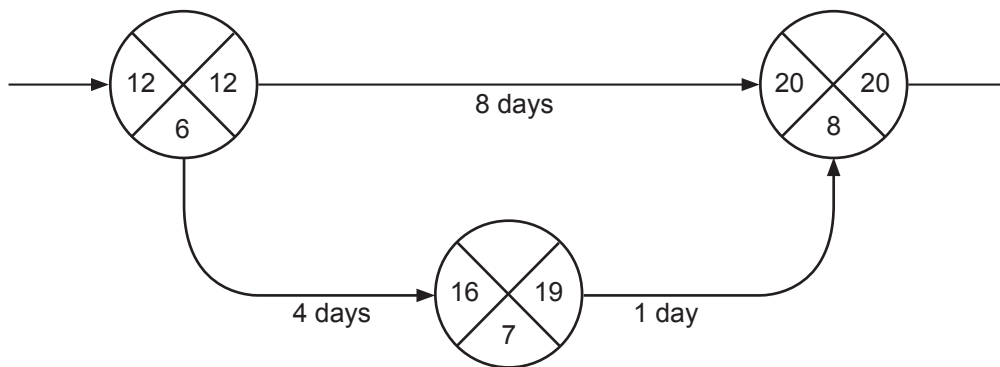


Fig 9.1 Duration

Activity 6–8 shows the earliest start time as Day 12 and the earliest finish time as Day 20. When the duration of eight days for the activity is added to the earliest start time, it can be established that there is no spare time or tolerance between the earliest start time and the earliest finish time of the respective tail and head nodes. Therefore the activity is critical.

Following the same process with Activity 7–8, it can be seen that, when adding the duration of one day to the earliest start time of Day 16, the earliest finish time required is Day 20. Therefore there is a tolerance of three days in which to complete the activity. Similarly, if the combined durations of Activities 6–7 and 7–8 are considered, it can be seen that the two activities between them have a tolerance of three days in which they may be completed before the succeeding activity/activities out of Node 8 are programmed to begin. This tolerance is referred to as *float*.

Classes of float

Float is the 'spare' time possessed by a non-critical activity, the use of which will not affect the finishing time of the project. Three classes of float are discussed below.

1. Total float

This is the amount of time an activity or chain of activities may be delayed without affecting the scheduled completion date of the project or the critical path activities. The total float is the excess time available when preceding activities are completed as early as possible and all immediately succeeding activities start as late as possible.

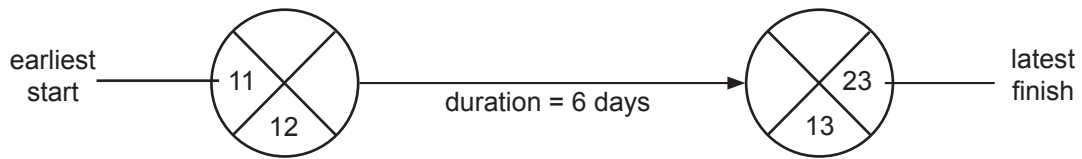


Fig 9.2

$$\begin{aligned}
 \text{Total float} &= \text{latest finish time} - (\text{earliest start time} + \text{duration}) \\
 &= 23 - (11 + 6) \\
 &= 23 - 17 \\
 &= 6 \text{ days total float}
 \end{aligned}$$

2. Free float

This is the amount of time an activity may be delayed without affecting the earliest starting time of the activity immediately following. It is the excess time available for an activity when all preceding activities are completed as early as possible and all succeeding activities start as early as possible.

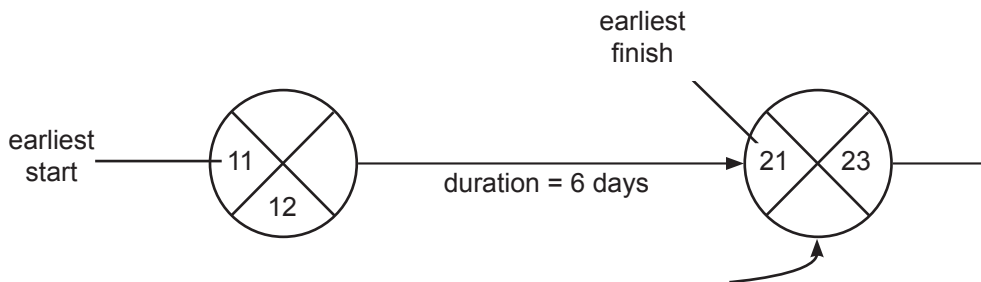


Fig 9.3

$$\begin{aligned}
 \text{Free float} &= \text{earliest finish time} - (\text{earliest start time} + \text{duration}) \\
 &= 21 - (11 + 6) \\
 &= 21 - 17 \\
 &= 4 \text{ days free float}
 \end{aligned}$$

3. Independent float

This is the amount of time an activity may be delayed without affecting preceding or succeeding activities. It represents the excess time available for an activity when preceding activities finish as late as possible and succeeding activities start as early as possible.

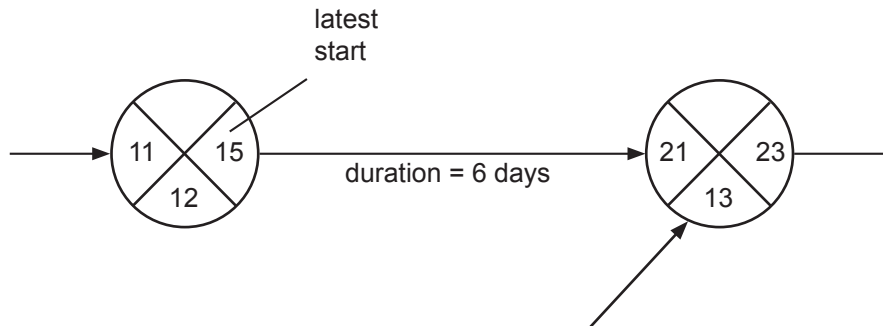


Fig 9.4

$$\begin{aligned}
 \text{Independent float} &= \text{earliest start for succeeding activity} - (\text{latest finish for preceding activity} + \text{duration}) \\
 &= 21 - (15 + 6) \\
 &= 21 - 21 \\
 &= 0 \text{ independent float}
 \end{aligned}$$

It is advisable to note that a negative result is possible when analysing activities for independent float.

An activity which contains no float is critical.

Once the total float of any activity or string of activities has been absorbed, the activities concerned will become critical. It is possible for the critical path on a project to change as work proceeds.

Float types – illustration

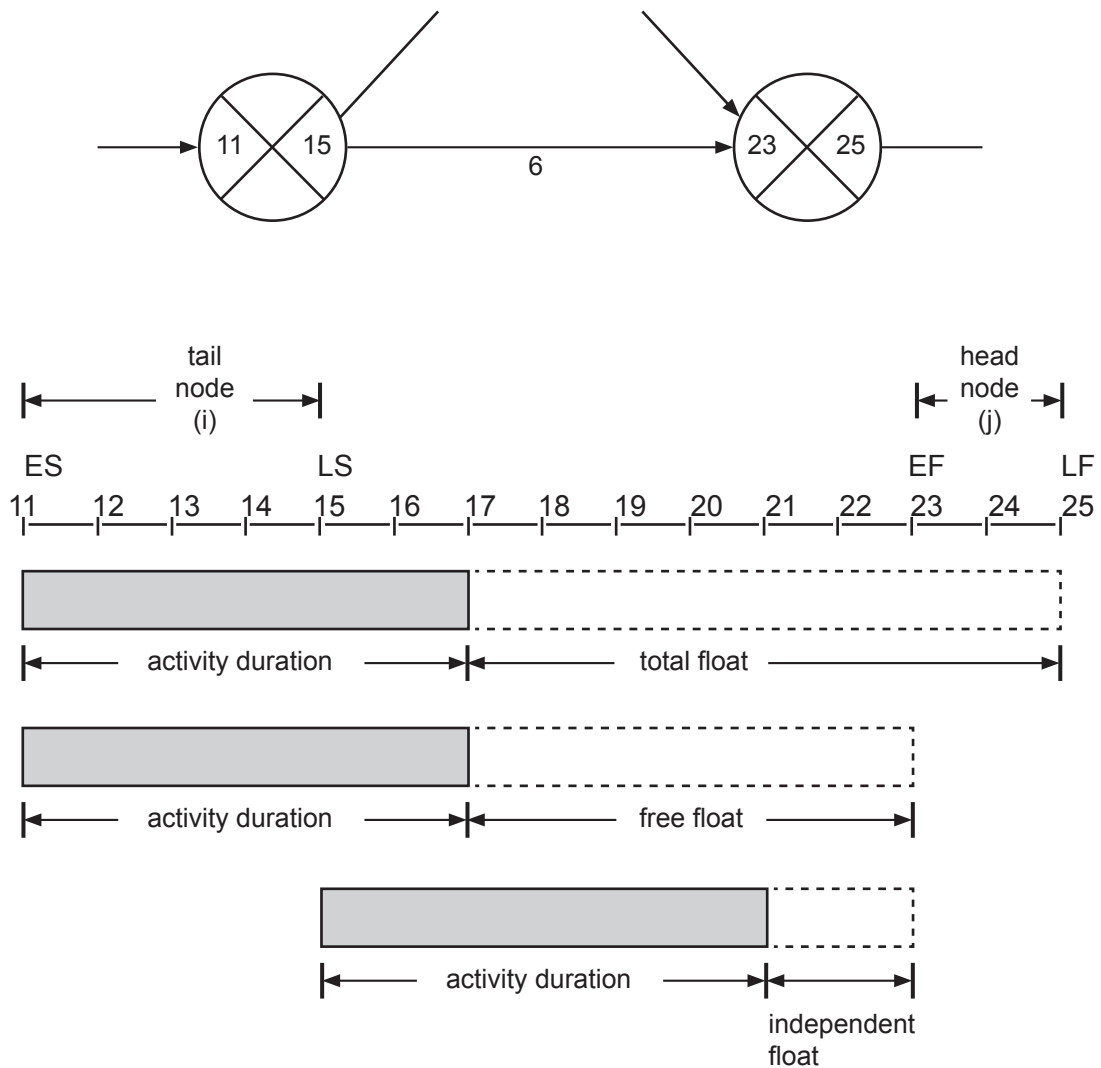


Fig 9.5

This diagram uses the bar form to illustrate graphically the three types of float discussed in this chapter.

Total float

It can be seen from the chart that the earliest possible time the activity can start is Day 11, while the latest it can finish is Day 25. Therefore, the maximum time available to carry out the activity is 14 days. To determine the amount of tolerance (float) available, the earliest start time plus the duration is subtracted from the latest finish time, ie:

$$25 - (11 + 6) = 8 \text{ days total float.}$$

Free float

As for free float, the earliest the activity can be started is Day 11 – but the activity must be completed by Day 23, a total of 12 days being available to complete the activity. To establish what free float is available, the earliest start time plus duration is subtracted from the earliest finish time in the succeeding node, ie:

$$23 - (11 + 6) = 6 \text{ days free float.}$$

Independent float

To establish whether there is any independent float available to the activity, the latest start time of the preceding node plus the activity duration is subtracted from the earliest finish time in the succeeding node, ie:

$$23 - (15 + 6) = 2 \text{ days independent float.}$$

When establishing the type and amount of float available, it should be borne in mind that the figures shown in the preceding and succeeding nodes are the result of calculations made from all the activities entering and/or leaving the nodes.

Preparing a network

The successful use of the critical path method depends on two main factors:

- the correctness of the activity sequence shown
- the accuracy of the estimated durations.

For these two factors to be maintained throughout the project, it is necessary to regularly update and revise the network diagram.

Before anyone begins the preparation of a network diagram, all aspects of the project should be considered and understood. Discrepancies and ambiguities should be clarified before proceeding further.

The preparation and presentation of a network can be considered in three main stages:

1. network logic
2. duration
3. analysis sheet.

The first two of these stages will be discussed in this chapter, while the third will be discussed in the next chapter.



Network logic

The aim of a planning team is to arrange, in a logical sequence of events, a network which depicts the key and interrelated activities in a project.

The size of the planning team is usually determined by the magnitude and/or complexity of a project.

Network diagrams are often prepared in stages. The initial stage consists of planning a network from preliminary information, in order to establish a logical sequence of events and also to estimate durations for each activity.

A brief description on each activity line is necessary to enable planners to swiftly assess their planning logic.

The second-stage presentation network – for use by those involved in the project – is prepared when the planners are satisfied that the planning network represents a logical sequence of events and appropriate durations. This diagram can delete activity descriptions and substitute symbolic references, for example letters of the alphabet, as a means of identification. A brief description of the activity is contained on the analysis sheet.

It is this network which is used to aid the project team. Accurately prepared, it provides a unified source of information on which important decisions can be based. It assists the project management team to supervise a project more easily and efficiently. The progress status of a project can be rapidly assessed at any time. The clarity of a network diagram enables any new managers or other personnel to familiarise themselves rapidly with a project.

Duration

The following principles should be observed when obtaining duration for activities.

- The logic of the network should be complete before any attempt is made to nominate times; that is, complete the diagram first.
- Ensure that the activity is sufficiently defined to enable a realistic time estimate to be made. As an example, it would be impossible to obtain an estimate for the laying of a water main without knowing how long and deep it was to be, the type of country involved etc.
- Durations should represent normal times for a normal workforce. It is essential that the times used and the logic of the network represent the way in which it is intended to do the work.
- Durations and labour constraints should be obtained from people who are most familiar with the work to be done.
- The durations obtained should be reviewed by the contractor or planner to ensure that they appear realistic. It has been found occasionally that the contractor has a better idea of some subcontractors' times than the subcontractors themselves.
Note, however, that times should come from the subcontractors and then be reviewed by the contractor; that is, it is not a wise policy for the times to be determined by the contractor and thrust upon the subcontractor.
- A method of obtaining the most likely time is to obtain more than one estimate where possible – some people are naturally optimistic and others pessimistic.

As soon as all duration estimates have been obtained, the network can be evaluated. The normal times which have been used may then have to be revised if they are on the critical path and the forecast duration of the project is too great.

Note: If times for critical activities need revising, only then should pressure be exercised to reduce the duration. If this can be done without an increase in cost, well and good. But, as a general rule, shortening activities below their normal duration will increase the cost one way or another.

For example, an increase in the labour force may be needed or, alternatively, working an amount of overtime may be necessary.

Summary

Previous chapters have introduced the information necessary to prepare a critical path network diagram. The method of establishing this type of network is to develop it in a logical sequence, allowing at all times for flexibility in design. The stages previously noted for the development of such a network can be broken down into the following steps.

- (a) Study the project to be developed.
- (b) Select a logical sequence of activities and systematically develop the planning network. Include a brief description of each activity on the appropriate activity line and number the nodes in an ascending sequence.
- (c) Review the completed planning network for logic and make adjustments if considered necessary.
- (d) Estimate and allocate durations for each activity.
- (e) Total the duration times along each path of the network to establish that the project time allocation has not been exceeded. If it has, the logic may have to be revised or the duration of some activities compressed.

When it has been established that the sequence of activities is logical and the durations are achievable:

- (f) Use the forward pass rule to establish earliest starting and finishing times and position each in the left-hand section of the appropriate node.
- (g) Use the backward pass rule to establish the latest start and finishing times and position each in the right-hand section of the appropriate node.
- (h) Establish which path through the network is the critical path and clearly identify it.

An indication of an activity being critical is identical figures in the left-hand and right-hand sections of a node associated with it, as shown below.

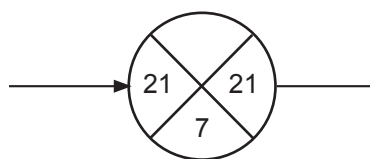


Fig 9.6

This general rule cannot be taken for granted, however. If there is any float associated with an activity, it does not usually form part of the critical path.

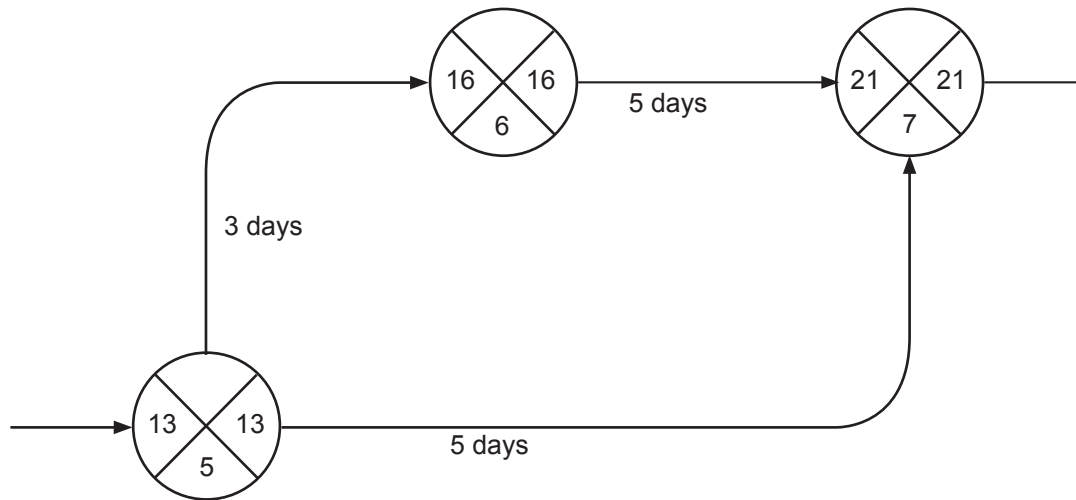


Fig 9.7

In the above figure, Activity 5–7, although bounded by nodes which form part of the critical path, is not itself critical since it contains three days float.

Example – service station network

Figures 9.8 and 9.9 show two network diagrams which, together with the associated activity list, illustrate the procedure of network planning to this stage of discussion. The network is for construction of a typical service station. The planning network, as previously discussed, is used to develop a logical sequence of activities. The initial layout is adjusted until the planning team is satisfied that a logical sequence has been achieved. A description of each activity is placed above its activity line for ease of identification during planning.

Once the logical sequence is satisfactory, durations are estimated and placed below the appropriate activity line, as shown in Figure 9.8 (planning network).

To verify that the durations established will allow the project to be completed on time, the forward pass should be performed. If this shows that the time span is incorrect, adjustments must be made and the time span recalculated. Once this is found to be correct, the forward and backward passes are performed and the results placed in the relative section of each node. The critical path is identified and the presentation network is drawn up (Figure 9.9).

Note: 'gap' numbering – to the arrows – has been used in these examples of a network for a service station.

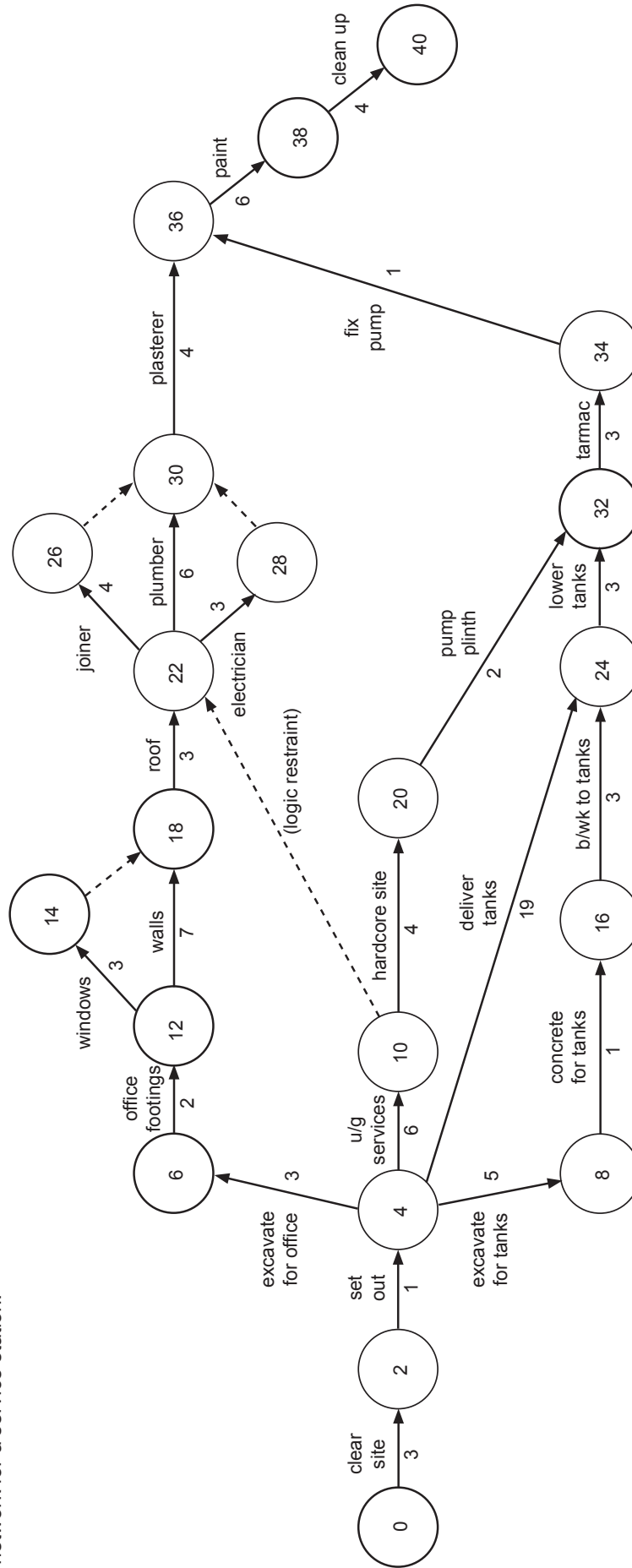


Fig 9.8 Planning network for a service station

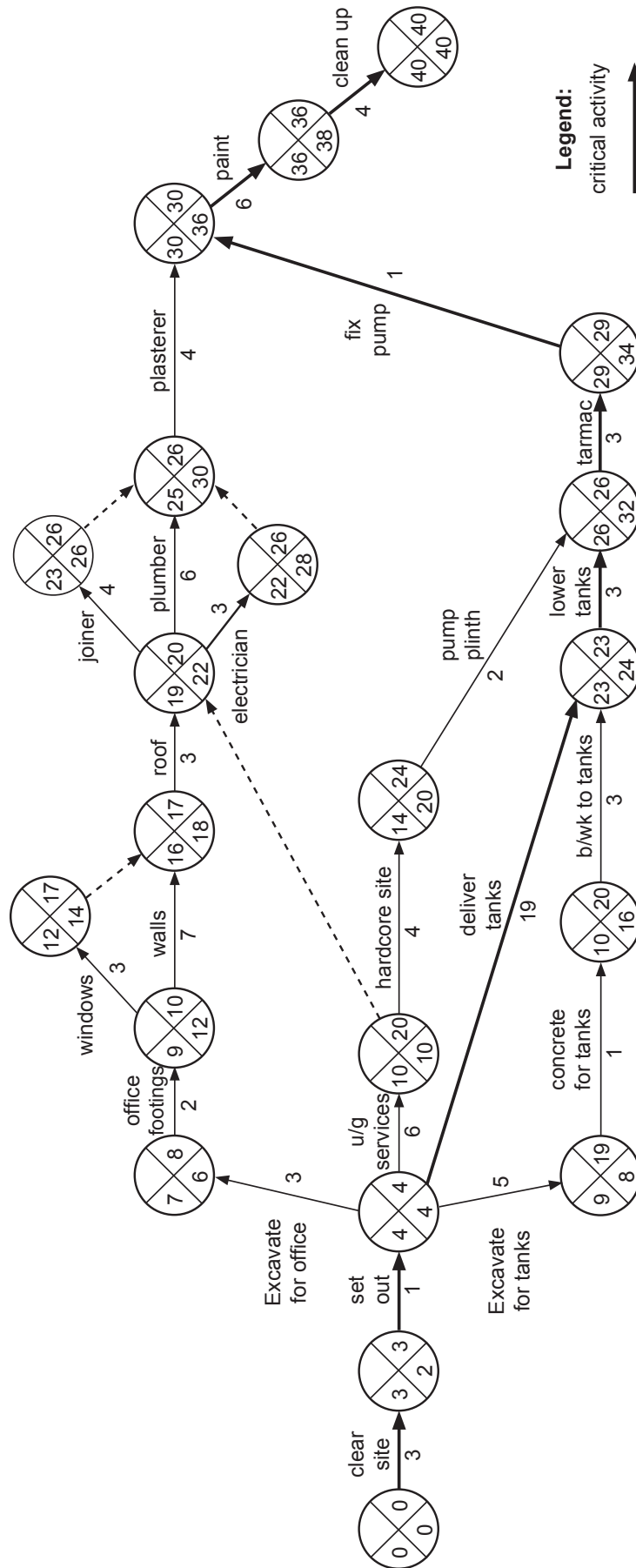


Fig 9.9 Presentation network for service station

Service station – activity list

Number	Arrow	Description	Duration (days)
1	0–2	Clear site	3
2	2–4	Set out	1
3	4–6	Excavate for office	3
4	4–8	Excavate for tanks	5
5	4–10	Underground services	6
6	4–24	Deliver tanks	19
7	6–12	Footings for office	2
8	8–16	Concrete for tank bases	1
9	10–20	Hardcore site	4
10	10–22	Dummy	0
11	12–14	Windows	3
12	12–18	Walls	7
13	14–18	Dummy	0
14	16–24	Brickwork	3
15	18–22	Roof	3
16	20–32	Pump plinth	2
17	22–26	Joiner	4
18	22–28	Electrician	3
19	22–30	Plumber	6
20	24–32	Lower tanks	3
21	26–30	Dummy	0
22	28–30	Dummy	0
23	30–36	Plaster	4
24	32–34	Tarmac	3
25	34–36	Fix pump	1
26	36–38	Paint	6
27	38–40	Clean up	4



Overlapping and ladder construction

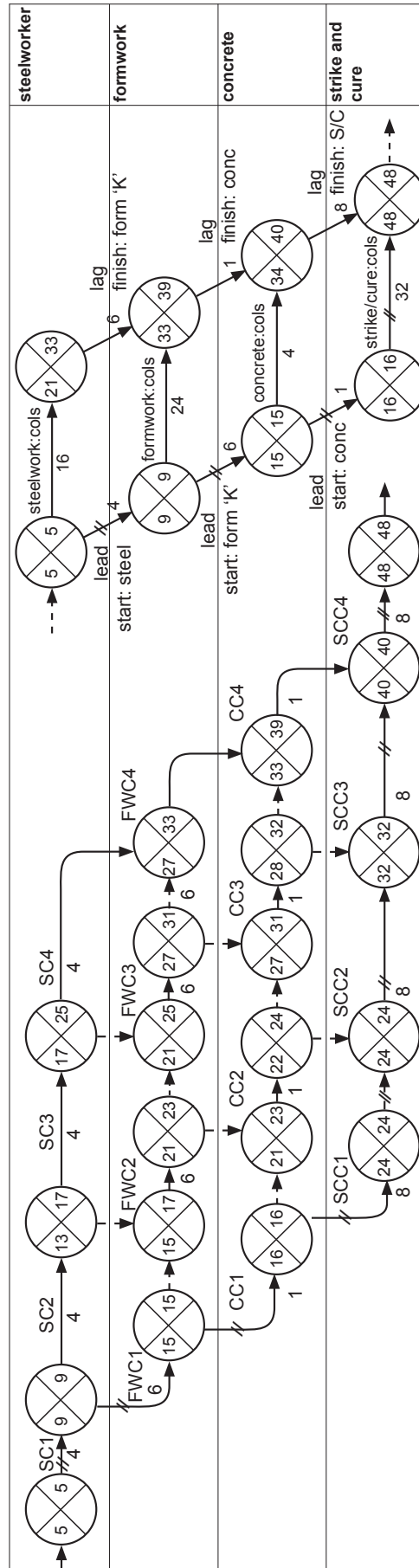
During the planning of the logic of a network, situations often arise in which some succeeding activities may start before their preceding activities are completed. This is referred to as 'overlapping' and allows for more realistic planning to be achieved. Overlapping has a number of advantages, including that it helps:

- in reducing the overall duration of a project
- to reduce the cost of construction
- in providing for continuity of resources.

On large, complex projects, simple finish–start relationships are often inadequate. Where activities with prolonged durations occur, and where such activities can be 'split' into phases or sections such as reinforcing, formwork, concrete, strike/cure etc, practical need dictates that, after a certain amount of the work in one phase is done, the next should begin.

For example, once a certain amount of column reinforcement has been put in place, the formwork can commence, followed by concrete etc.

The following diagram illustrates the network techniques of 'overlap' and 'ladder'. The standard rules and conventions apply in these formats, as they do for those previously dealt with.



ladder activities

overlapping activities

Fig 9.10



The diagram in Figure 9.10 shows a sequence of activities relating to the erection of reinforced, in-situ concrete columns. On a large project, it is obvious that, after some of the steelwork has been fixed, formwork would start. Likewise, concreting would not be held back until all of the formwork had been completed but would begin after a certain number of column 'boxes' were completed. Striking and curing would follow in a similar fashion.

The diagram illustrating overlapping activities shows such a sequence of operations. To retain the logic, and avoid unnecessary dependencies being created in the diagram, dummies must be inserted and this practice results in a large, complex arrangement as shown. In this particular case, the trade activity has been 'split' into four 'phases'; there could be five or any number of 'phases', as necessary or appropriate.

The diagram illustrating ladder activities is making a similar statement to the overlapping diagram. 'Lead' (on the 'start' of the activities) shows that, after the start of steelwork to columns, formwork can begin. Likewise 'lag' (on the 'finish' of the activities) shows that formwork to columns will not be completed until a given period of time has elapsed **after** completion of steelwork. This is the same statement that is being made on the overlapping diagram, where 'SC4' is followed by 'FWC4'. The 'internal' part of the overlapping diagram shows similar relationships. For example, 'FWC2' is followed by 'CC2'. As stated, dummies are required to retain the logic.

An advantage with both of these formats is that each trade activity can be clearly shown, as indicated by the listing to the right of the diagrams.

The ladder diagram is obviously simpler to construct, as illustrated here. However, the inclusion of ladders in 'normal' diagrams can lead to errors, if only because of the tendency to treat them as being isolated from the rest of the network. In addition, ladders sacrifice the precision of the logic statement contained in the overlapping diagram.

Establishing the critical path

The forward and backward passes are made in a conventional manner. It can be seen that the critical path has been isolated by the use of the double line through the appropriate arrows (and dummy in the case of the overlap diagram). The critical activities are identical in both diagrams. The times within the overlap diagram give the added detail or information that is referred to above. Note the use of the dummies which 'enter' and 'leave' the ladder diagram, thus 'isolating' the ladder sequences from the rest of the network.

Finally, note that there is no set layout to be followed with regards to the pattern the diagram follows, provided that the rules and conventions of network planning are obeyed. The type of project, together with the skills and ideas of the programmer, will influence the final network presentation.

Chapter 10

Critical path analysis

The preceding chapters devoted to critical path networks dealt with terminology and other aspects of network planning. In the last chapter, reference was made to three aspects of network preparation, namely logic, the time element and the analysis sheet. Logic and the time element have already been discussed. Consideration will now be given to the analysis sheet and its functions.

Analysis sheet

For any devised system to be effective, it must provide sufficient detailed information and be easily analysed to determine the success or otherwise of the planning. In complex network diagrams, it is not always convenient, and is perhaps even difficult, to calculate floats manually for various activities. The seriousness of delays and their effect on the scheduled completion date should be easily determinable. The analysis sheet, used in conjunction with the network, enables such information to be readily obtained.

The analysis sheet is prepared in table form, with appropriate headings under which applicable data derived from the network plan are placed.

Work on the analysis sheet can begin once the planning team is satisfied with the network logic and the accuracy of the time element. Correctly prepared, the sheet ensures that no essential activities have been overlooked. Once completed, it provides a concise table of network information which management can use as a simple means of evaluating progress and verifying information.

The preparation of the network diagram and establishment of the activity durations require considerable skill and judgement on the part of the planners. Once these are established, however, the transfer of this information to the analysis sheet is routine, provided basic guidelines are followed.

Analysis sheets are designed by companies or planners to satisfy network analysis requirements. They contain column headings similar to those shown in Figure 10.1. The following is a brief explanation of the information contained in each column.



Activity/number	Arrow	Description	Duration	Start		Finish		Float			Remarks/ critical path
				Earliest	Latest	Earliest	Latest	Total	Free	Independent	
1	0-2	Clear site	3	0	0	3	3	0	0	0	*

Fig 10.1 Analysis sheet format

1. Activity number – This column records the actual number of activities, including dummies, which make up the CPN diagram.
2. Arrow – The unique identification number of each activity is placed in this column. Keeping the tail numbers of activities in ascending sequence has benefits.
3. Description – This provides a brief description of each activity. Therefore it is a ready means of identifying the activity. As stated earlier, the description is not always written onto the activity arrow of the presentation network.
4. Duration – This column lists the estimated time required to complete each activity.
5. Start/Finish – Each of these columns is in two parts; that is, the *Start* columns list the earliest and latest start times for each activity in the network, while the *Finish* columns indicate the earliest and latest finishing times for each activity. The earliest start time for an activity is established from the network and placed in the appropriate column. The activity duration is added to it to establish the earliest finishing time of the activity – and this is placed in the relevant column. It should be noted that this figure does not necessarily agree with the figure in the head node. The latest start/finish times are calculated in the same way – except, in this case, it is the latest finish time which is established from the network and the duration is subtracted from this figure to give the latest start. Again, this figure does not necessarily agree with the figure in the tail node.
6. Float – This section of the analysis sheet comprises three columns to represent total, free and independent floats and records the amount of each type of float, if any, that each activity possesses. This is established from the network, using the formula discussed in Chapter 9.
7. Remarks/critical path – This column can be designated to allow comments to be entered against the various activities or to highlight which activities in the network are critical.

As mentioned at the start of this chapter, once the network logic and time element have been established, the information can be transferred to an analysis sheet for recording and analysing. This can also be a way of detecting discrepancies in the network.

Preparing an analysis sheet

To illustrate the technique for this, analysis sheets will be prepared using, firstly, the 'part network' in Figure 10.2 and then the service station network (Figure 10.4).

Start by giving each activity a number in the left-hand column and arranging the activity identification numbers in the arrow column according to the tail numbers in ascending order – for example, in the case of the service station network: 0–2, 2–4, 4–6 etc through to the last activity (38–40). Note the 'gap' numbering used on this network diagram.

As each arrow number is being recorded, enter a brief description of the activity in the description column. At the same time, the duration can be recorded in the appropriate column.

Next, select the earliest starting time and the latest finishing time from the network for each activity and place them in the relevant columns as stated previously.

To obtain the earliest finishing time, add the duration to the earliest starting time; to determine the latest starting time, *subtract* the duration from the latest finishing time.

A note of caution at this stage
Do not automatically transfer the latest start and earliest finishing times directly from the network to the analysis sheet.

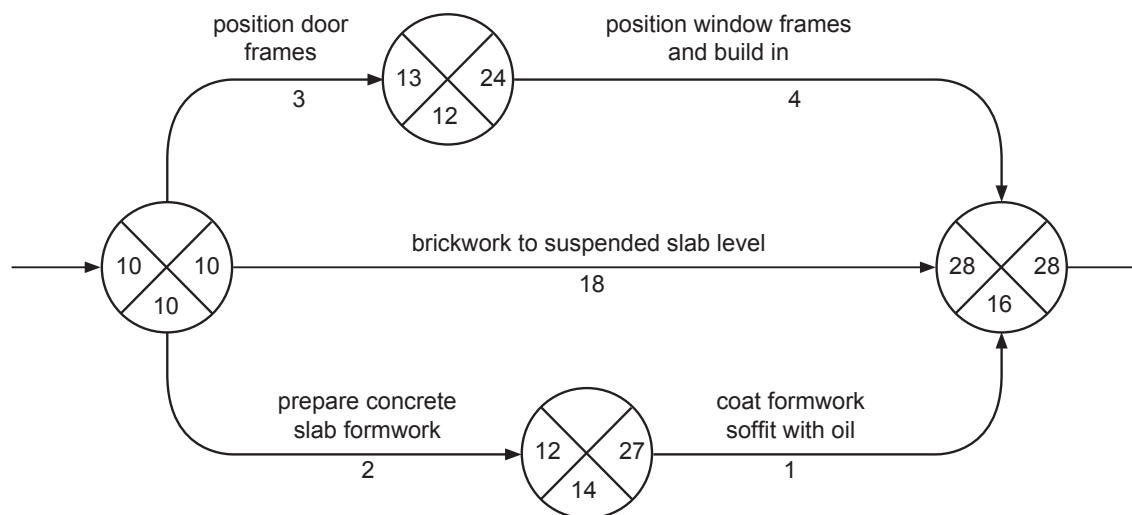


Fig 10.2 Part network

Activity/number	Arrow	Description	Duration	Start		Finish		Float			Critical path
				Earliest	Latest	Earliest	Latest	Total	Free	Independent	
11	10–12	Position door frames	3	10	21	13	24	11	0	0	
12	10–14	Prepare concrete slab formwork	2	10	25	12	27	15	0	0	
13	10–16	Brickwork to suspended slab level	18	10	10	28	28	0	0	0	
14	12–16	Position window frames and build in	4	13	24	17	28	11	11	0	*
15	14–16	Coat formwork soffit with oil	1	12	27	13	28	15	15	0	

Fig 10.3 Analysis sheet for part network in Fig 10.2

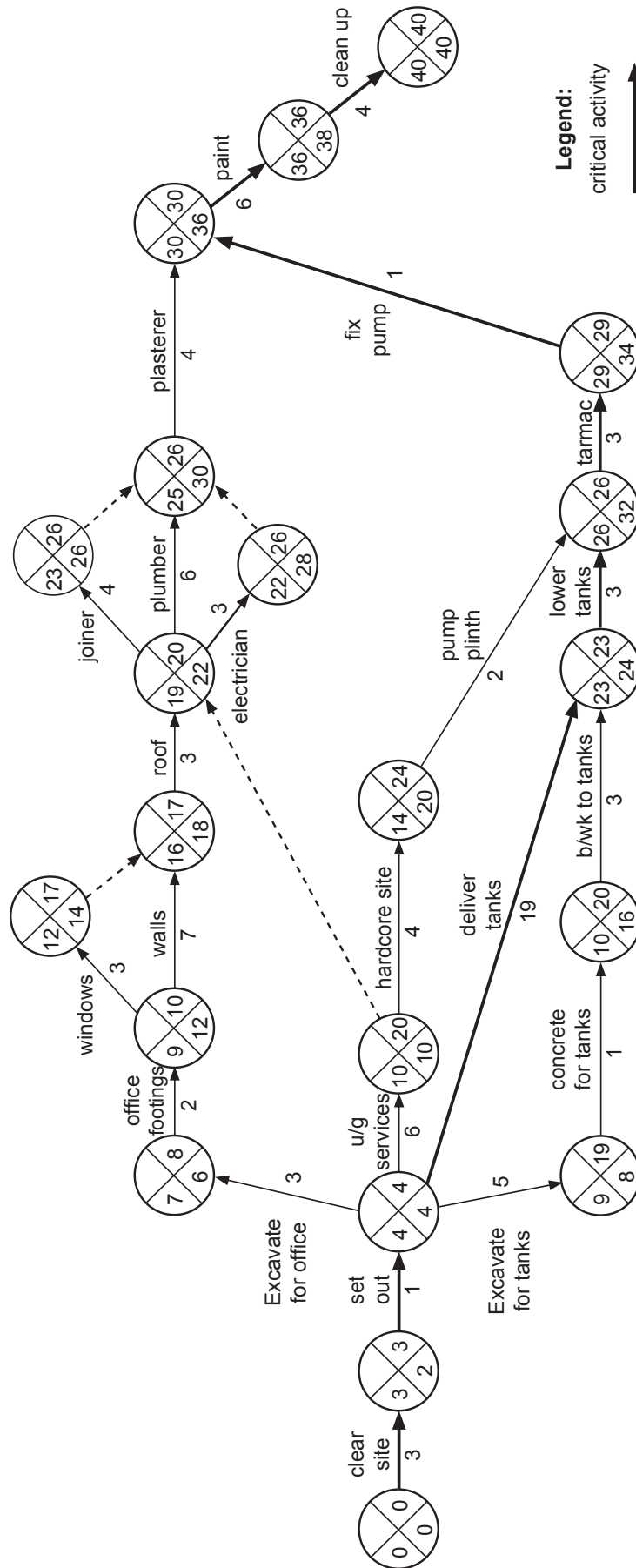


Fig 10.4 Network for service station

Activity/number	Arrow	Description	Duration	Start		Finish		Float			Remarks/ critical activity *
				Earliest	Latest	Earliest	Latest	Total	Free	Independent	
1	0-2	Clear site	3	0	0	3	3	0	0	0	*
2	2-4	Set out	1	3	3	4	4	0	0	0	*
3	4-6	Excavate for office	3	4	5	7	8	1	0	0	
4	4-8	Excavate for tanks	5	4	14	9	19	10	0	0	
5	4-10	Underground services	6	4	14	10	20	10	0	0	
6	4-24	Deliver tanks	19	4	4	23	23	0	0	0	*
7	6-12	Footings for office	2	7	8	9	10	1	0	0	
8	8-16	Concrete for tank bases	1	9	19	10	20	10	0	0	
9	10-20	Hardcore site	4	10	20	14	24	10	0	0	
10	10-22	Dummy	0	0	0	0	0	0	0	0	
11	12-14	Windows	3	9	14	12	17	5	0	0	
12	12-18	Walls	7	9	10	16	17	1	0	0	
13	14-18	Dummy	0	0	0	0	0	0	0	0	
14	16-24	Brickwork to tanks	3	10	20	13	23	10	10	0	
15	18-22	Roof	3	16	17	19	20	1	0	0	
16	20-32	Pump plinth	2	14	24	16	26	10	10	0	
17	22-26	Joiner	4	19	22	23	26	3	0	0	
18	22-28	Electrician	3	19	23	22	26	4	0	0	
19	22-30	Plumber	6	19	20	25	26	1	0	0	
20	24-32	Lower tanks	3	23	23	26	26	0	0	0	*
21	26-30	Dummy	0	0	0	0	0	0	0	0	
22	28-30	Dummy	0	0	0	0	0	0	0	0	
23	30-36	Plasterer	4	25	26	29	30	1	1	0	
24	32-34	Tarmac	3	26	26	29	29	0	0	0	*
25	34-36	Fix pump	1	29	29	30	30	0	0	0	*
26	36-38	Paint	6	30	30	36	36	0	0	0	*
27	38-40	Clean up	4	36	36	40	40	0	0	0	*

Fig 10.5 Analysis sheet for service station

A study of the two networks above (Figures 10.2 and 10.4) and their respective analysis sheets (Figures 10.3 and 10.5) will reveal that, unless an activity is on the critical path, there will be some discrepancy between the network and analysis sheet figures.

For example, on the service station network, compare the latest start figures of Activity 22–28, which is not on the critical path, and Activity 4–24, which is.

With Activity 4–24, it can be seen that the figures in the network nodes correspond with the figures in the related columns on the analysis sheet.

With Activity 22–28, the latest start time of 20 in Node 22 (Figure 10.4) differs from the figure of 23 showing in the related column of the analysis sheet.

The analysis sheet therefore indicates the latest time at which an activity can start (assuming that any available float which may have existed has been consumed) if the planned schedule is to be maintained.

The 'float' columns of the analysis sheet can be completed as other necessary information for each activity is being established or they may be completed separately after the starting and finishing times for the network have been calculated. Note: The technique used to determine the various types of float which may exist in an activity was explained in Chapter 9.

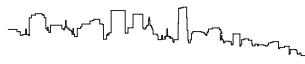
The type and amount of float are established using the network diagram and, once obtained, the information is transferred to the appropriate column of the analysis sheet.

Finally, the analysis sheet is completed by selecting and identifying critical activities. This is achieved by placing a symbol in the 'Remarks/critical path' column alongside the appropriate activities.

The criteria for determining critical activities from the analysis sheet are as follows.

- a) Starting times have identical figures.
- b) Finishing times have identical figures.
- c) There is no float.

Note: There may be the occasional exception to point c) but this need not concern us at this stage and will not be discussed in this text.



Chapter 11

Introduction to precedence diagrams

Introduction

Previous chapters discussed the conventions and application of activity-on-the-arrow diagrams for critical path networks. As shown in Figure 11.1, circles (referred to as 'nodes' or 'events') were used to indicate the start or finish of an activity or group of activities and an arrow represented an activity. A description of the activity was placed above the arrow and its estimated duration was placed below the arrow. Broken-line arrows, known as 'dummies', were used to act as restraints or a means of linking activities to maintain network logic.

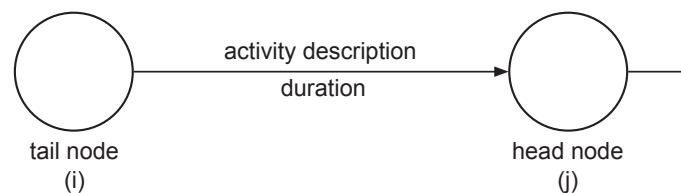


Fig 11.1

As previously stated, the arrow diagram had its origin in the 1950s and proved to be a useful management tool for programming and controlling large projects. It was realised, however, that the technique contained certain difficulties and was not always readily adaptable to all the planner's needs. The need to use dummy activities to express logic and the need to subdivide certain activities increased considerably the number of activities in a network.

Research on network development continued and, in 1961, Professor John W Fondahl (of Stanford University) laid the foundations for the *precedence diagram* technique when he assigned the activity to the node rather than adhering to the previously accepted convention of placing it on the arrow. Professor Fondahl termed his method the *circle-and-connecting-line* technique. The networks produced are now known more commonly as *activity-on-the-node* or *precedence* diagrams. It is this last term which will be used here to discuss the basic principles of this networking technique.

Precedence diagrams differ from arrow diagrams in that nodes represent activities, and the logical flow of the network is achieved by linking nodes with lines or arrows which are referred to as 'dependencies'.



Fig 11.2

This technique has overcome many of the deficiencies which exist in activity-on-the-arrow networks.

Fondahl's original concept used the circle for the node. Square or rectangular nodes have since gained favour, as they record more readily the type of activity information required. The set-out of the activity node is dependent on the amount of information that needs to be recorded for a specific project or to display the preferred method of individual planners. Figure 11.3 illustrates one form of node presentation.

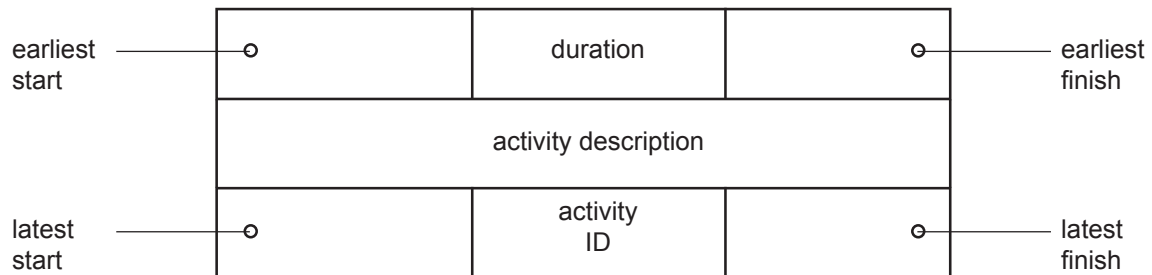


Fig 11.3

Advantages

Advocates of the precedence diagram technique suggest it provides the following advantages.

1. Precedence diagrams are simple to draw and easier to read and understand than the other systems.
2. Each activity node contains a unique alphanumeric identity, thus eliminating the possibility of parallel activities occurring.
3. Information relating to the activity is contained within the node.
4. The technique provides flexibility in expressing project constraints. Time delays can be introduced without resorting to the detail which may be required to represent the logic in an arrow diagram.
5. Dummy activities are not necessary, so reducing the number of activities in a network.

Learning the significance and proper usage of dummies requires time and experience. False dependencies are a real hazard.

6. Start/finish logic presentation can be achieved without breaking down the activity.
7. It is easier to expand and modify the network and overlapping activities are more easily represented.
8. Unusual logic requirements can be represented more easily. Activities can be connected from either their start or finish.
9. The technique is readily adaptable to both manual and computer programming.

Comparisons

The following figure illustrates and compares some common conventions in activity-on-the-arrow and precedence diagrams.

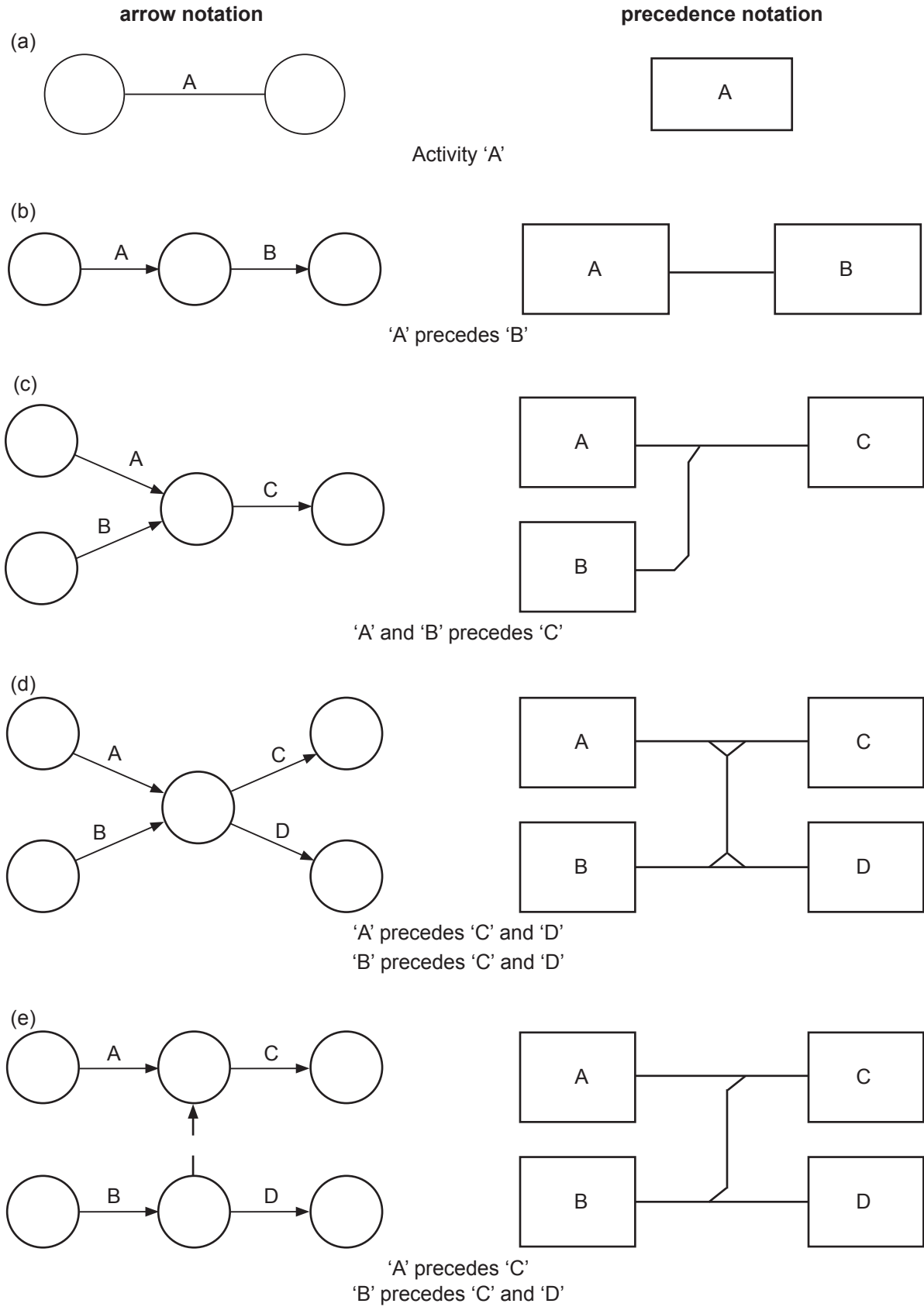


Fig 11.4

The above conventions are such that all the preceding activities must be completed before the succeeding activities can start and those succeeding activities must be completed prior to subsequent dependent activities commencing.



This is referred to as a single relationship. In precedence diagrams when using a single relationship presentation and needing to start a succeeding activity prior to the completion of its preceding activity, the preceding activity must be divided into two parts to satisfy this assumption. Presentation of this type of relationship is illustrated later in this chapter.

Integral factors

Basic conventions

In precedence diagrams, the following basic conventions apply.

1. It is customary initially to consider all the activities in a network as starting and finishing at their earliest possible time.
2. Dependence arrows enter activity nodes from either the left-hand side or top of the node.
3. Dependence arrows leave activity nodes from the right-hand side or bottom of the node.

Overlapping and delays

Precedence diagrams may express various relationships between activities which cannot be readily shown on arrow diagrams.

To prepare a realistic network requires skill and imagination in project planning. The inclusion of overlapping and activity delays is often necessary to produce the most efficient network logic.

A *delay* creates a restraint between related activities and involves a lapse in time that does not require the use of additional resources – for example, the curing period between a concrete pour and the start of a succeeding activity.

Network logic often requires activities to overlap. As previously stated, overlapping tends to produce more realistic programs and to reduce the project duration. Precedence diagramming represents more simply and accurately the overlapping principle.

To illustrate the overlapping principle, take, for example, the laying of a stormwater drain. The operation consists of three activities, namely 'excavate trench', 'lay drain' and 'backfill'. If the length of drain to be laid is considerable, it could be considered reasonable to overlap sections of the work. It is possible to start laying the drain sometime after the excavation has begun but before its completion. The drain laying cannot be completed until sometime after the excavation has been finished. Similarly, the backfilling of the excavation could be started before completion of the drain laying but could not finish until after completion of that activity.

Figure 11.5 (a) illustrates this operation in bar form. In Figure 11.5 (b), the same operation is shown using the precedence format.

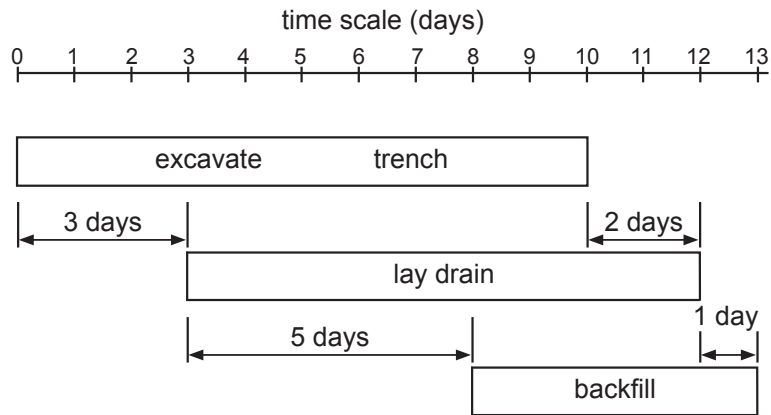


Fig 11.5 (a) Overlapping (bar form)

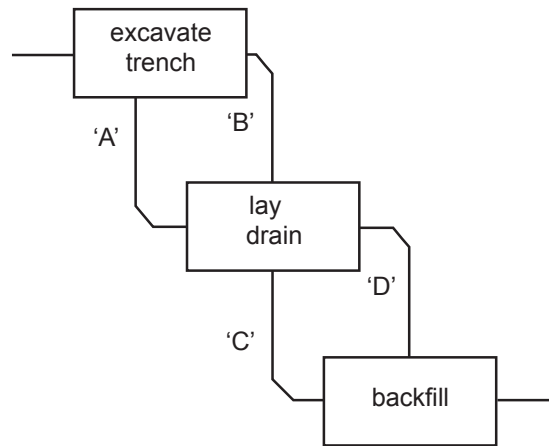


Fig 11.5 (b) Overlapping (precedent form)

In Figure 11.5 (b), the position of depending arrow 'A' shows that 'excavate trench' does not have to be completed before 'lay drain' can begin. The position of dependency arrow 'B' indicates that 'excavate trench' must be completed before 'lay drain' can be completed.

Dependency arrows 'C' and 'D' likewise illustrate the relationships between the activities 'lay drain' and 'backfill'.

Lag factors

Lag or *link lag* can be defined as the time restraint that can elapse between the activities, according to the lag type specified.

A *lag start* is a restraint requirement that one activity cannot start until a specified duration after the start of another activity.

A *lag finish* is a restraint requirement that one activity cannot finish until a specified duration after the finish of another activity.

Lag is a property of the linking dependency arrow and not the activity. There is a lag value for each dependency in a network and that value is broadly accepted as never being less than zero.

The lag factor needs to be considered in conjunction with the type of precedence relationship.

As an example, in Figure 11.6, a lag factor of six (6) units of time with a finish-to-start (FS) relationship indicates that activity 'B' cannot start until at least six units of time after Activity 'A' has finished; that is, there is a delay of six units of time between the finish of 'A' and the start of 'B'.

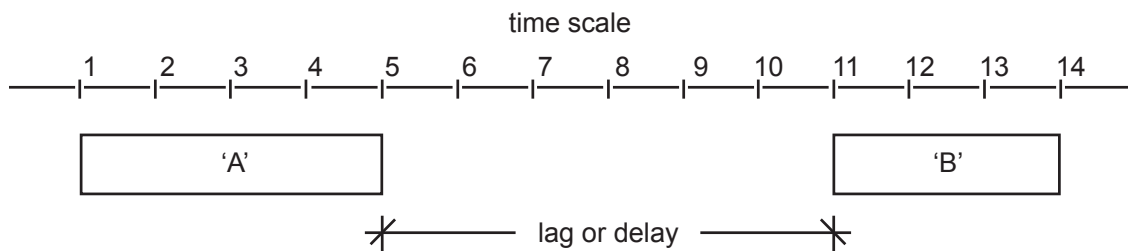


Fig 11.6 (a) Lag illustrated in bar form

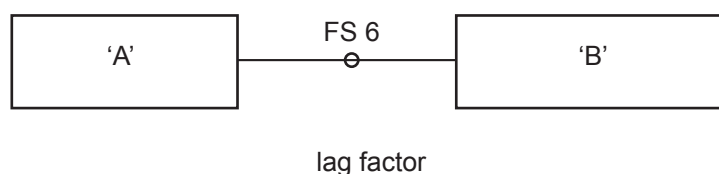


Fig 11.6 (b) Lag shown as a precedence relationship

Relationships

Now that basic conventions, overlapping and lag factors, which are an integral part of precedence network planning, have been discussed, precedence relationships must be considered.

In precedence networks, there are four types of relationship which may link related activities. Three of these will be addressed in this chapter – namely:

- finish-to-start
- start-to-start
- finish-to-finish.

Figure 11.7 displays an overview in bar form of these three types of relationship.

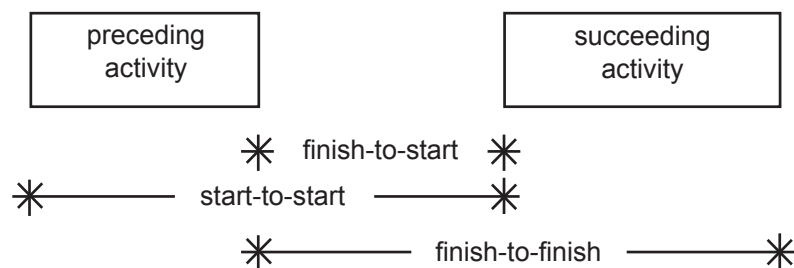


Fig 11.7 Relationships

The manner in which dependency arrows are used to link related activity nodes in precedence networks can be varied from the previously discussed basic conventions. It is done by locating the dependency arrow so as to create a more manageable and space-saving format while still maintaining the activity relationship. It is sufficient to use an abbreviated code comprising the first letter of each word of the relationship type (FS, SS, FF) and the associated lag factor on the dependency arrow to identify the type of relationship.

In the following explanations of precedence relationships, diagrams are included to illustrate the relationships in both bar form and precedence format. The precedence format shows alternative methods of presentation and use of the dependency arrow. Single-relationship and overlapping models are used to illustrate the various types of relationships and lag factors.

Finish-to-start relationships

This name implies that the start of the succeeding activity is determined by the finish of the preceding activity. Where the lag factor in a finish-to-start relationship is zero (0), the succeeding activity may start immediately the preceding activity has finished. A lag factor greater than zero imposes a restraint on the start of the succeeding activity according to the value of the lag. It should be noted that 'FS 0' is the normal relationship in network convention and therefore is not required to be shown on the dependency arrow. Comparative examples of how finish-to-start relationships would be shown in bar and precedence forms are shown in Figure 11.8 below.

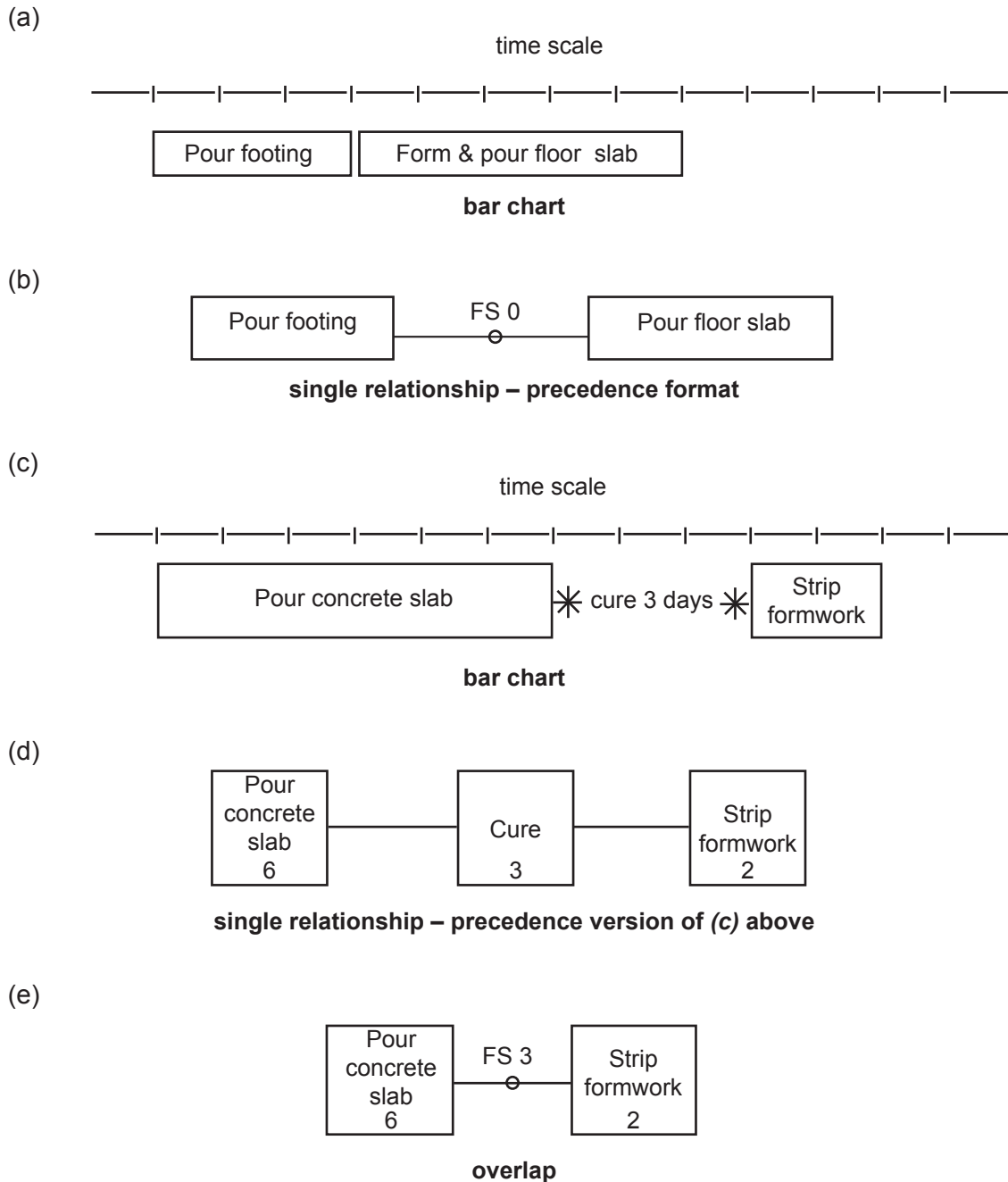


Fig 11.8 Finish-to-start relationships

Diagram 11.8 (a) is a bar chart showing two activities, 'pour footing' and 'pour floor slab', where there is no delay between the pouring of the footing and the pouring of the floor slab. Immediately the footing has been poured, work may start on the slab.

Diagram 11.8 (b) is the precedence equivalent of the same operation. Although the symbol 'FS 0' is indicated on the dependency arrow to highlight the relationship, in this instance it may be dispensed with.

Diagram 11.8 (c) uses a bar chart to indicate how activities with a lag factor or delay between the finish of one activity and the start of the next are shown.

Diagram 11.8 (d) shows the same operation in precedence format as a single relationship where the lag factor is shown as an activity.

Diagram 11.8 (e) uses the overlapping model in which the same information can be provided by showing just two activities. The delay required for curing is shown on the dependency arrow by way of the relationship type symbol and its associated lag factor.

Start-to-start relationships

This type of relationship implies that the start of the preceding activity determines the start of the succeeding activity. Where the lag factor is zero, the two activities begin together; where the lag is greater than zero, the succeeding activity cannot start until at least the designated lag factor has elapsed. Comparative examples of how start-to-start relationships would be shown in bar and precedence forms are given in Figure 11.9.

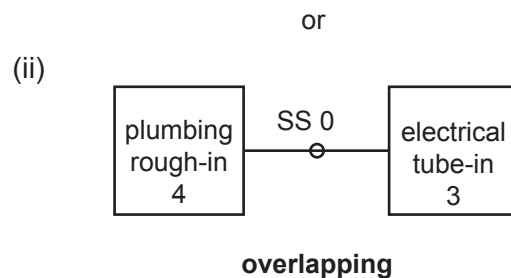
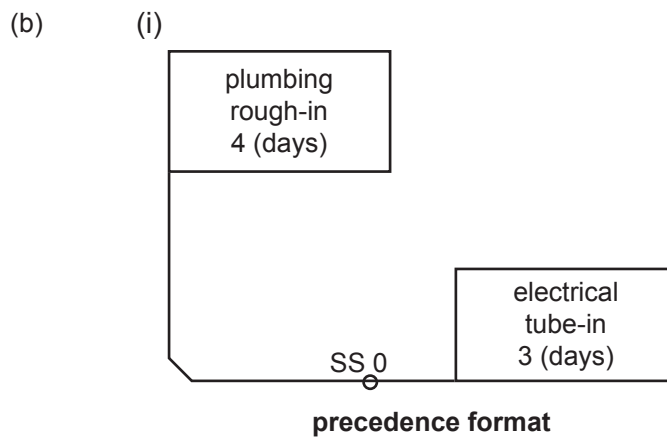
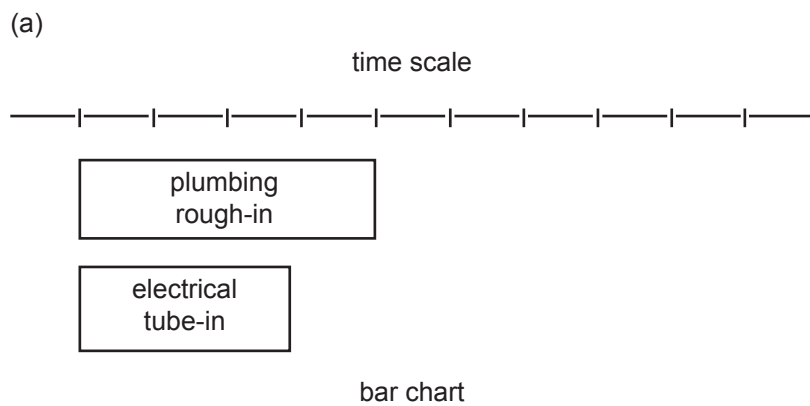


Fig 11.9 (a) and (b)

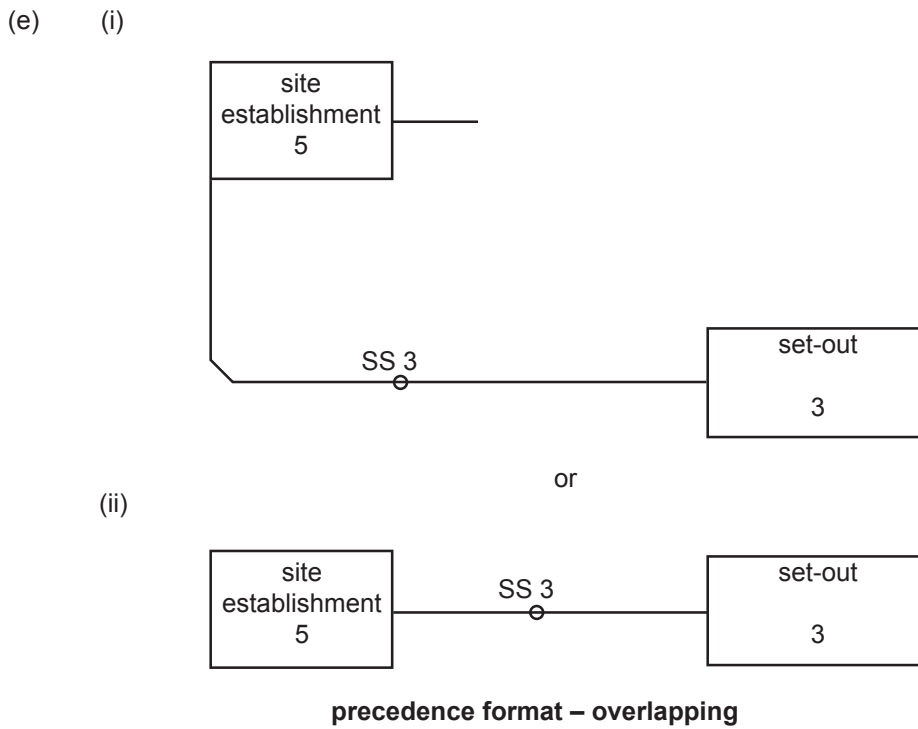
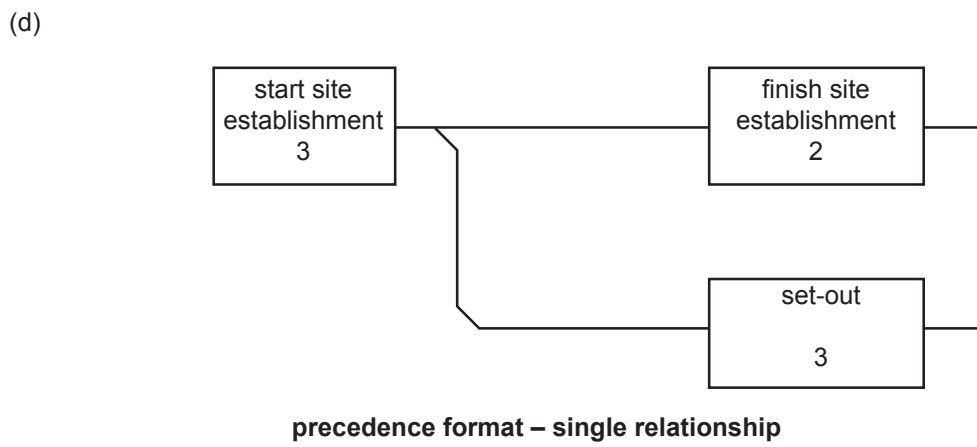
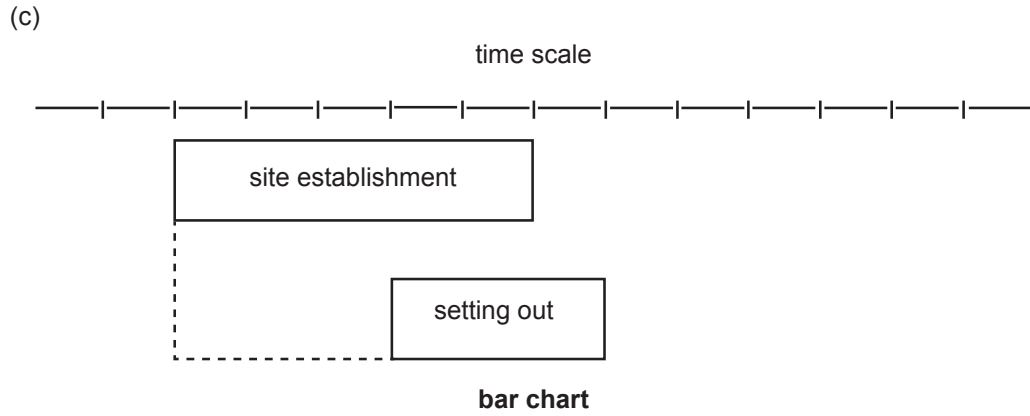


Fig 11.9 Start-to-start relationships

Diagrams 11.9 (a) and (b) represent two activities, plumbing rough-in and electrical tube-in, which are programmed to start simultaneously.

Diagram 11.9 (b) (i) illustrates the conventional method of positioning the start-to-start dependency arrow in precedence diagrams, which clearly identifies the relationship type even before the code type is applied to the arrow.

Diagram 11.9 (b) (ii) uses the short form of dependency line to the activities. This method does not conform strictly to convention but reduces the amount of line work required to link related activities in the network. The placing of the appropriate code on the arrow is sufficient to identify the relationship type.

Diagrams 11.9 (c), (d), (e) (i) and (e) (ii) have start-to-start relationships with a three-day lag factor. This implies that the set-out cannot start until at least three days after the start of site establishment. Diagram 11.9 (d) shows how the relationships and lag are drawn in precedence format if presented as a single relationship. Diagrams 11.9 (e) (i) and (e) (ii) show the conventional and short forms respectively using the overlapping principle.

Finish-to-finish relationships

This name implies that the finish of the succeeding activity is determined by the finish of the preceding activity. Where the lag factor is zero, the two activities may finish at the same time; where the lag factor is greater than zero, the succeeding activity cannot finish until at least the designated lag factor has elapsed.

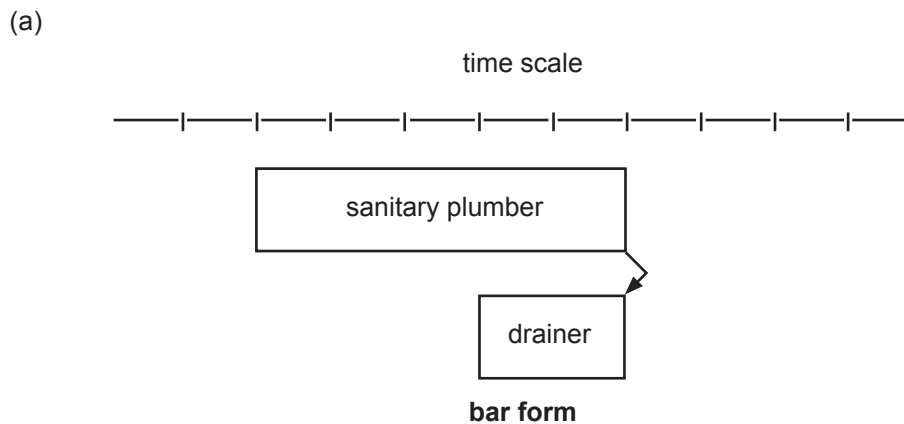
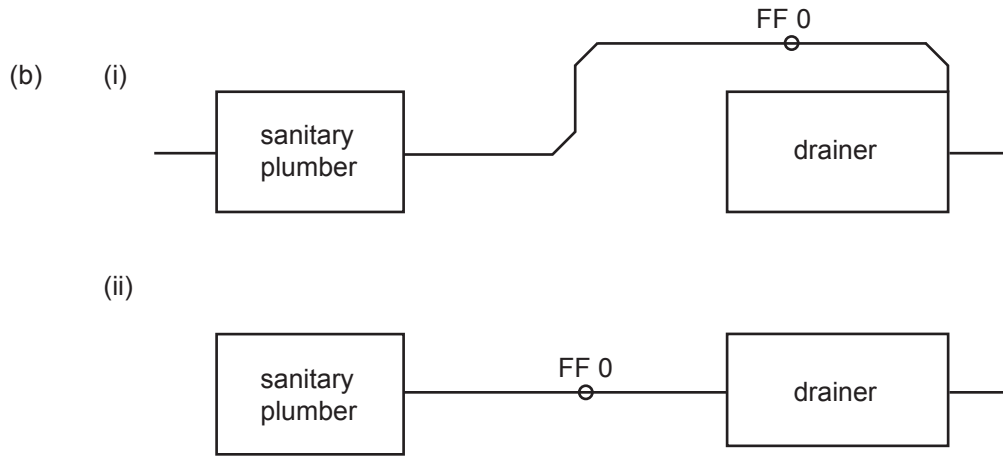
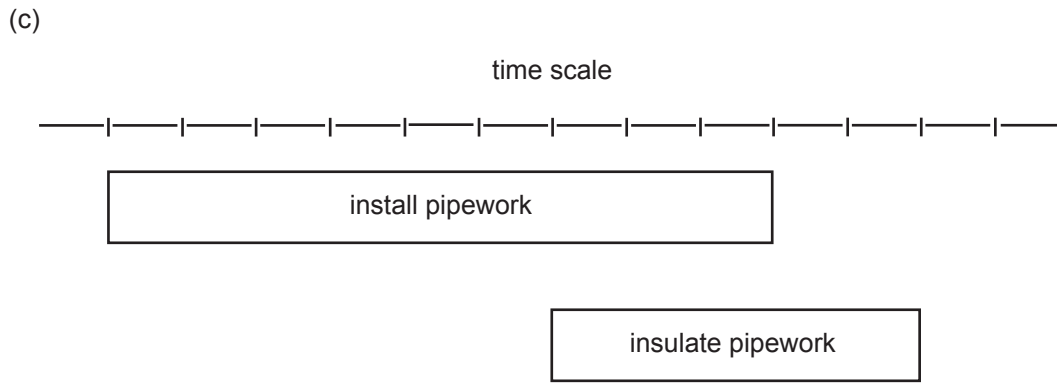


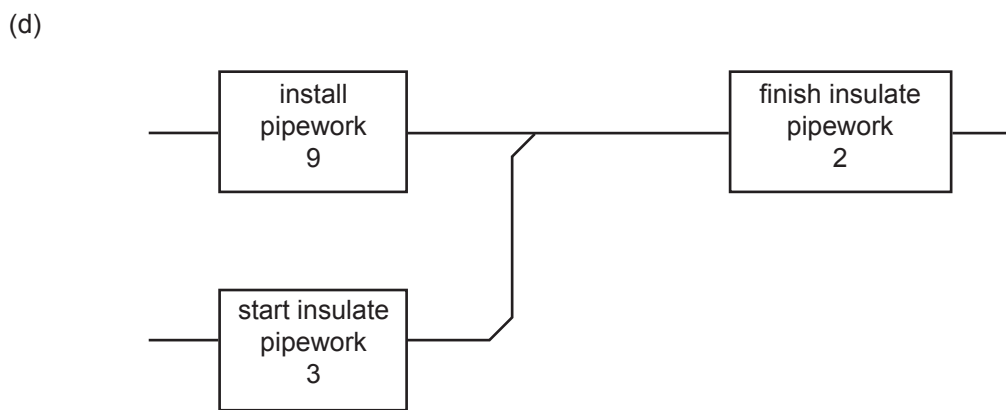
Fig 11.10 (a)



overlapping



bar form



precedence form – single relationship

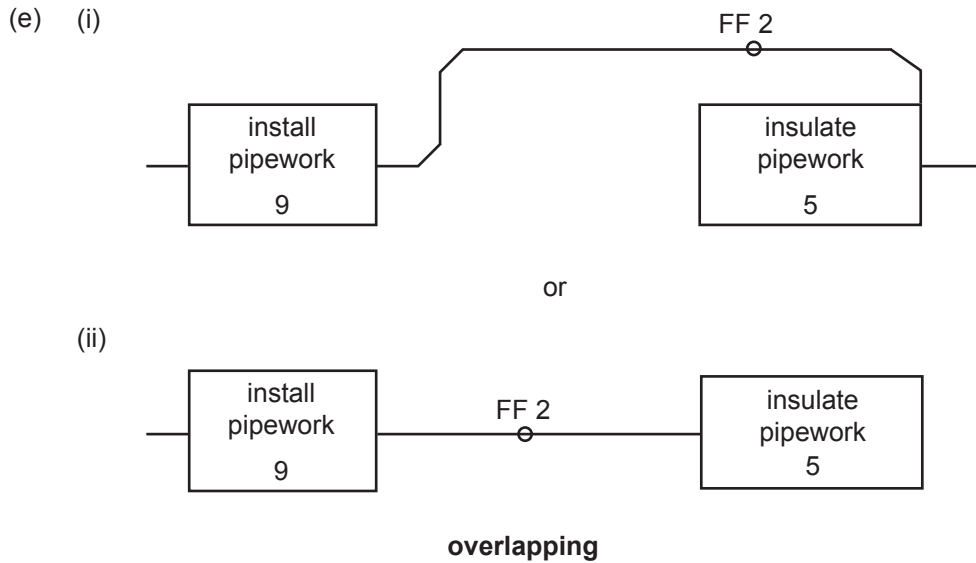


Fig 11.10 Finish-to-finish relationships

Diagrams 11.10 (a) and (b) represent two activities, sanitary plumber and drainer, which are programmed to finish simultaneously. Diagram 11.10 (a) illustrates this using the bar form. Diagram 11.10 (b) (i) uses the conventional method in precedence format of positioning the finish-to-finish dependency arrow and requires the relationship code and lag factor to be positioned on the dependency arrow to identify the relationship type.

Diagrams 11.10 (c), (d), (e) (i) and (e) (ii) have finish-to-finish relationships with a lag factor of two days. This implies that the insulating of the pipework cannot be completed until two days after the pipework has been installed. Diagram 11.10 (c) shows this using the bar form. Diagram 11.10 (d) uses the single relationship model in precedence format, while Diagrams 11.10 (e) (i) and (e) (ii) use the overlapping model principle.

Start-to-finish relationships

This is the fourth type of precedence relationship. It implies that the start of a preceding activity will determine the finish of a succeeding activity. This type of relationship may be of special significance in large projects and its presentation is sometimes difficult to understand.

Compound relationships

There are times during the development of a project network when the need arises to start a succeeding activity before completion of its preceding activity but where it will not be possible to complete the activity until at least a specified time after the preceding activity has finished.

To illustrate how this sort of compound relationship can be presented, the example of laying a stormwater drain will again be used.

Assume the excavation of the trench will take ten (10) days to complete, the laying of the stormwater pipes requires seven (7) days and the backfilling operation two (2) days. It is anticipated that drain laying may begin three (3) days after the trench excavation has started but cannot be completed until two (2) days after its finish; the backfilling can start five (5) days after the drain laying begins but cannot be completed until one (1) day after the drain laying has been completed.

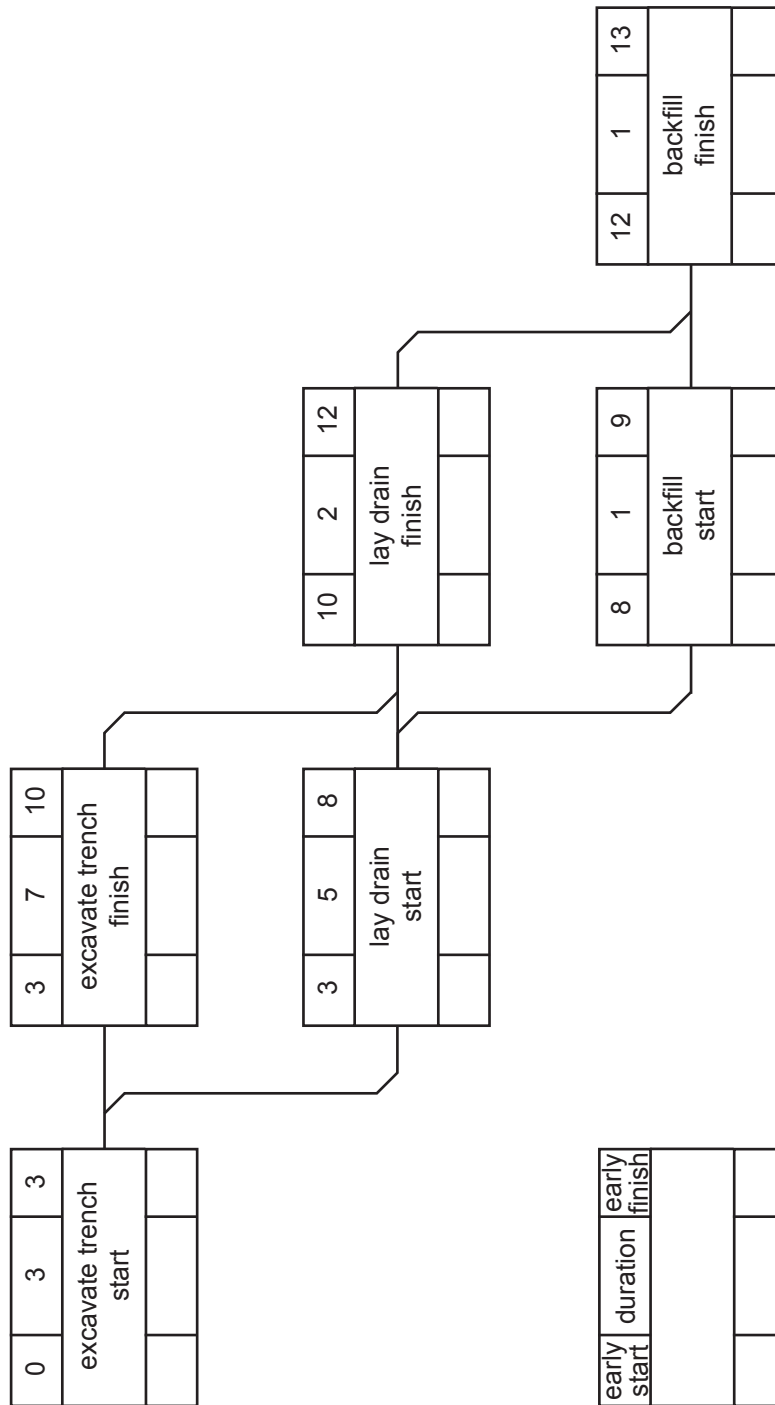


Fig 11.11 (a) Single relationship – precedence

Figure 11.11 (a) shows the single network presentation in precedence form for the three activities. The drain laying can start three days after the start of the excavating but requires two days to complete after excavation has finished. The backfilling can begin five days after the start of the drain laying but cannot be completed until at least one day after the drain laying activity.

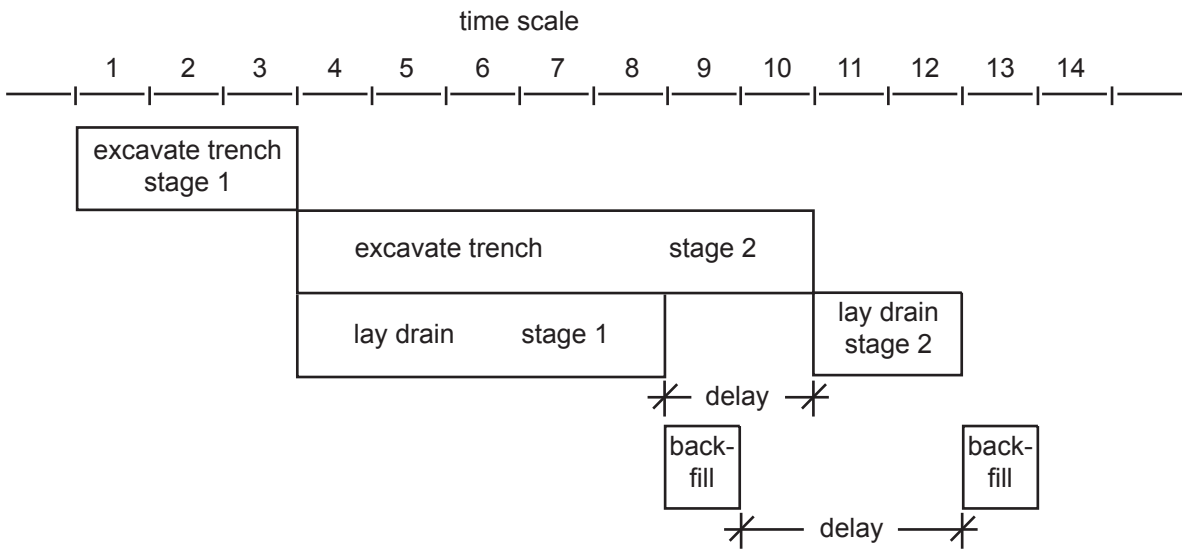


Fig 11.11 (b) Single relationship – bar form

Figure 11.11 (b) represents the single relationship in bar form with the start-to-start and finish-to-finish relationships observed. It can be seen from the time scale that the operation requires an estimated 13 days to complete.

The same operation, drawn as an overlapping network using alternative presentations, is shown in Figures 11.11 (c) (i) and (ii). The two relationships, start-to-start and finish-to-finish, show their respective lag factors on their dependency arrows. In calculating the early and late starting dates for the succeeding activities, each dependency is calculated individually.

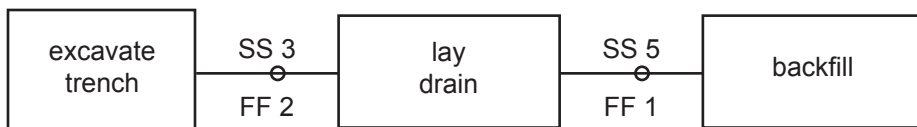


Fig 11.11 (c) (i) Compound relationship – short format

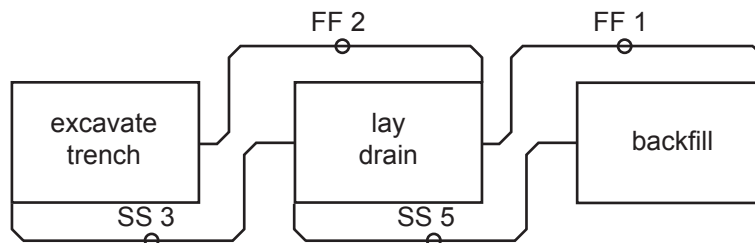


Fig 11.11 (c) (ii) Compound relationship – conventional format

Figure 11.11 (d) shows the compound relationship in bar form. The options for succeeding activities are shown, the most probable preference being the late starts which are solidly lined in. This option provides for continuity of each activity.

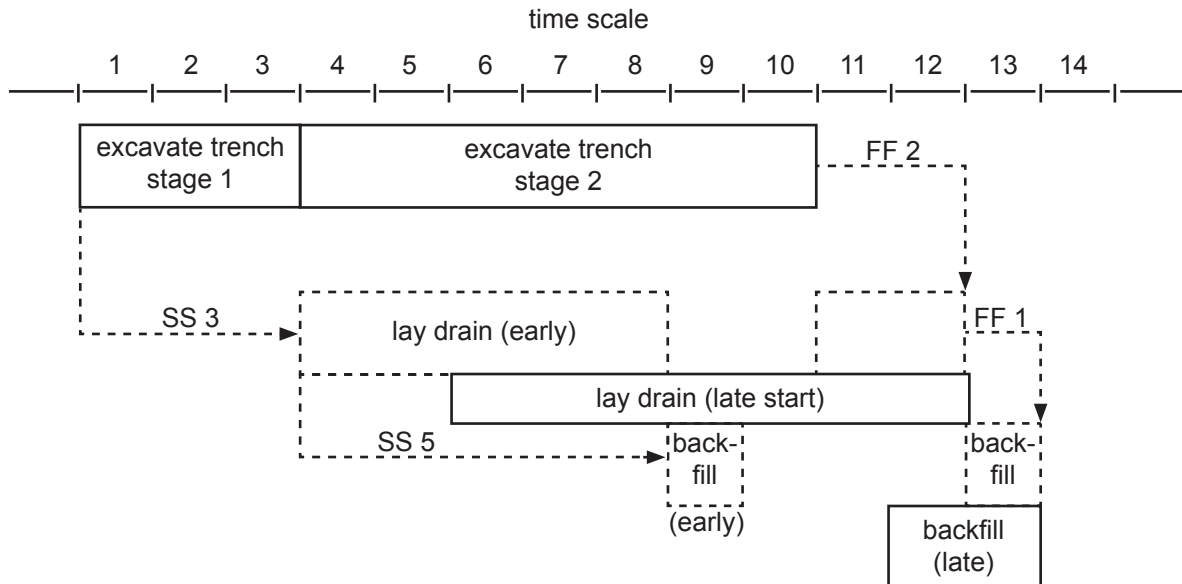


Fig 11.11 (d) Compound relationship – bar form

Conclusion

This chapter has introduced the basic conventions, relationships and terminology necessary for the preparation and presentation of precedence networks. The bar chart has been used in conjunction with the precedence format in an endeavour to reinforce the visual concept of the planner's intentions. Throughout the section on precedence relationships, two alternative approaches to positioning the dependency arrow have been used:

1. the standard convention in which the dependency arrow enters the node from the left or top and leaves from the right or bottom of the node
2. the 'short format' in which the planner uses the most direct path for the dependency arrows to connect related activities. To identify the relationship type and lag value, alphabetical symbols and lag values are positioned on the dependency arrows.

In the following chapters, where discussions of precedence diagram networks occur, the short form of dependency arrow will be used.

Finally, the use of single relationships to express logic where overlapping occurs is unnecessary, as, like the dummy in arrow networks, it can increase considerably the number of activities in a network.

Chapter 12

Precedence networks

Precedence – preparation and analysis

The previous chapter dealt with the basic terminology, conventions and relationships developed for precedence diagrams. The techniques required to develop those characteristics into a network presentation will now be described and illustrated.

This text will concentrate on the manual method of constructing precedence networks to demonstrate the principles involved. However, the use of software packages is standard in industry.

Manual establishment of a network comprises the following stages:

1. Research the documents.
2. Identify the activities.
3. List the activities.
4. Sketch the logic (planning diagram).
5. Give each activity a unique identity.
6. Establish activity durations.
7. Apply lag factors to activities where required.
8. Check logic. Any incorrect logic will affect the time analysis.
9. Complete forward and backward passes.
10. Draw the presentation network diagram.

Research the documents

It is important that all project documentation, including plans, specifications, bills of quantities etc, available to the planner be researched and all relevant information extracted. This establishes the amount of detail that will be incorporated into the network. Documentation is usually thorough and complete and provides the planner with the information necessary to produce an accurate network.

However, when the 'fast tracking' technique is adopted for major projects, total documentation is not available at the pre-tender stage. (See Chapter 1 *Management contracting*).

The planner may be provided with the structural documentation only and be required to envisage the types of services and finishes to be included and so have to prepare the initial network based on both factual information and intuition.

Identify the activities

This is performed at the same time as researching the documents. The various elements of construction are identified. From these elements, activities considered relevant to the planning process are identified for inclusion in the network. The amount of detail required in a network will determine the number of activities required.



List the activities

The creation of an activity list is the most important phase of network planning. For its practicality and accuracy, it is dependent upon the many factors which must be evaluated by the planner.

For the purpose of this discussion, the service station example that has already been used as a model for arrow diagram presentations (See Chapter 9) will again be used to explain the preparation of a precedence diagram network.

The list below shows the activities considered necessary to prepare the precedence diagram for the service station. Note dummy activities are not included.

Activity list – service station

Clear site	Roof
Set out	Pump plinth
Excavate for office	Joiner
Excavate for tanks	Electrician
Underground services	Plumber
Deliver tanks	Lower tanks
Footings for office	Plaster
Concrete for tank bases	Tarmac
Hardcore site	Fix pump
Windows	Paint
Walls	Clean up
Brickwork to tanks	

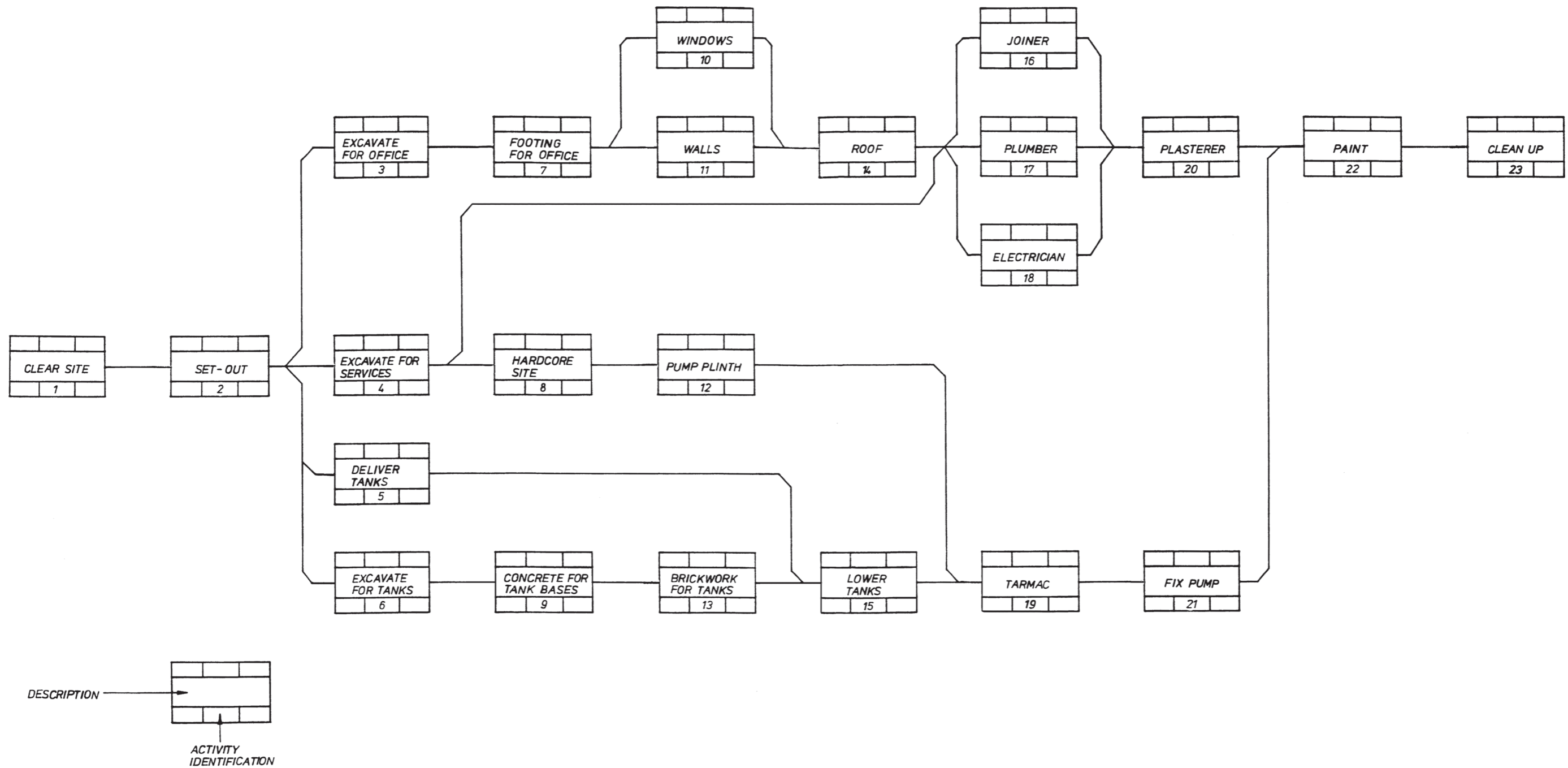


Fig 12.1 Precedence logic network for service station



Logic diagram

From the list of activities, the planning team will be able to establish the method of working, taking into consideration any restraints which may need to be imposed on parts of the network and which dictate the order in which the work needs to be performed.

Where a method statement has been prepared for the project, it will provide a guide in stating the way in which the work is intended to be carried out.

The service station network comprises two sub-projects:

1. the office building
2. the installation of the tanks, pumps and associated services.

The two elements can be performed independently of each other, other than for the initial and concluding activities.

Care should be taken when linking the dependency arrows to the nodes to ensure that ambiguity is not incorporated into the logic, particularly when the short form of dependency linking is used.

To highlight this, Activities 4, 14, 16, 17 and 18 have been selected from the service station network (Fig 12.1) and the linking dependency arrows rearranged (in Fig 12.2 below) so they give the logic a different meaning.

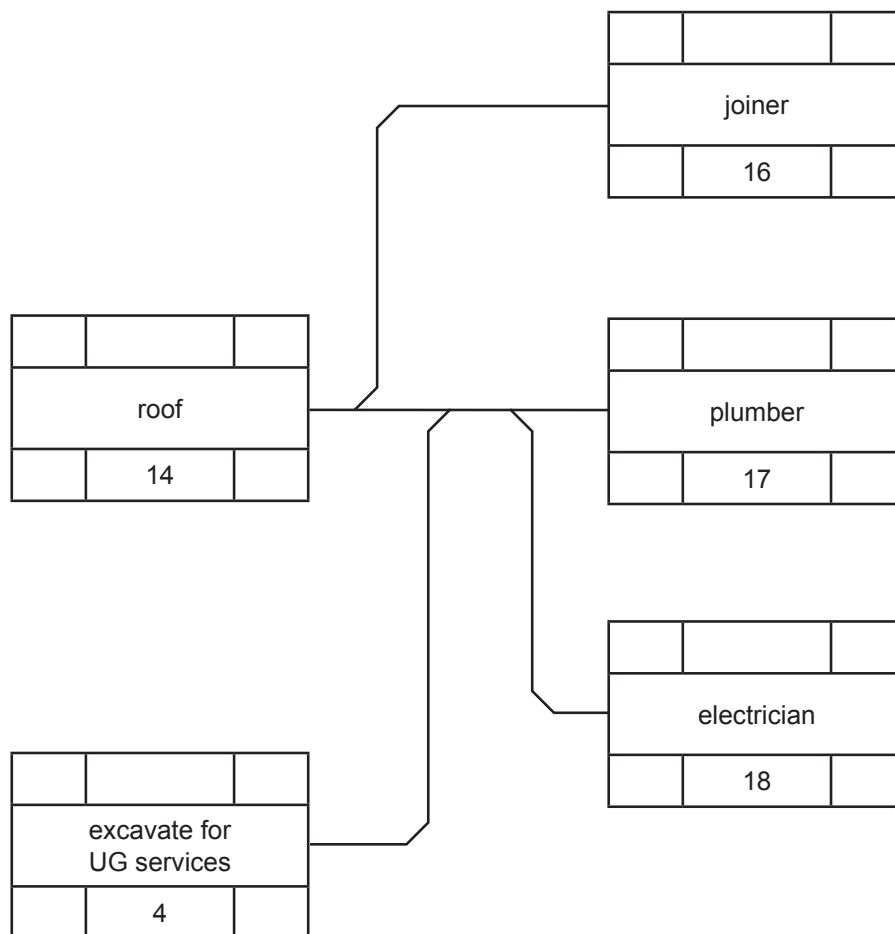


Fig 12.2 Dependency arrow logic

Figure 12.2 alters the logic of the network so that the dependency arrow from Activity 4 no longer controls Activity 16, as is the case in Figure 12.1. By creating a dependency arrow from 14 to 16 prior to where Activity 4 links into the dependency arrow connecting Activities 14 and 17, the logic now shows that Activities 4 and 14 control the start of Activities 17 and 18 but only Activity 14 controls the start of Activity 16.

It is important to understand this feature of logic presentation.

Activity identification

Once the logic of the network has been established, a unique identity can be given to each activity. It is preferable that the numerical identity for activities be in an ascending sequence, as discussed in an earlier chapter. Where a project is complex and the network made up of many activities, the planning team may consider it advantageous to use an alphanumeric system of identification. An alphabetical letter in conjunction with a numeral can be used to highlight specific areas within the project – for example, the letter 'E' could be used to denote the 'electrical services' component.

The numeral following the letter indicates the position of the activity within the component. Figure 12.1 uses the numerical coding only, while Figure 12.3 illustrates alphanumeric identification.

electrical fit-off		
	E10	

Fig 12.3 Alphanumeric activity identification

Establishing durations

At this stage, it is necessary to know, or to be able to establish, estimated durations for each activity in the network, so that the project duration can be calculated. The assigned durations are often based on specific data gathered from field personnel or specialist consultants or on data recorded on previous projects of a similar type and modified by the planners to satisfy the needs of the project under consideration.

Figure 12.4 shows an appropriate position to place the duration on the node.

	duration	
activity description		
	ID	

Fig 12.4 Duration

As the initial planning of a network is usually based on the earliest starting and finishing times, the centre box at the top of each activity node has been selected as a practical position to enter the duration, as it allows the earliest start and finish times to be simply calculated across the diagram when using the node format illustrated in Figure 11.3 in the previous chapter, *Introduction to precedence diagrams*.

Lag factors and logic check

Before starting to schedule the network, re-examine it to make certain that the relationship types and the lag factors (and hence the logic of the network) are accurate and that the diagram produced provides a practical solution.

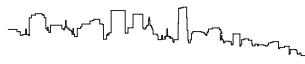
Types of relationship and lag factors have been discussed in the previous chapter and their correct assessment and application are important to the accuracy of the network.

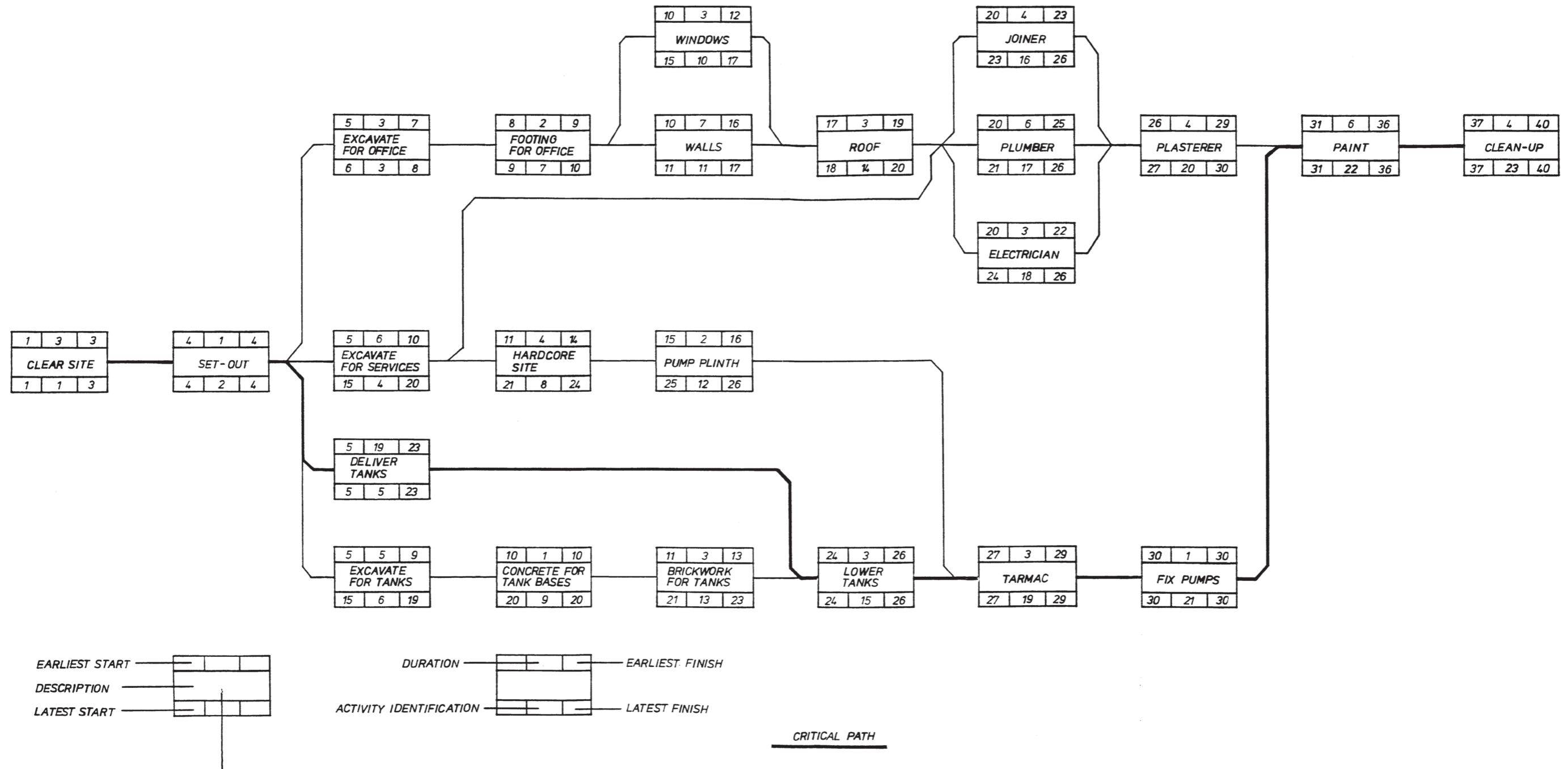
The service station network (Figure 12.1) is a simple network diagram in which every relationship is a finish-to-start relationship, where succeeding activities cannot begin until preceding activities have been completed. When a different type of relationship and lag factor are involved, this must be considered when scheduling is carried out.

Network analysis

When the planner is satisfied that the network logic is accurate, the analysis of the network can begin – that is, performing the forward and backward passes through all activities to determine the current early and late times (days/dates) for each activity, and for the project as a whole. The ‘passes’ are performed in exactly the same way as in arrow diagram networks.

The analysis for the service station network is illustrated in Figure 12.5.





Each activity node may contain the same identity number as exists on the equivalent CPN arrow activity – the arrow number can be placed in the space allocated for the activity description.

Fig 12.5 Precedence network analysis for service station



It can be seen that each activity node contains the information related to the individual activity – that is, earliest start and finishing times and latest start and finishing times. Activity floats can be included as required.

Two alternative approaches are commonly used by planners when calculating the activity times to be placed in the nodes. One method is to enter the same figure for the earliest start time for a succeeding activity as was entered for the earliest finishing time for its preceding activity, as shown in Figure 12.6.

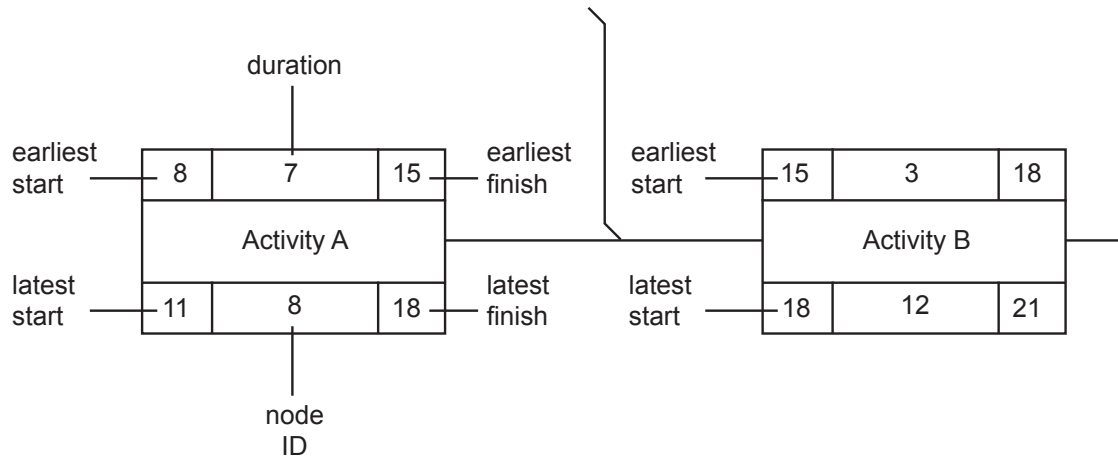


Fig 12.6

This method is similar to that applied in the arrow network technique, in which, at a glance, the earliest finish of the preceding activity and the earliest start of the succeeding activity appear to be on the same day or date.

The second method, the one used to analyse the service station in Figure 12.5, deducts one time unit from the duration in order to establish the earliest finishing time for the activity when calculating the forward pass, as shown in Figure 12.7.

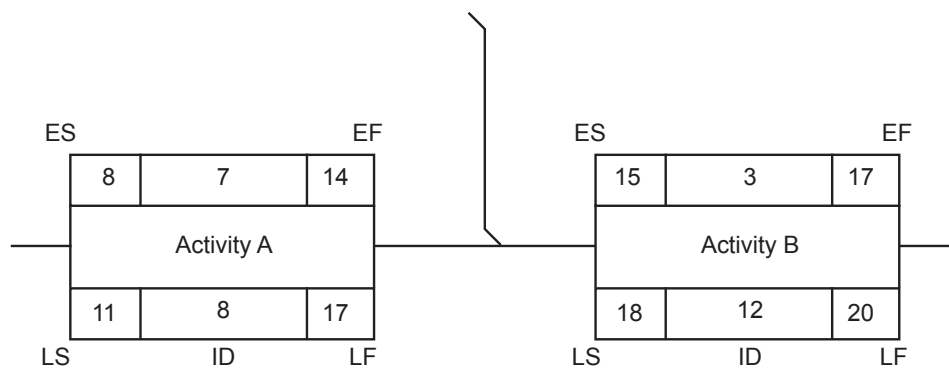


Fig 12.7

For example, in Figure 12.7:

1. earliest start + duration – 1 = earliest finish of activity
 $8 + 7 - 1 = 14$
2. earliest start + duration = earliest start of succeeding activity
 $8 + 7 = 15$
3. latest finish – (duration – 1) = latest start of activity
 $20 - (3 - 1) = 18$
4. latest finish – duration = latest finish of preceding activity
 $20 - 3 = 17$

This technique can be clarified by referring to the bar chart in Figure 12.8.

From the chart, it can be seen that, if Activity 'A' starts at the beginning of Day 8 and has a duration of 7 days, the earliest it will finish is at the end of Day 14. Activity 'B' can then begin at the start of Day 15 and finish at the end of Day 17. The dotted line represents the latest finishing times for activities 'A' and 'B', from which their respective durations are subtracted.

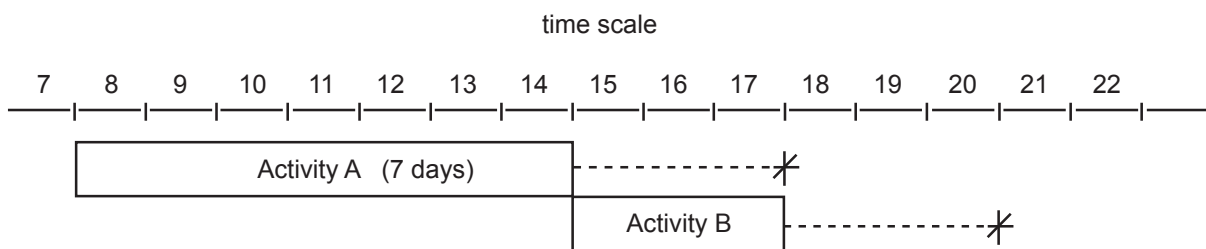


Fig 12.8

Once the analysis of the network is completed, the critical activities and the critical path through the network are established. Nodes which have the earliest and latest start dates identical, and earliest and latest finishing times identical, are critical activities. The chain of critical activities forms the critical path or paths through the network.

Analysis involving lag

If the relationship between activities contains a lag factor greater than zero, this must be taken into consideration when analysing the network.

The following examples illustrate the analysis of different relationship types both with and without a 'positive lag factor'.

Finish-to-start

(a) Floor slab cannot start until footings are complete.

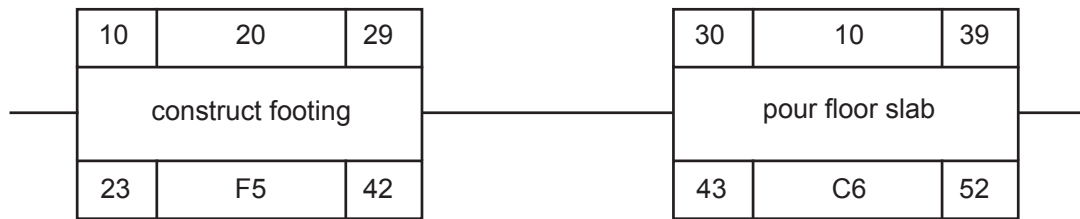


Fig 12.9 Finish-to-start – lag factor 0

(b) Here there is a delay between activities. Formwork cannot be stripped until 10 days after concreting is completed. This period may be for curing the concrete floor slab.

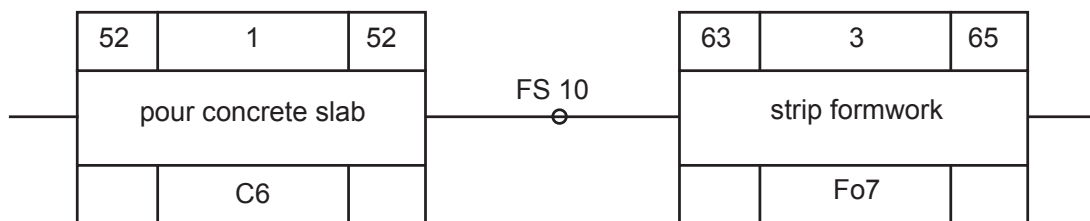


Fig 12.10 Finish-to-start – lag factor 10

Start-to-start

(a) The setting out can start at the same time as the site establishment but not before.

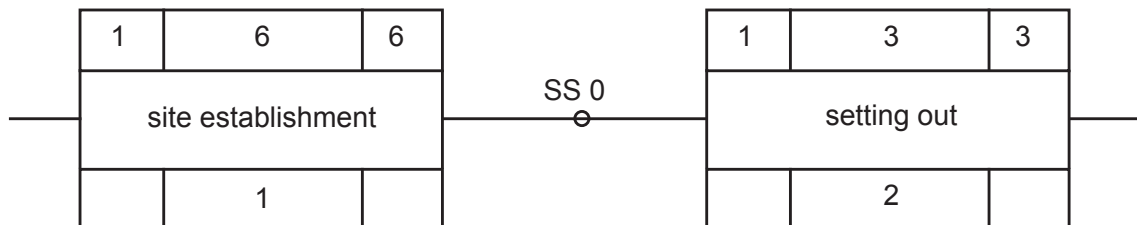


Fig 12.11 Start-to-start relationships – lag factor 0

(b) Construction of road sub-base cannot begin until nine (9) days after start of the land drain to the retaining wall.

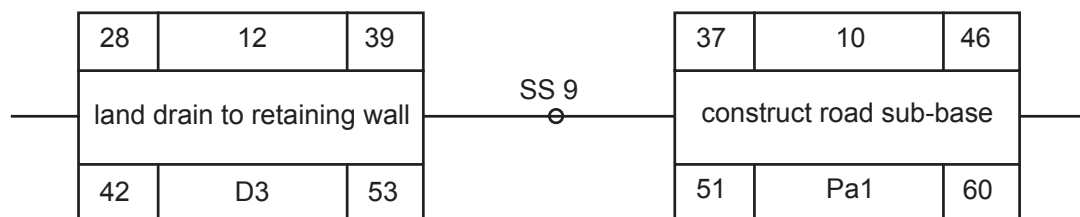


Fig 12.12 Start-to-start – lag factor nine days

Finish-to-finish

- (a) Backfill to retaining wall cannot be finished until excavation of bulk is complete – that is, both activities finish at the same time.

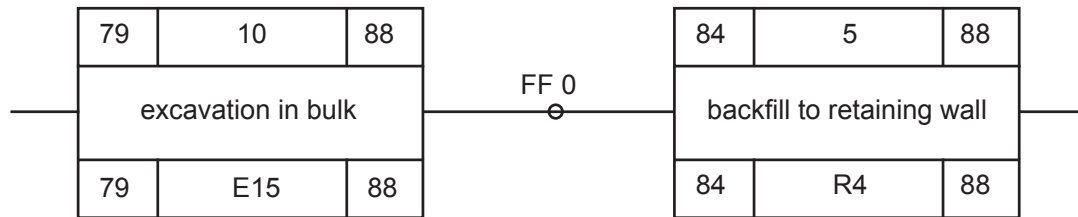


Fig 12.13 Finish-to-finish – lag factor 0

- (b) Clearing of site cannot finish until four (4) days after seeding the embankment is completed.

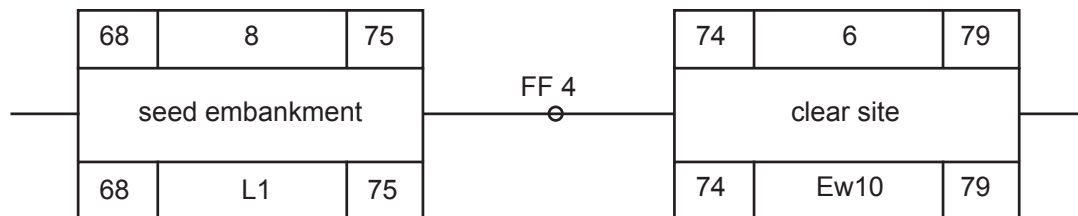
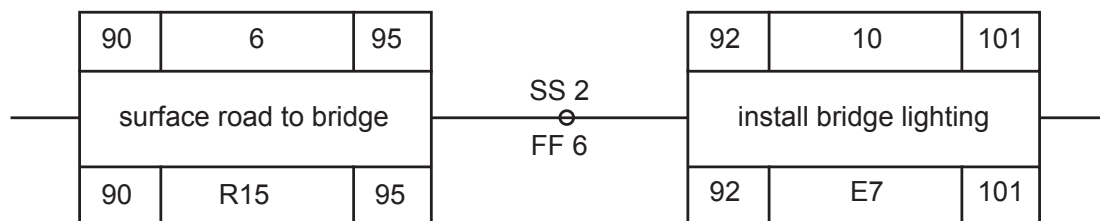


Fig 12.14 Finish-to-finish – lag factor four days

Compound relationships

Installation of bridge lighting cannot start until two (2) days after the start of road surfacing and cannot finish until six (6) days after the finish of the surfacing.



**Fig 12.15 Compound relationship:
start-to-start – lag; finish-to-finish – lag**

Note: The short form of using dependency arrows has been used in all of the examples above.

More than one dependency arrow

The positioning of lag code on dependency arrows is important.

Where more than one dependency arrow merges into a succeeding activity and each has its own lag factor, the positioning of the lag code should be as illustrated in the following sketch.

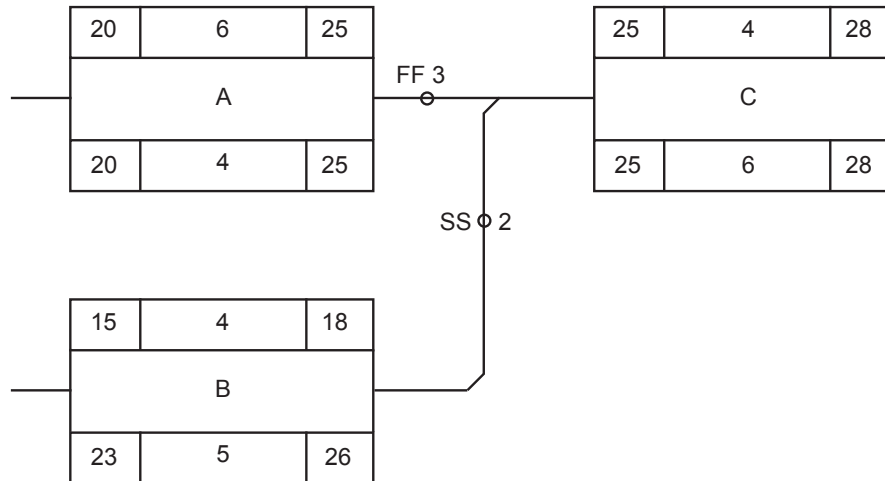


Fig 12.16 Positioning of lag code on dependency arrows

Analysing information for network activities in situations like those in Figure 12.16 is performed using the same rules of convention as described earlier, but bearing in mind the relationship type and the lag factor.

Figure 12.16 shows a finish-to-finish relationship between Activities A and C, with a lag factor of three, while there is a start-to-start relationship between Activities B and C with a lag factor of two. No relationship exists between Activities A and B.

Note that the relationship code and lag factor between Activities A and C are positioned before the intersection of the dependency arrow from Activity B. This indicates that the finish-to-finish relationship is applicable between Activities A and C only.

To calculate the *forward pass* through Activity C, the paths from both Activities A and B must be considered.

Forward pass

Activity A: earliest start + duration – 1 = earliest finish of A
 $20 + 6 - 1 = 25$

The existence of a finish-to-finish relationship with a lag factor of three signifies that Activity C can finish no earlier than three units of time, say days, after the earliest finishing time of Activity A – that is $25 + 3 = 28$. This is the earliest day on which Activity C can finish.

Before this is entered on the network, the path from *Activity B* must be calculated. A start-to-start relationship with a lag factor of two exists in this instance.

Therefore, the earliest start time, Day 15, has the lag factor of two added, to provide an earliest start time of Day 17 for Activity C. To this is added the duration of Activity C minus 1, which provides the earliest finish time from Activity B to Activity C, which is Day 20. As this figure is less than that from Activity A to Activity C, it is the figure of 28 which is entered as the earliest finishing time for Activity C.

Backward pass

Assuming the backward pass through the network has calculated that the latest finishing time for Activity C is Day 28, the following calculations will establish the entries to be made for Activities A, B and C.

1. latest finish C – (duration C – 1) = latest start for C
 $28 - (4 - 1) = 25$
2. latest finish C – lag factor = latest finish for A
 $28 - 3 = 25$
3. latest finish A – (duration A – 1) = latest start A
 $25 - (6 - 1) = 20$
4. latest start C – lag factor = latest start B
 $25 - 2 = 23$
5. latest start B + (duration B – 1) = latest finish B
 $23 + (4 - 1) = 26$

The various relationship types, together with relevant lag factors, are calculated along similar lines to those shown above, basing the calculations on the type of relationship existing between linked activities.

Activity float

Float for the activities and network in a precedence diagram is calculated using the same definitions and procedures as in the arrow diagram process discussed earlier.

Figure 12.17 illustrates the method of calculating the types of float previously discussed (namely, *total*, *free* and *independent*) applicable to Activity A in the example.

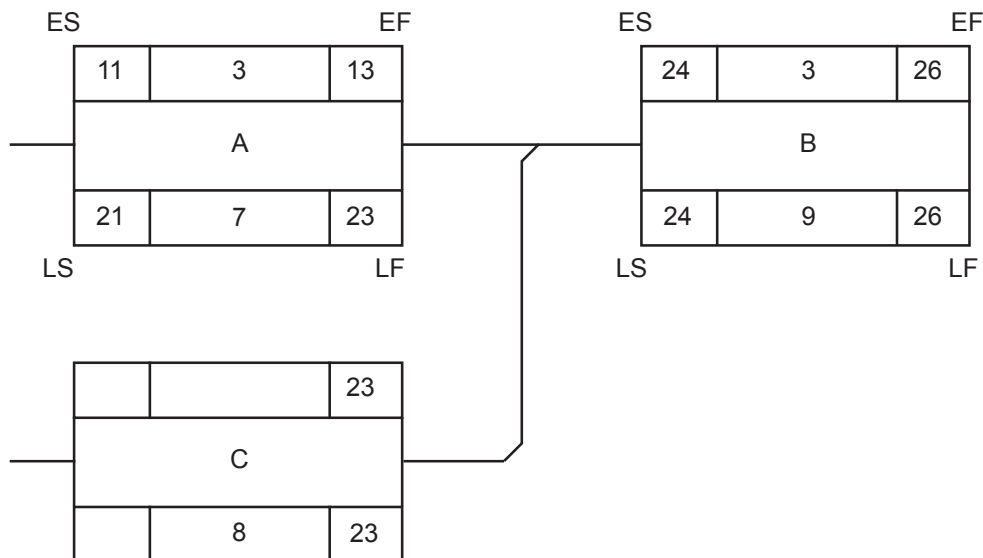


Fig 12.17

Total float

Latest finish (Activity A) – earliest finish (Activity A)

$$23 - 13 = 10$$

total float = 10 days

Free float

Earliest start (Activity B) – [earliest start + duration] (Activity A)

$$24 - (11 + 3) = 10$$

free float = 10 days

Independent float

Earliest start (Activity B) – [latest start + duration] (Activity A)

$$24 - (21 + 3) = 0$$

independent float = 0

Note: It is important that the relationship type and associated lag factor be considered when establishing the type and amount of float for each activity. Where more than one dependency exists between preceding and succeeding activities, the most restrictive dependency takes precedence when analysing the network's activities.

Conclusion

The last six chapters have dealt with planning and analysis procedures for both arrow and precedence networks. The information included has intentionally been kept to a basic level as an introduction (only) to network planning and its uses. Many libraries contain reference books which provide more advanced information and explanation on the subject.

System preference is up to the individual planner or planning team based on their understanding of particular systems and the complexities of individual projects.



Chapter 13

Gantt chart (or bar chart or time and progress schedule)

Introduction

In Chapters 7–12, we have covered the fundamentals of network diagrams in the form of activity-on-the-arrow (arrow diagrams) and activity-on-the-node (precedence diagrams) as used in the construction industry.

We must now consider another well-known graphical presentation which has served the building industry well for many years. It is referred to alternatively as a Gantt chart, bar chart or time and progress schedule. Any of these terms can be used when referring to a chart designed to compare a project's work content and time factor. The term *Gantt chart* has been selected for use in this text.

The Gantt chart was popularised in the early 1900s by Henry L Gantt and Frederick W Taylor, who devised a graphical method for comparing work content versus time concept as part of their research into scientific management. This chart has provided the basis for modern charts and graphs, including time-scaled networks and link-bar charts, which will not be discussed in this text.

Although Gantt and Taylor's method was originally designed for production scheduling, it has since been modified and refined to be a more effective tool for planning projects and recording progress. The Gantt chart is immediately intelligible to people who have no knowledge of network diagrams.

Definition

The Gantt chart is a simple time-scaled diagram showing timeframes for activities or areas of work. The activities are represented by horizontal lines or bars whose length is proportional to the time involved.

Conventions

The basic conventions are:

- Time (duration) flows from left to right.
- Activities are listed from top to bottom.
- When used in conjunction with budget graphs, activities may be listed from bottom to top.

Dependencies and logic restraints are not usually shown on a Gantt chart presentation. In this, they differ from the previously discussed network diagrams in which dependency lines and logic restraints are key factors. Also, the length of the arrows or dependency lines in networks bears no relationship to time and their direction is not essentially horizontal.

General uses

The Gantt chart can be used in conjunction with a network diagram, particularly with respect to large or complex projects, or used independently for projects of a lesser nature. These charts are often prepared at the pre-tender stage to assist the builder in early planning and for assessing resource requirements and hence the business's capacity to bid for the job being considered or any future projects within the planning period. Post-tender, during the construction phase, the successful tenderer can utilise the chart for short-term planning and monitoring and for controlling finance and progress at regular intervals.

Progress control, as previously discussed, establishes the following:

- work begun but behind schedule
- work ahead of schedule
- work which has been programmed to start but hasn't
- information upon which to base financial claims.

Gantt charts can be used to establish or derive the following information:

- the number and sequence of activities
- the estimated duration of each activity
- the estimated duration of the contract
- the estimated start time of each activity
- the number of trades and specialist areas involved
- the number of tradespersons employed
- the number of semi-skilled and unskilled workers employed
- subcontract work involved
- other resource requirements and scheduling
- estimated person-hours involved in the project, and in each activity
- budget information.

Comparisons – networks and Gantt charts

As a planning aid, the Gantt chart on its own is restricted in what it can present. As mentioned earlier, it is difficult to indicate the interrelationships and interdependencies which control the progress of a project. Because of intense competition, rising costs, limited time schedules and changing techniques for construction, there has been a need to develop more efficient methods of planning for construction purposes. This has seen the introduction of various types of critical path network.

When comparing the use of critical path networks and Gantt charts, the following aspects are listed for consideration.

Network

Advantages

1. Logic can be divorced from the time element in the preparation of the plan.
2. Allows flexibility in planning.
3. Critical path is easily identifiable.
4. Critical activities can be altered easily if other activities become critical because of delays.
5. Clearly shows interrelationships and interdependencies between activities.
6. Detailed schedules can be established from the network, eg labour, materials and plant schedules.
7. Detailed analysis can be produced from the network.

Disadvantages

1. Not easily understood or prepared by untrained personnel.
2. Does not show overlap in trades.
3. Length of activity line does not give an indication of time.

Gantt chart

Advantages

1. Easily understood by most site personnel.
2. Allows a simple and easily read plan of operation to be prepared for site personnel.
3. Actual performance may be plotted against the plan.
4. Length of bar or line is proportional to time.
5. Readily adaptable to suit a variety of situations.
6. Provides a simple means of communication between personnel involved in a project.

Disadvantages

1. Activity durations must be known before the chart can be prepared.
2. Does not readily inform of critical relationships/activities.
3. Where floats are not indicated, bottlenecks may result.
4. On large projects, it is difficult to depict the total project on one chart.
5. Does not show interrelated activities.
6. Does not readily lend itself to revision.



Procedure for preparing Gantt charts

A Gantt chart may be used independently of any other form of programming or as a derivative of network programming.

Various formats may be used for a Gantt chart, depending on the amount of information it is required to convey. The final decision on format is left to the builder or project planner.

The format used in this text is just one of many and is intended only as a guide.

The title block for such a chart should contain sufficient information to enable it to be readily identified and associated with a particular project. Among information which may be included are date prepared, the project's title, number and location, the stipulated duration or due date for completion and name of client. The amount of information included in the 'heading' is usually left to the discretion of the firm concerned.

The heading system adopted for charts used in this course is as shown in Figure 13.1, which is a Gantt chart for an example project we'll call the Smith residence.

The title block shows:

- the date the chart was prepared
- the title of the project
- the name of the person who prepared the chart.

The body of the chart comprises the following columns for recording data:

- (a) the *Number* column in which is placed a number for each activity on the network
- (b) the *Arrow* column into which the identity numbers of the activity arrows are inserted (dummies are not included)
- (c) the *Operation* column – which is for the main 'trade headings' only. These headings can be obtained from the labour constants sheets issued with each assignment.
- (d) the *Section* column – which lists each activity used in the network. All the activities should be recorded adjacent to their associated trade heading. This additional information is also obtained from the labour constants information sheets – see example later in this chapter. As mentioned in an earlier chapter, the number of activities shown on a constants sheet can be reduced by combining associated trade tasks into the one activity. For example, hanging doors and window sashes, attaching architraves and skirting etc can be combined to comprise one activity only, that of 'fixing carpenter'.
- (e) the *Plant* and *Materials* columns – which are used to indicate the major items of materials and plant required for each activity. An associated legend provides an identifying symbol (figure or letter) for each item. These symbols are used in the plant and materials columns to indicate the requirements for each activity. The symbols are also used with the activity lines as an indication of when the items are required on site.
- (f) *duration* columns – which occupy the remainder of the chart. Each of these columns is evenly subdivided – with each subdivision representing a unit of time, such as a day, week or month. The chart used in the following example is divided into columns each representing one week and subdivided into a five-day working week.

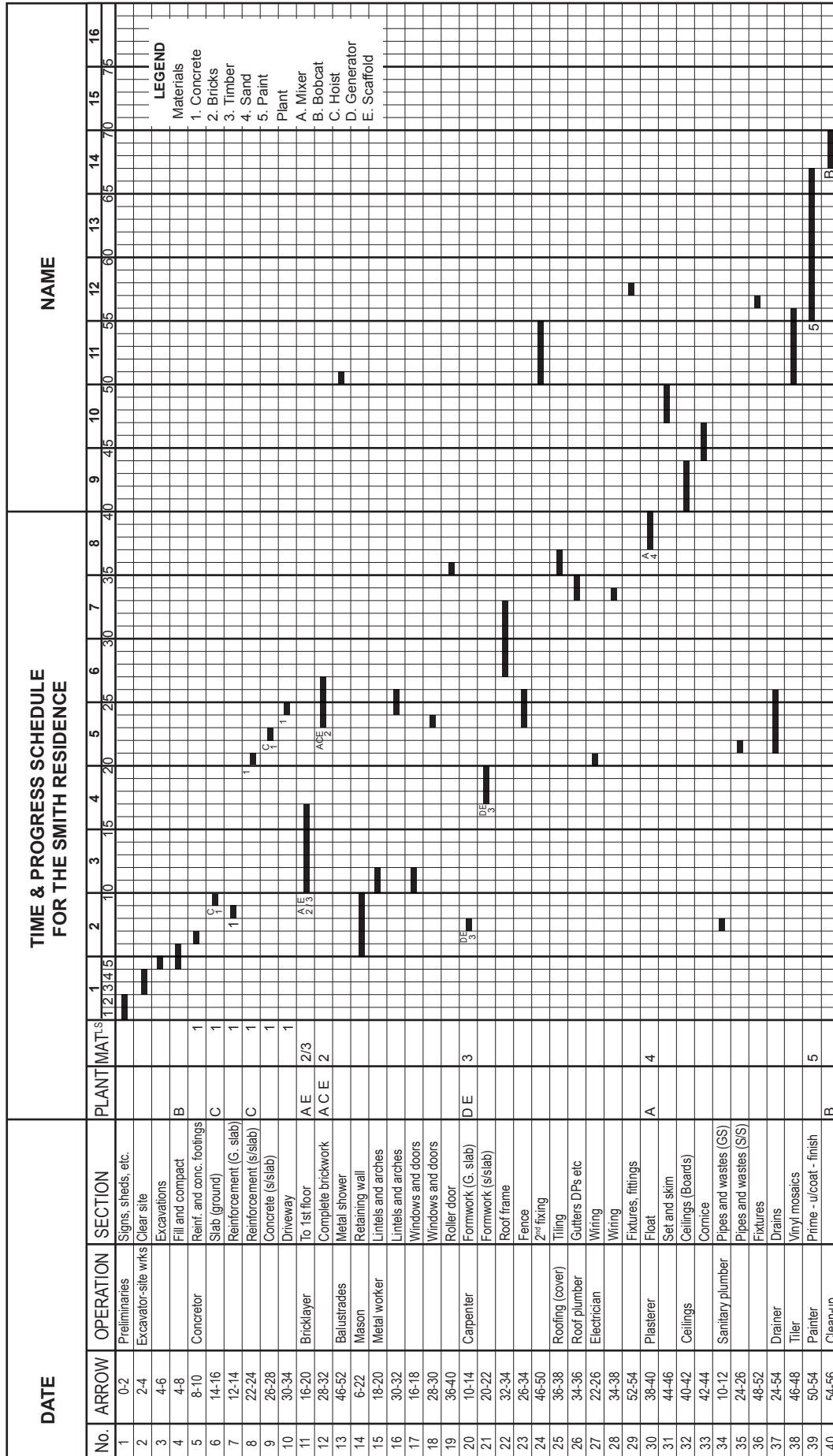


Fig 13.1 Example of Gantt chart for Smith project



- | | |
|---------------------------------|-----------------------------|
| 0-2 Preliminaries | 28-30 Windows and doors |
| 2-4 Clear site | 28-32 Complete brickwork |
| 4-6 Excavate footings | 30-32 Arches and lintels |
| 4-8 Fill and compact | 30-34 Driveway |
| 6-22 Rubble walls | 32-34 Roof |
| 8-10 Reinforcement and footings | 34-36 Roof plumbing |
| 10-12 Plumbing for slab | 34-38 Electrical wiring |
| 10-14 Formwork for slab | 36-38 Roof cover |
| 12-14 Reinforcement | 36-40 Roller door |
| 14-16 Pour slab | 38-40 Plasterer float |
| 16-18 Windows and door frames | 40-42 Ceiling |
| 16-20 Brickwork 1st Fl | 42-44 Cornice |
| 18-20 Lintels and arches | 44-46 Plaster set |
| 20-22 Formwork | 46-48 Tiler |
| 22-24 Reinforcement | 46-50 2nd fixing |
| 22-26 Electrical work (wiring) | 46-52 Balustrade and shower |
| 24-26 Plumbing | 48-52 Plumber |
| 24-54 Drainer | 50-54 Painter |
| 26-28 Concrete suspended slab | 52-54 Electrical finish |
| 26-34 Fence | 54-56 Clean-up |

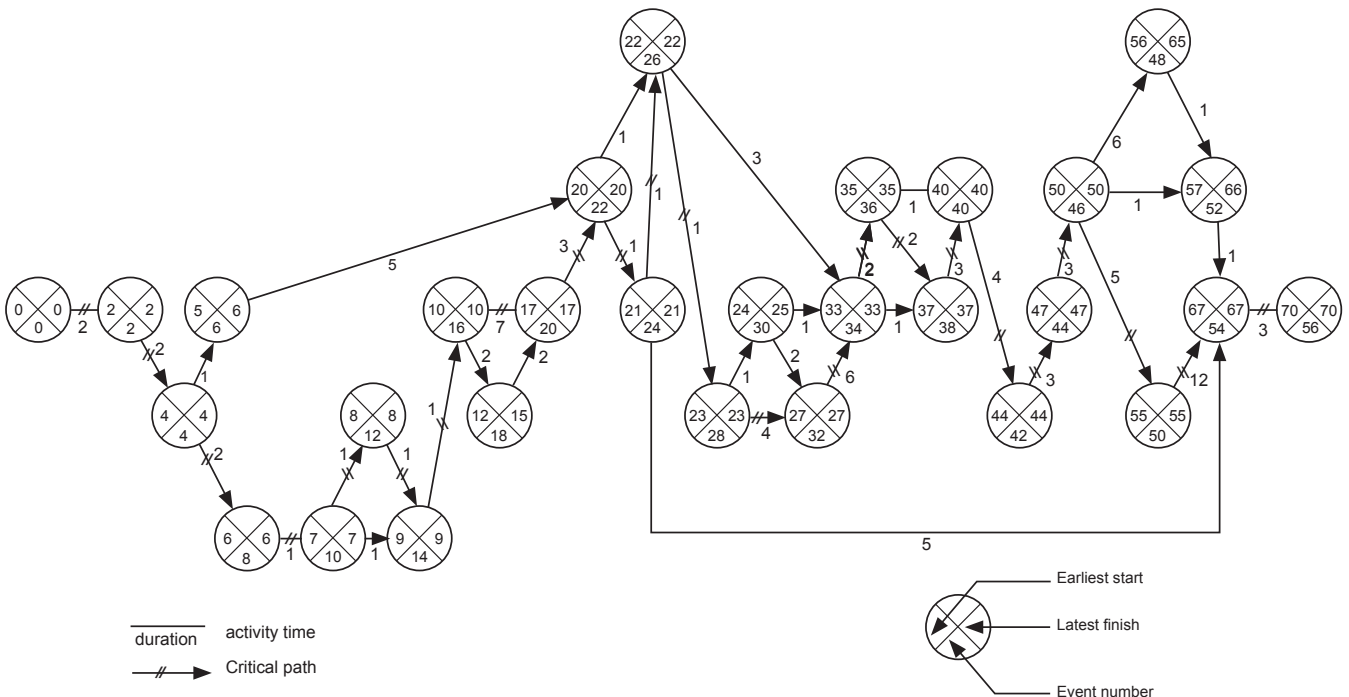


Fig 13.2 Arrow diagram for Smith project

Analysis sheet for Smith residence project

*E = earliest, *L = latest, *T = total, *F = free, *I = independent

No	Arrow	Activity	Duration	Start		Finish		Float			Critical path
				*E	*L	*E	*L	*T	*F	*I	
1	0-2	Preliminaries	2	0	0	2	2	0	0	0	*
2	2-4	Clear site	2	2	2	4	4	0	0	0	*
3	4-6	Excavate footings	1	4	5	5	6	1	0	0	
4	4-8	Fill and compact	2	4	4	6	6	0	0	0	*
5	6-22	Rubble wall	5	5	15	10	20	10	10	9	
6	8-10	Reinforcement and footings	1	6	6	7	7	0	0	0	*
7	10-12	Plumbing for slab	1	7	7	8	8	0	0	0	*
8	10-14	Formwork for slab	1	7	8	8	9	1	1	1	
9	12-14	Reinforcement	1	8	8	9	9	0	0	0	*
10	14-16	Pour slab	1	9	9	10	10	0	0	0	*
11	16-18	Windows and door frames	2	10	13	12	15	3	0	0	
12	16-20	Brickwork to 1 st floor	7	10	10	17	17	0	0	0	*
13	18-20	Lintels and arches	2	12	15	14	17	3	3	0	
14	20-22	Formwork	3	17	17	20	20	0	0	0	*
15	22-24	Reinforcement	1	20	20	21	21	0	0	0	*
16	22-26	Electrical work (wiring)	1	20	21	21	22	1	1	1	
17	24-26	Plumbing	1	21	21	22	22	0	0	0	*
18	24-54	Drainer	5	21	62	26	67	41	41	41	
19	26-28	Concrete suspended slab	1	22	22	23	23	0	0	0	*
20	26-34	Fence	3	22	30	25	33	8	8	8	
21	28-30	Windows and doors	1	23	24	24	25	1	0	0	
22	28-32	Complete brickwork	4	23	23	27	27	0	0	0	*
23	30-32	Arches and lintels	2	24	25	26	27	1	1	0	
24	30-34	Driveway	1	24	32	25	33	8	8	7	
25	32-34	Roof	6	27	27	33	33	0	0	0	*
26	34-36	Roof plumbing	2	33	33	35	35	0	0	0	*
27	34-38	Electrical work (wiring)	1	33	36	34	37	3	3	3	
28	36-38	Roof cover	2	35	35	37	37	0	0	0	*
29	36-40	Roller door	1	35	39	36	40	4	4	4	
30	38-40	Plasterer float	3	37	37	40	40	0	0	0	*
31	40-42	Ceiling	4	40	40	44	44	0	0	0	*
32	42-44	Cornice	3	44	44	47	47	0	0	0	*
33	44-46	Plaster set	3	47	47	50	50	0	0	0	*
34	46-48	Tiler	6	50	59	56	65	9	0	0	
35	46-50	2 nd fixing	5	50	50	55	55	0	0	0	*
36	46-52	Balustrade and shower	1	50	65	51	66	15	6	6	
37	48-52	Plumber	1	56	65	57	66	9	0	0	
38	50-54	Painter	12	55	55	67	67	0	0	0	*
39	52-54	Electrician finish	1	57	66	58	67	9	9	0	
40	54-56	Clean up	3	67	67	70	70	0	0	0	*



Smith residence

Constants and quantities sheet for: Smith residence							
Activity	Unit	Qty	Constant	Hrs (8 hr day)	Man days	Dura- tion	Resources
Preliminaries (permits, approvals, order material, erect sheds, signs, water peg)	-	-	-	30		2	
Excavator and site works							
Site clearing	m ²	1000	0.05 hrs per m ²				
Excavations	m ³	14	3.6 hrs per m ³				
Filling	m ³	21	1.7 hrs per m ³				
Concretor							
Footings	m ³	10	2.8 hrs per m ³				
Slab	m ³	19	2.2 hrs per m ³				
Slab to upper floor	m ³	11	3.7 hrs per m ³				
Driveway	m ³	3	1.5 hrs per m ³				
Reinforcement – fabric	m ²	390	0.04 hrs per m ²				
Bars – stairs	T	1.2	2.5 hrs per T				
Bricklayer							
Up to DPC	m ²	20	} 1 bricklayer 1.0 hr per m ² } 1 labourer 0.5 hrs per m ²				
Up to 1 st floor level	m ²	390					
Up to plate height	m ²	270					
Arches and beams	No.	7	0.3 hrs each				
Pre-cast concrete balustrades	m	10	2.6 hrs per m				
Mason							
Stone retaining wall	m ³	35	3.4 hrs per m ³				
Metal worker							
Lintels and arches bars	T	0.8	7.2 hrs per T				
Metal windows	No.	15	1.6 hrs each				
Metal door frames	No.	18	1.0 hr each				
Balustrade	m	10	2.2 hrs per m				
Shower screens	No.	1	6 hrs				
Roll-a-door	No.	1	4 hrs				
Carpenter							
Formwork	m ²	110	0.6 hrs per m ²				
Roof framing	m ²	210	1.0 hr per m ²				
Cement fibre linings	m ²	80	0.3 hrs per m ²				
Corrugated cement fibre fencing	m	30	0.8 hrs per m				

Constants and quantities sheet for: Smith residence							
Activity	Unit	Qty	Constant	Hrs (8 hr day)	Man days	Duration	Resources
Doors	No.	26	2.5 hrs each				
Skirting	m	320	0.05 hrs per m				
Cupboards	No.	12	1.6 hrs each				
Shelving	No.	20	0.8 hrs each				
Roofer							
Terracotta tiles	m ²	237	0.2 hrs per m ²				
Roof plumber							
Gutter	m	70	0.3 hrs per m				
Downpipes	m	35	0.2 hrs per m				
Flashings	m	18	1.0 hr per m				
Electrician							
Points	No.	52	1.0 hr per point				
Fixtures	No.	52	0.5 hrs per fixture				
Plasterer							
Float	m ²	440	0.25 hrs per m ²				
Set	m ²	420	0.25 hrs per m ²				
Send finish render	m ²	60	0.25 hrs per m ²				
Skim coat	m ²	75	1.0 hr per m ²				
Ceilings							
Gyprock	m ²	88	0.7 hrs per m ²				
Cornice	m	120	1.0 hr per m				
Sanitary plumber							
Fixtures	No.	10	2.0 hrs per fixture				
Hot and cold water	No.	22	2.0 hrs each				
Drainer							
Drains	m	50	1.5 hrs per m				
Paviour and tiles							
Tiles – vinyl	m ²	28	0.6 hrs per m ²				
Tiles – mosaic	m ²	17	2.0 hrs per m ²				
Tiles – wall	m ²	28	10.0 hrs per m ²				
Painter							
Prime	m	920	0.3 hrs per m				
Under	m	920	0.3 hrs per m				
Finish	m	920	0.3 hrs per m				
Narrow width	m	420	0.5 hrs per m				
Clean up	item		24 hrs				

Preparing the chart

The following is a suggested sequence for preparing a Gantt chart for a project, using the Smith residence as an example.

Start by filling in the required information for the title block. Once this is completed, it is necessary to collate the items to be included in the body of the chart. The items to be listed in the 'Operation' column are those which are extracted from the main headings on the quantities summary and labour constants sheets. Take the first operation, for example 'Preliminaries', and place it in the 'Operation' column. Refer to the network and/or analysis sheet and select the arrow number which has been allocated to the activity and place it in the 'Arrow' column adjacent to the activity it represents. Note also that the extreme left-hand column needs to be completed – this records the actual number of activities/arrows.

Next, move to the 'Section' column. Under this heading, list all of the activities related to each item in the 'Operation' column – for example, next to 'Concretor', which begins with arrow number 8–10, insert the first activity relating to the concretor, which is 'Reo and footings'. Beneath that activity, insert 'Slab' (which is arrow 14–16). Notice that the arrow numbers are not in any sequence.

Continue with this process until all the information has been recorded in the columns discussed to this point.

The next stage is to establish the time schedule in the 'Duration' columns.

Starting with Activity 0–2, place a horizontal line, beginning on the first day and extending across the number of columns equivalent to the time required to perform this activity. The model being used shows the duration as two days. Fill in the remaining durations using the network and schedule as your guide.

When checking the 'start' times for each activity as entered on the analysis sheet, use the earliest start time for each activity.

Note: If an activity possesses an *early* start time of, say, Day 4 (eg 'fill and compact' – Activity 4–8 on the Smith CPN), it is important to count off four columns and start drawing the bar in the fifth column. This procedure will ensure that the project will be completed on Day 70.

Important rules to consider are:

1. Activities leaving the same node, that is those having the same tail number, should begin at the same time, irrespective of their listed position in the 'Section' column. For example, Activities 4–6 and 4–8 should be programmed to start at the completion of Activity 2–4. Activity 6–22 is scheduled to begin when 4–6 is completed and Activity 8–10 is scheduled to start when 4–8 is completed. Keep a constant check to ensure that activities with the same tail number are programmed for the same starting date and that each following activity does not begin before its preceding activity has been completed.
2. There should be no 'idle' days between activities; that is to say, something should occur on each *working* day.
3. If it is required to 'highlight' the critical path on the chart, the use of a different

colour or some other identifying means may be adopted.

4. The total duration shown on the completed chart should correspond with the time specified to complete the project, in this instance, 14 weeks or 70 *working days*.

The legend

To help project administrators schedule the necessary resources for the various activities involved, a legend is often prepared and used in conjunction with the chart. The legend lists the resources required under major headings. Each item listed is allocated a symbol for identification purposes. Symbols are positioned on the chart to indicate when and for how long particular resources are required on site.

The legend in the Smith residence example selects the resources of plant and material to illustrate the principle involved. The symbols used for materials are the numbers 1 to 5, while letters of the alphabet represent items of plant. Only a portion of the resource requirements has been included on the chart, but it should be sufficient to enable an understanding of the principle. Where plant or machinery is required for an activity, the relevant symbol or symbols are placed close to the activity line to indicate the time required on site. The symbol/s are also placed in the appropriate resource column/s adjacent to that activity.

Determining the critical path

Brief consideration will now be given to the method of establishing the critical activities on a Gantt chart, using information from the service station example discussed earlier (in Chapters 10 and 12). Figure 13.3 shows a Gantt chart for the service station.

The critical activities must obviously be on a path somewhere between the first and last activities. These critical activities can be found either by working from the right-hand side of the chart to the left or vice versa. Using the service station Gantt chart, project upwards from Activity 38–40 until it meets the furthest right-hand point of an activity whose head number matches its tail number – which, in this instance, is Activity 36–38. Project upwards again until the tail number 36 of Activity 36–38 meets the furthest right point of an activity with a head number of 36, in this case Activity 34–36. Continue with this procedure until the first activity in the network, that is Activity 0–2, is reached. This will show that the critical activities for the service station are 0–2, 2–4, 4–24, 24–32, 32–34, 34–36, 36–38, 38–40.

By reversing the above procedure, the critical path can be established working from left to right.

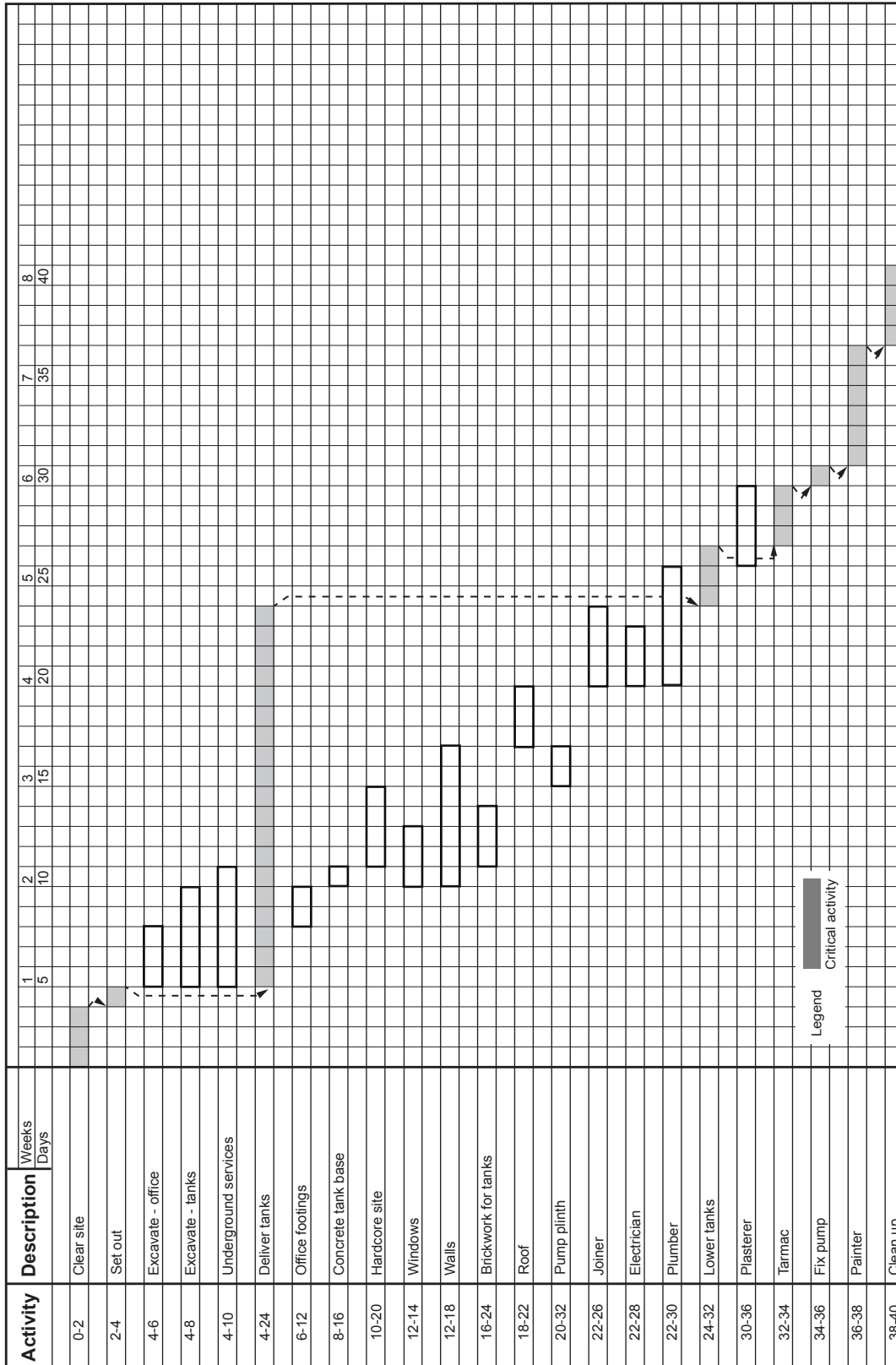


Fig 13.3 Simplified Gantt chart for the service station

Float

As you will remember from an earlier chapter, float represents the amount of 'spare time' that non-critical activities possess and it allows them to begin after their planned early starting time without delaying the start of a succeeding activity or extending the completion date of the contract.

The method of calculating float is identical to that of establishing floats for a network. Often a network is prepared, complete with all necessary information, including float factors, and then it is converted to a Gantt chart.

Whether or not the activity floats are highlighted on the chart is optional. The inclusion of available float for non-critical activities assists the project manager with their programming by clearly indicating the manoeuvrability available within the project program. One method of highlighting float is to extend a broken line from the earliest finishing time for an activity and terminating it with an asterisk which denotes the latest possible finishing time (see Figure 13.4).

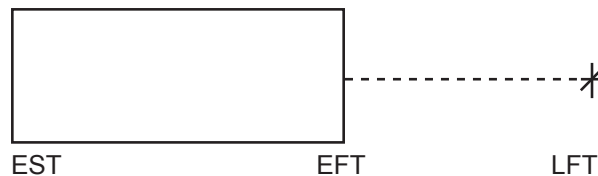


Fig 13.4

A disadvantage of showing float on charts that will be viewed by the site workforce is that it may provoke operatives such as subcontract teams to reschedule their workload and undertake additional work on other sites, which on occasions could lead to an unnecessary delay in starting activities, resulting in them becoming critical or, worse still, causing the project to fall behind schedule.

Conclusion

Although it possesses intrinsic weaknesses, the Gantt chart still has a very important part to play as a management tool for both planning and controlling. Its visual clarity and ease of understanding make it a valuable medium for summarising complex networks, displaying project scheduling information and affording an easy and convenient way to monitor progress.



Chapter 14

Resources

Introduction

A condition of most major contracts is that the project be completed on time and to the tendered cost. This necessitates careful planning by the contract team. Preceding chapters have covered the use of network diagrams and bar charts as management tools which are readily adaptable to logic planning, establishing time estimates and for scheduling purposes.

Resource scheduling

Resource scheduling is designed to provide effective work schedules and efficient use of resources. Poor work schedules usually result in poorly used resources and increased costs. In the most general sense, a resource can be considered as anything which is necessary to complete the performance of an activity, other than its technological relationship to other activities as indicated in a prepared network. Typically, these resources include labour, plant, materials, finance, time and space.

When it is first prepared, the network diagram shows relationships only and depicts no resource restraints whatsoever. A comprehensive analysis of resources and subsequent scheduling is required to produce a meaningful result. To achieve this, the planning team needs to be conscious of what is *practical*, *economic* and *realistic*.

It is important to establish from the outset whether a project is to be time-limited or resource-limited, and the implications this will have on planning.

Time-limited scheduling

This assumes that all the resources necessary to complete a project are unlimited in quantity and therefore available as and when required. The activities are scheduled to ensure that the project completion date is met, even though certain resources may be overloaded.

This method of scheduling is uneconomical because of ramifications arising from the constant movement of resources to and from the site as the demands change. Undesirable peaks of resources may occur at many points in the program and additional administrative burdens are created by the increased documentation necessary to record the various changes.

Resource-limited scheduling

This acknowledges that restraints on resources exist for specific projects. This approach requires resources to be scheduled in such a manner that available levels are never exceeded. If insufficient resources are available, the completion date of the project will need to be extended. Sometimes, to obtain a better balanced schedule, an activity may be split, though this should only be done when resource limits are extremely tight. Similarly, two activities may be scheduled non-consecutively.



In developing a program of work, the durations and resources required are totally dependent on each other. The time needed to complete an activity is dependent upon the resources being available as and when required. The shorter the time for performance, the greater will be the resource requirement. Where resource levels are excessive, a revision of the activity list and network logic may be necessary.

The resource scheduling process may be thought of as the imposition of resource restraints on activities in the network; this keeps resource usage within acceptable limits, while still preserving a total duration that is acceptable.

When scheduling resources, it is important to establish:

- the resources required for each activity
- the resources available to the project as a whole
- management impositions to be observed during scheduling.

Assessing resources

In practice, all projects are both 'time-limited' and 'resource-limited'.

We must now consider the basic steps for assessing resources using the commonly adopted techniques of *resource aggregation* and *resource levelling*. For simplicity, a single resource, labour, will be considered. It should be borne in mind, however, that more than one type of resource is usually necessary to complete a task.

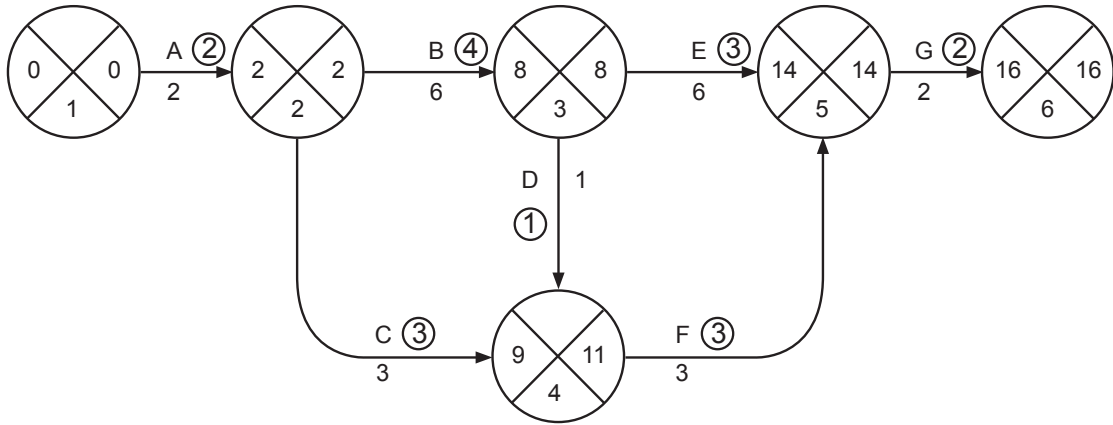
Resource aggregation

Resource aggregation is simply a period-based summation – using days, weeks or months etc – of the resources which are considered necessary to carry out the program.

This can be easily achieved by adding resource requirements to a chart and totalling each column to provide a resource aggregate for each time period. Histograms and frequency polygons, when used in conjunction with bar charts, provide management with a visual appreciation of the fluctuation of resource levels. The most common forms of resource aggregation are:

- aggregation by earliest start time
- aggregation by latest start time.

To explain both forms of aggregation, the arrow diagram network below (Figure 14.1) has been prepared as a basis for discussion. The activity schedule shows starting and finishing data, together with the float and resource availability, for each activity. This information is used to prepare the bar chart (Figure 14.2), which includes the labour aggregation along the bottom of the chart.



Resource availability = ○

Fig 14.1 Arrow diagram including labour resources

Activity schedule									
I-J	Activity description	Duration	Early start	Late start	Early finish	Late finish	Total float	Free float	Resource level
1-2	A	2	0	0	2	2	0	0	2
2-3	B	6	2	2	8	8	0	0	4
2-4	C	3	2	8	5	11	6	4	3
3-4	D	1	8	10	9	11	2	0	1
3-5	E	6	8	8	14	14	0	0	3
4-5	F	3	9	11	12	14	2	2	3
5-6	G	2	14	14	16	16	0	0	2

Arrow	Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1-2	A	<u>2</u>	<u>2</u>														
2-3	B			<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>								
2-4	C			<u>3</u>	<u>3</u>	<u>3</u>											
3-4	D									<u>1</u>							
3-5	E									<u>3</u>	<u>3</u>	<u>3</u>	<u>3</u>	<u>3</u>	<u>3</u>		
4-5	F										<u>3</u>	<u>3</u>	<u>3</u>				
5-6	G															<u>2</u>	<u>2</u>
		(- →* - float)															
Labour aggregation		2	2	7	7	7	4	4	4	4	6	6	6	3	3	2	2

Fig 14.2 Bar chart showing labour resources and aggregation

Aggregation by earliest start time

This form requires that all activities be scheduled to start at their earliest possible time, regardless of the resource levels available to the project. This type of scheduling yields an inflationary cost curve, as some work would be performed earlier than necessary, but the risk of failing to meet the scheduled completion date is minimised. The histogram (Figure 14.3) indicates the resource load pattern. Where management is uncertain about the level of resources to be made available, aggregation using both early and late start times is useful since it indicates the maximum and minimum levels from which an average level can usually be estimated.

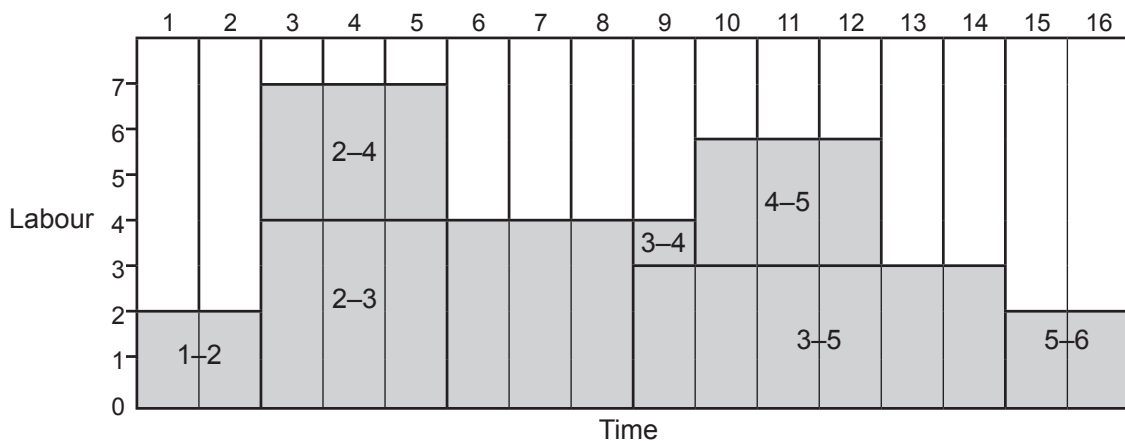


Fig 14.3 Labour aggregation using early start time

Aggregation by latest start time

In this form, all activities are scheduled to begin at the latest possible start time without delaying the project completion date. Again the resources available to the project are not taken into consideration at this stage. In this form, every activity becomes critical and there is a high risk of not meeting the scheduled completion target. The cost outlay is minimised, though the load pattern would be unacceptable in many instances. The histogram (Figure 14.4) illustrates an example of this form of load pattern.

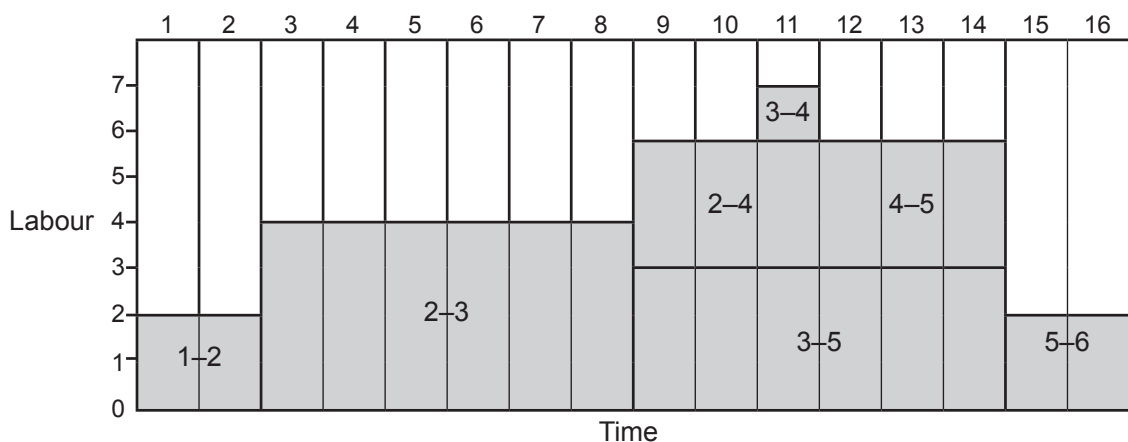


Fig 14.4 Labour aggregation using late start time

Resource levelling (resource smoothing/resource balancing)

Most projects are subject to resource limitations and, in some cases, these are severe. This increases the need to achieve a high level of utilisation of these resources.

The process of resource levelling allows adjustments to be made to the project based on the availability of a set of resource items, and is designed to avoid possible conflict of resource usage within the project. If the combined usage of a group of activities exceeds the daily availability of the specified resources, some activities will need to be delayed until the resource becomes available.

Reasons for levelling:

1. Levelling provides a means of securing maximum usage of resources by securing continuity of use within an established program sequence.
2. Site and welfare items, such as canteen, toilet and first aid facilities, may only be sufficient to support a certain number of workers at any one time.
3. It may be difficult to maintain adequate levels of supervision if resources fluctuate greatly.
4. Adequate materials storage and supply are more easily sustained if worker and plant levels remain reasonably constant.

When a resource aggregation chart shows that the resource requirement exceeds the available limits, or there are undesirable peaks at a number of points in the contract, it will be necessary to reassess the project program in order to provide a more effective work schedule and to make efficient use of the available resources. By starting at a point where an assumption is made that resources are unlimited, the problem can be viewed in its raw state. Then, by including the obstacles one by one, the situation which actually exists will eventually be arrived at. Thus, assumptions about resource usage will have been made and priorities established.

The demand for resources should be as even as possible over the total contract period, with a gradual increase in resource requirements in the early stages and a smooth tapering off of them towards the end. The terms often used to describe this process include 'levelling', 'balancing' or 'smoothing'. In this text, *levelling* will be used.

The levelling of resources is seldom perfect, but it is necessary to strive for a solution as near the optimum as possible.

Levelling process

The resource aggregation chart is a key feature of the levelling process, resource levels being plotted vertically and units of time horizontally. When using the aggregation chart to establish resource levels, enter the critical activities first to give the project direction and then enter the non-critical activities using their earliest start time. This often produces an uneven balance, as shown in Figure 14.3.

The levelling process involves considering the optimum allocation of resources against a three-point set of priorities once the critical activities have been plotted. The priorities are as follows:

1. Work through the resource aggregation chart systematically, considering activities in order of their earliest start date.
2. Activities with the least total float should be considered before activities with a lot of float.

3. Should a further priority be required, the activity with the least free float should be considered.

The following network diagram will now be developed to investigate the levelling process using the priority sequence listed above.

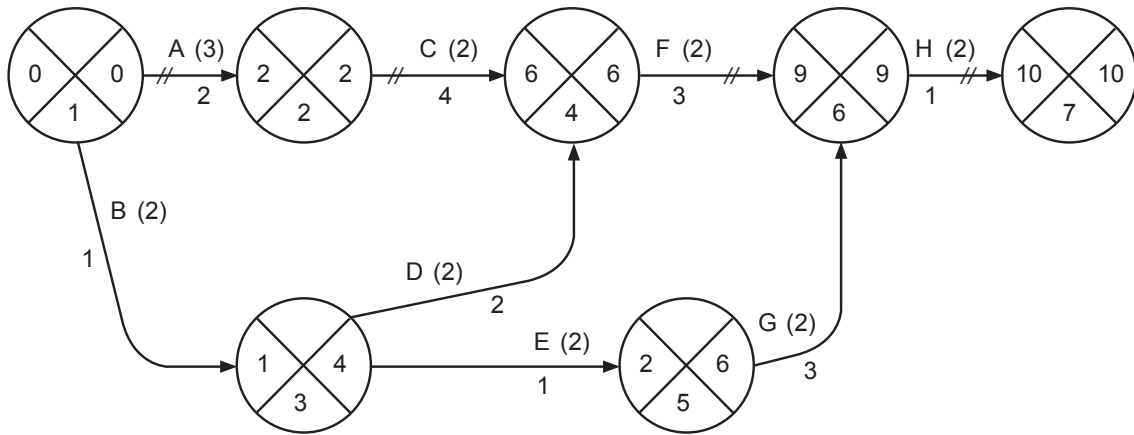


Fig 14.5

Below is the activity schedule for the network shown in Figure 14.5.

Activity schedule									
I-J	Activity description	Duration	Early start	Late start	Early finish	Late finish	Total float	Free float	Resource level
1-2	A	2	0	0	2	2	0	0	3
1-3	B	1	0	3	1	4	3	0	2
2-4	C	4	2	2	6	6	0	0	2
3-4	D	2	1	4	3	6	3	3	2
3-5	E	1	1	5	2	6	4	0	2
4-6	F	3	6	6	9	9	0	0	2
5-6	G	3	2	6	5	9	4	4	2
6-7	H	1	9	9	10	10	0	0	2

I-J	Activity description	1	2	3	4	5	6	7	8	9	10	11	12
1-2	A	<u>3</u>	<u>3</u>										
1-3	B	<u>2</u>	—	—	—	*							
2-4	C			<u>2</u>	<u>2</u>	<u>2</u>	<u>2</u>						
3-4	D		<u>2</u>	<u>2</u>	—	—	—	*					
3-5	E		<u>2</u>	—	—	—	—	*					
4-6	F							<u>2</u>	<u>2</u>	<u>2</u>			
5-6	G			<u>2</u>	<u>2</u>	<u>2</u>	—	—	—	—	*		
6-7	H										<u>2</u>		
	Resource level	5	7	6	4	4	2	2	2	2	2		

Fig 14.6 Resource schedule

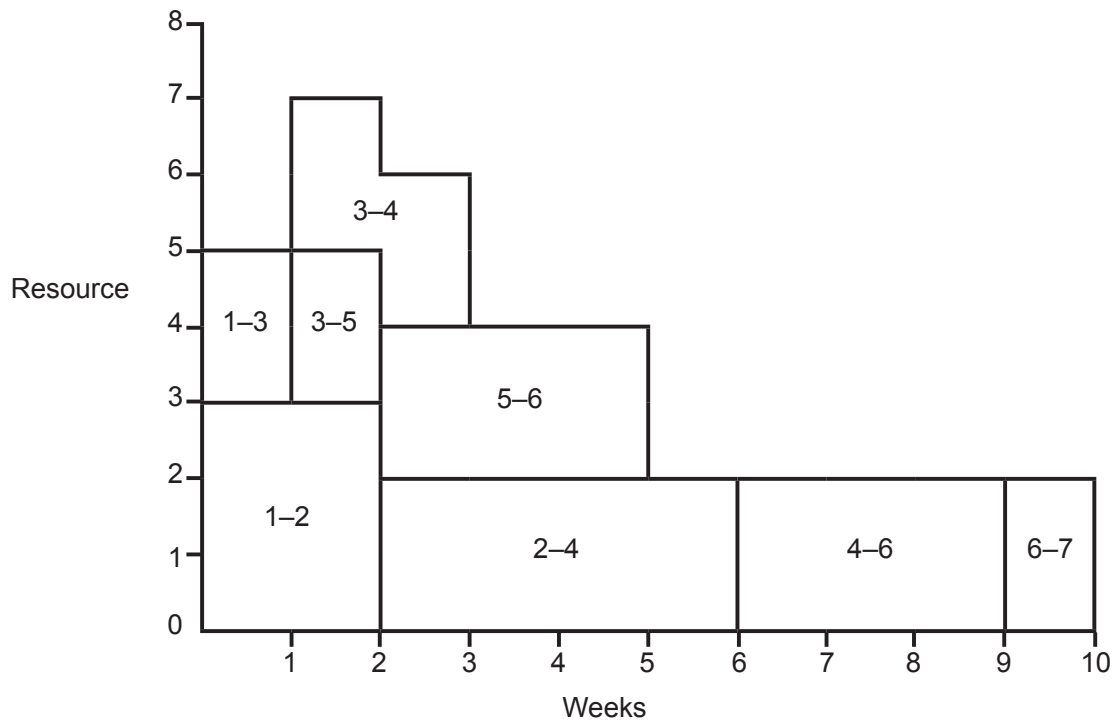


Fig 14.7 Resource aggregation chart

From the resource schedule (Figure 14.6) and the resource aggregation chart (Figure 14.7), it can be seen that a fairly varied resource level exists, peaking at seven in the second week and falling to two over the last five weeks. As this is not an ideal situation, it is necessary to consider ways to improve the use of resources. The solution lies in the utilisation of the float available to some of the activities.

Using float allows an activity to be moved to a different time period without changing the activity's duration. It is important to note that an activity with a total float but no free float cannot be moved without affecting at least one other activity.

If we place a maximum resource limit of five on the project, the resource chart needs to be examined to determine whether this is possible without extending the completion date. The activities with float can be moved according to the priority rules established earlier but critical activities cannot be moved without affecting the project duration. The first step is to plot the critical activities on the resource chart as shown in Figure 14.8.

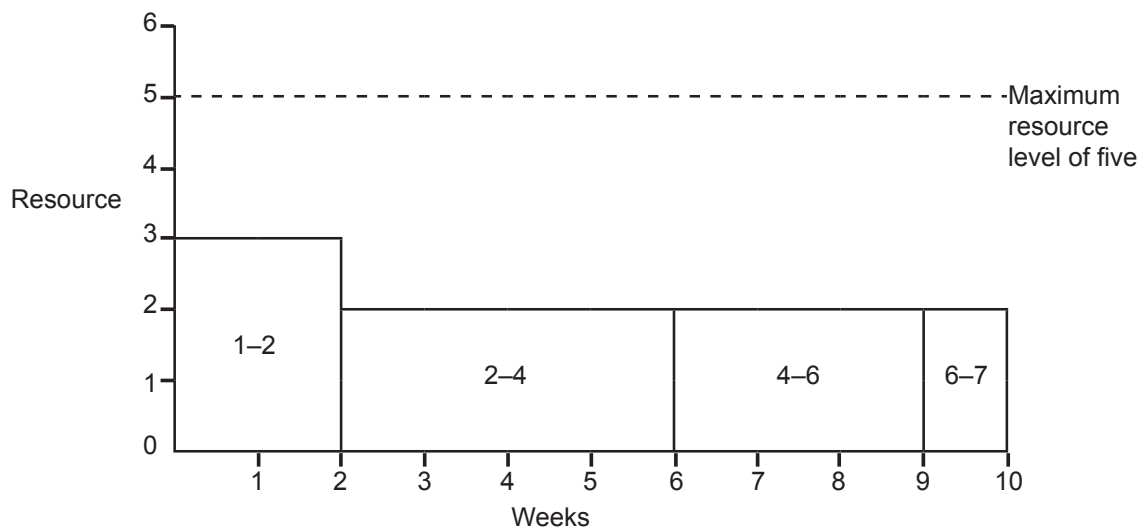


Fig 14.8 Critical activities

The non-critical activities can now be added to the chart in the order of the selected set of priorities. In this example, the priority order is early start, total float and then free float. The resource schedule shows that Activity 1-3 is the only non-critical activity to be plotted on the chart in Week 1. Next, there are two activities (3-4 and 3-5) which start from Week 1. Figure 14.7 shows that, if they are plotted together, the resource limit will be exceeded. Because Activity 3-4 has a lower total float than Activity 3-5, it has priority on the chart. The only other non-critical activity remaining is Activity 5-6, which has an early start time of Week 2. If this activity were to begin at its earliest start time, the resource level would be exceeded. Therefore, the earliest that Activity 5-6 can start is immediately after the completion of Activity 3-5. Figure 14.9 shows the activities plotted according to the priority rules so that the resource level of five is not exceeded.

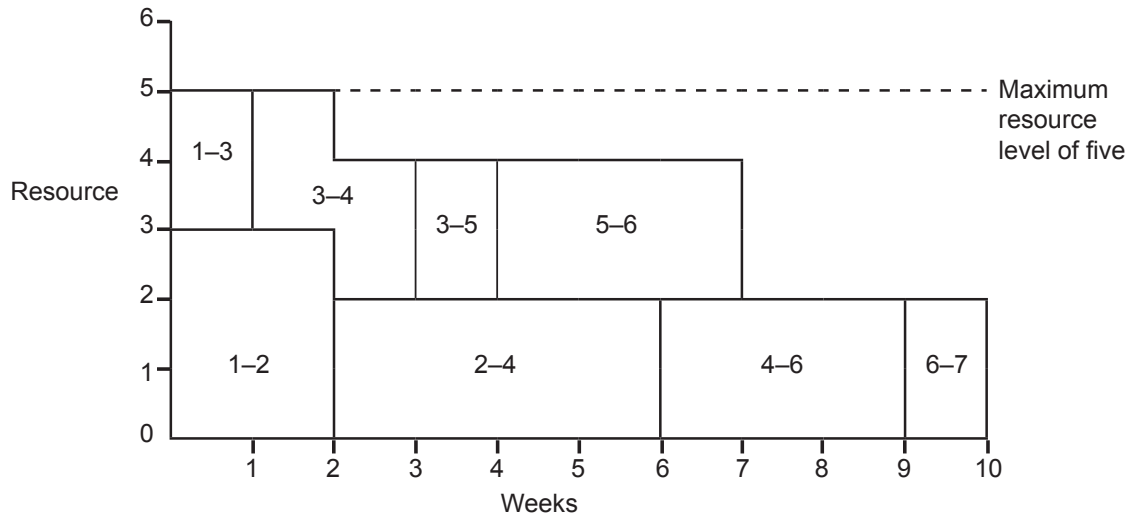


Fig 14.9

A further investigation using the same priority rules will show that the resource level for this project can be reduced to four without causing the project duration to be extended. Figure 14.10 shows the priority sequence for plotting the activities using the available float so that a resource level of four is achieved without affecting the project's estimated time for completion or the logic of the network.

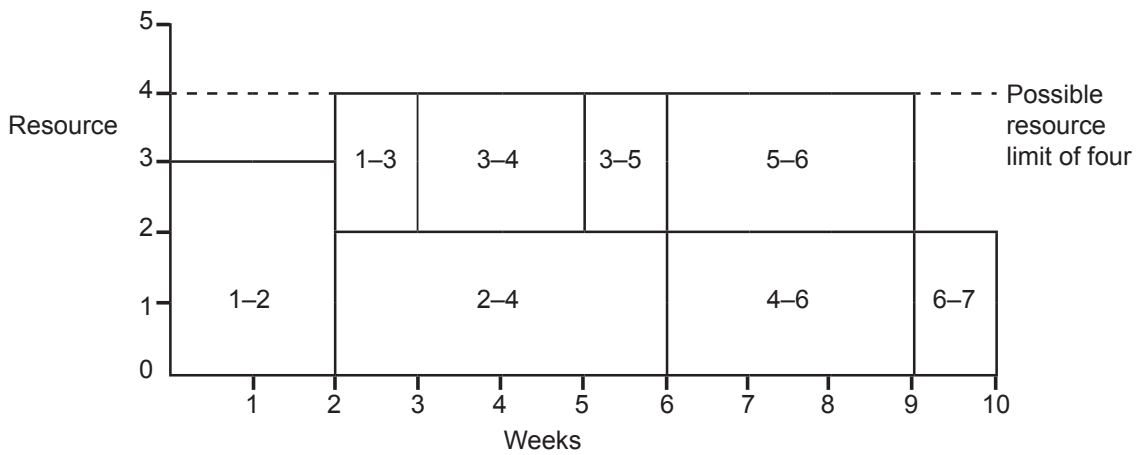


Fig14.10

If resource levelling is taken to the extreme, it must be realised that much of the float time associated with non-critical activities will be surrendered. Resource levelling always reduces the available float time, resulting in a possible increase in the number of critical activities.



Summary

The principles and techniques of resource allocation and resource levelling discussed in this chapter have been based on a manual presentation and calculation. The examples used have deliberately been kept to the use of one resource to maintain simplicity.

Where, as is usually the case, more than one resource is involved, the same principles and techniques can be adopted. For larger projects, sophisticated computer programs have been written to cater for a diversity of requirements – including, among many variations, splitting an activity, working within resource or time restraints and production of aggregation summaries within trades or total aggregation figures.

INTRODUCTION TO SITE MANAGEMENT DIPLOMA OF BUILDING AND CONSTRUCTION CPCBC5003A

LEARNER'S GUIDE

DESCRIPTION

This resource provides an overview of construction management at what might be described as three levels. An outline of management contracting is followed by more detailed consideration of two very practical aspects of construction management, organisation and control at site level and the use of critical path network planning and its derivatives to establish project programs. As an adjunct to the latter, the final chapter looks at resource scheduling.

This revised text provides an excellent overview for those who may be charged with management – at site level – of a building project, particularly in the commercial/industrial sector. As such, it is especially suitable for use in the *Diploma of Building and Construction (Building) (Builder's Registration)* course and other courses of similar academic standard.

COURSE/QUALIFICATION

Diploma of Building and Construction (Building) (Builder's Registration)

UNIT OF COMPETENCY

- CPCBC5003A (State code W9290) – *Supervise the planning of on-site medium-rise building or construction work*



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