MODERN CONSTRUCTION PROJECT MANAGEMENT

Second Edition

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1 PRINCIPLES OF ORGANIZATIONAL STRUCTURES

1. Introduction

An organizational structure involves a group of people among whom there are interaction, communication and coordination. There is usually an objective which the organization aims to achieve under a set of constraints. For example, a contractor's site organization has the objective of completing the works assigned to him, and the constraints are raw material supplies, labour supplies, finance and so on.

There are three principal types of organizational structures:

1. project organization
2. functional organization
3. matrix organization

2. Project Organization

In a project organization, each member of the team is responsible for a particular task. It is therefore task-oriented. An example of project organization is a highway project (Fig. 1.1) which consists of tunnelling, building and road works.

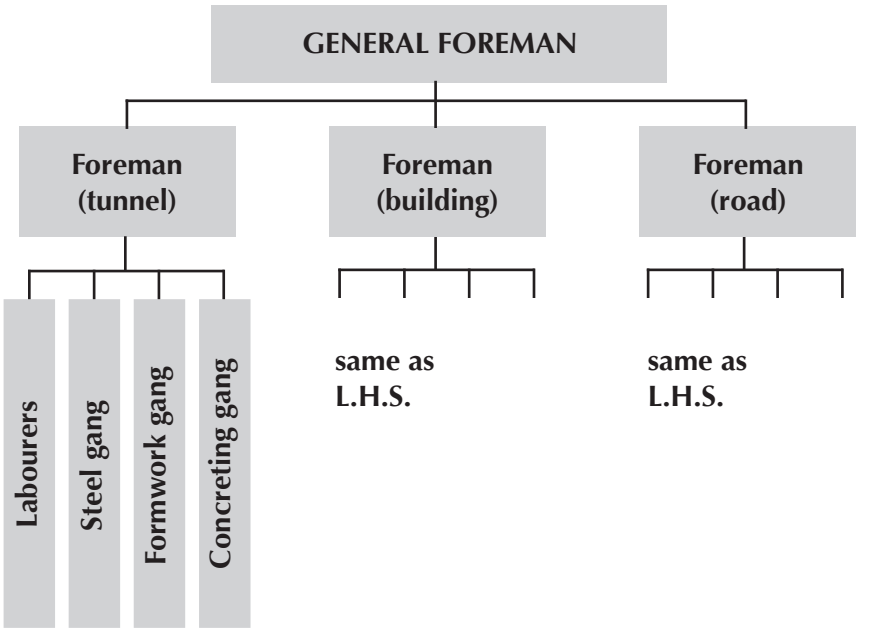

Fig. 1.1 Example of a project organization.

This form of organization has the merit of simplicity — each person is clearly instructed in his duty and authority. The disadvantage is that it sometimes does not fully utilize the resources available for each task. For example, the concreting gang attached to the tunnel section does not work in the building section even thought it is idle at times. The merits and demerits of a project organization will be further discussed in section 4 of this chapter.

3. *Functional Organization*

In contrast to the project organization (which is task-oriented), a functional organization is specialist-oriented. Specialists in each field are responsible for their own functions. An example of functional organization is shown in Fig. 1.2.

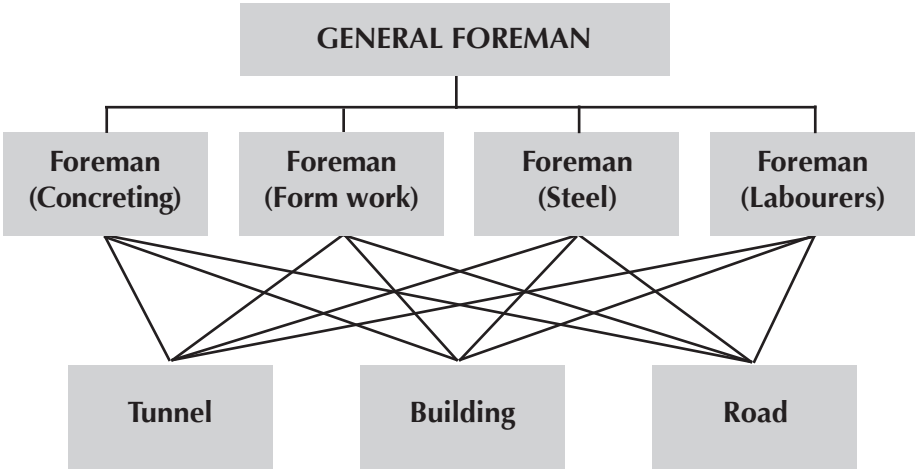

Fig. 1.2 Example of a functional organization.

From the organization chart (Fig 1.2), one can see that each foreman is responsible for carrying out work within his own specialism, e.g. for concrete work, steel work and so on. Each specialist contributes to the construction of tunnel, building and road works.

4. *Advantages and Disadvantages of Project Organization and Functional Organization*

4.1 A comparison of the characteristics of the two forms of organizations is shown in Table 1.1.

Characteristics	
Project organization	**Functional organization**
♦ Branch heads are generalists.	♦ Branch heads are specialists.
♦ Suitable for works which must be completed in a specific time.	♦ Suitable for works which run from calendar year to calendar year.
♦ Suitable for dynamic works.	♦ Suitable for routine works.
♦ Suitable for relatively small organizations.	♦ Suitable for large organizations.

Table 1.1 Comparison of characteristics of project organization and functional organization.

4.2 There are some aspects in which the project organization is better than the functional organization. They are shown in Table 1.2.

Advantages of project organization over functional organization	
Project organization	**Functional organization**
♦ Fast decision, due to simple and clear lines of duty and responsibility.	♦ Bureaucratic, probably due to protectionism between specialist branches.
♦ More innovative, since problems are usually solved on the spot or within a branch.	♦ Less innovative, since functions are separate and problems must be referred to the relevant branches.
♦ Very efficient in achieving specific target.	♦ Less efficient in achieving target.

Table 1.2 Aspects in which project organization is more advantageous than functional organization.

4.3 There are also aspects in which the functional organization is better than the project organization. They are shown in Table 1.3.

Advantages of functional organization over project organization	
Project organization	**Functional organization**
♦ More expensive, because resources are sometimes not fully utilized.	♦ Less expensive, because there is less wastage in utilizing resources.
♦ Less chance for staff development on special knowledge or skill.	♦ More chances for developing special knowledge or skill.

Table 1.3 Aspects in which functional organization is more advantageous than project organization.

5. Matrix Organization

A matrix organization is a combination of project organization and functional organization. Fig. 1.3 shows an example of a matrix organization. One can see that the labourer foreman (functional) is at the same level as the other project foremen.

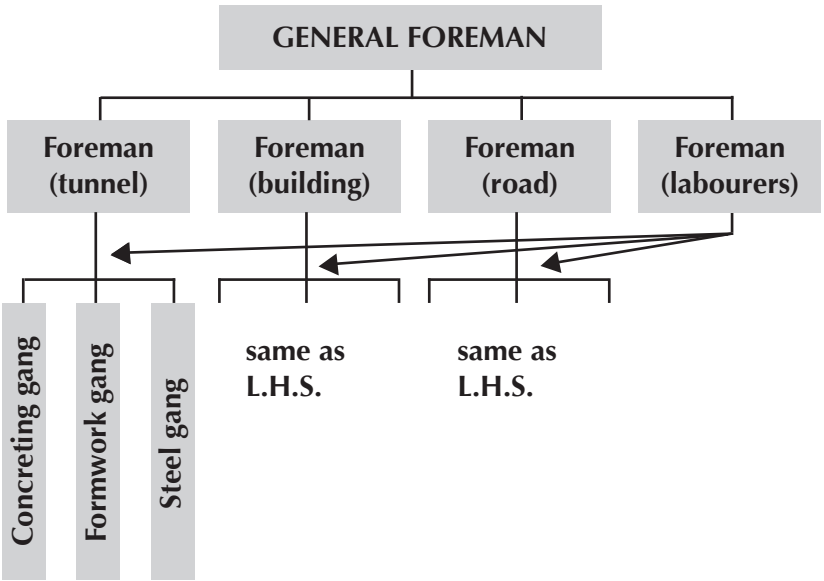

Fig. 1.3 Example of a matrix organization.

In this case, the project foremen do not have their own labourers. All labourers are supplied by a functional foreman who is at the same level/rank as the project foremen.

Sometimes, an organization can be purely matrix. Fig. 1.4 shows an example of a purely matrix organization. In this purely-matrix organization, the project foremen do not have working gangs of their own. All resources are supplied by the functional foremen.

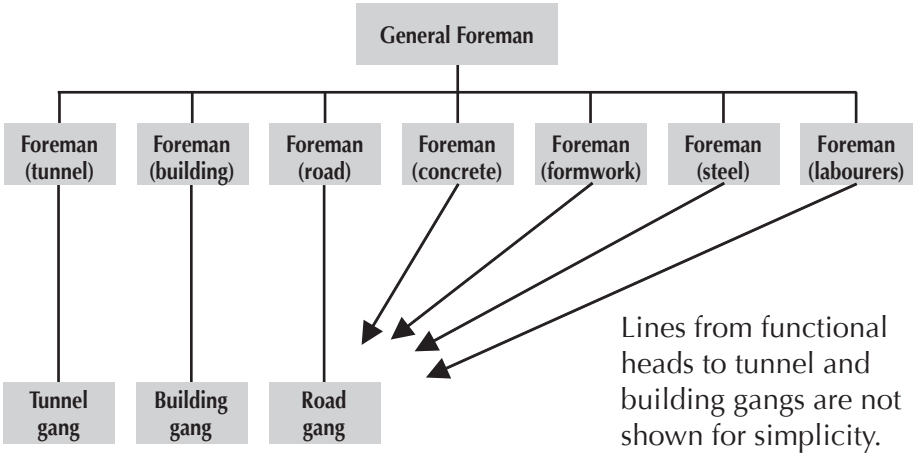

Fig. 1.4 Example of a purely matrix organization.

The purely matrix organization shown in Fig. 1.4 is usually represented by a diagram which looks like a matrix (Fig. 1.5). The horizontal lines represent functional responsibilities and the vertical lines represent project responsibilities.

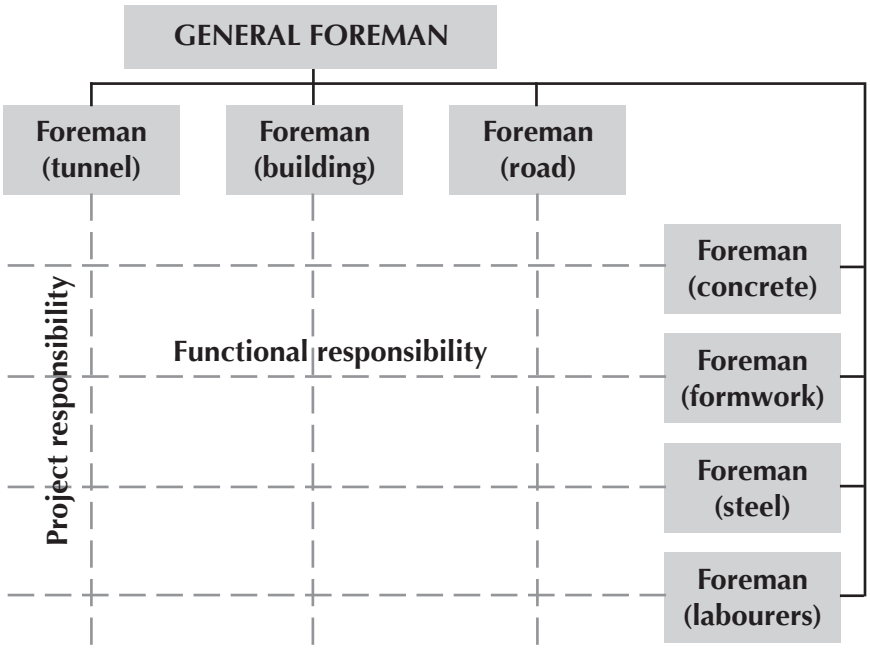

Fig. 1.5 A typical matrix organization.

The matrix organization has the advantages of both the project and the functional organizations. It attempts to optimize the efficiency of an organization in a particular environment and for a particular objective. However, there is a disadvantage in a matrix organization: one person may work under two bosses. For example, a carpenter working under the formwork foreman, a functional foreman, will also be working under the road foreman, a project foreman (Fig. 1.4). This is acceptable if the relationship between the formwork foreman and the road foreman is good, otherwise a lot of disputes may arise. Of course, the organization chart shows only the formal relationships; valuable informal relationships cannot be seen from the chart. These can increase cooperation within the organization, provided that the formal relationships are not overlooked.

In the next chapter, we will see how these different forms of organizations are applied in contracting and consulting firms.

2

ORGANIZATIONAL STRUCTURES FOR CONTRACTORS AND CONSULTANTS

1. Introduction

This chapter will describe typical organization structures for contractors and consultants in Hong Kong. The organization structures drawn were all derived from real situations after surveying a considerable number of large contractors and consultants. First, the typical organization structure for a large contracting firm's head office will be discussed. Then that of a large consulting firm's head office will be described. A typical contractor's site organization structure will also be presented. Finally, the typical organization of a consultant's site representative, i.e. the resident engineer, will also be discussed.

2. Organization of a Contractor's Head Office

2.1 Six large contracting firms' head office organizations in Hong Kong were surveyed. A typical organization structure was derived and is shown in Fig. 2.1. One can see that it is mainly a matrix organization (section 5 of Chapter 1). Each contracts manager undertakes several projects. Contracts managers are head office based. Under the contracts managers are project managers and site agents who are site based personnel (section 3 of this chapter).

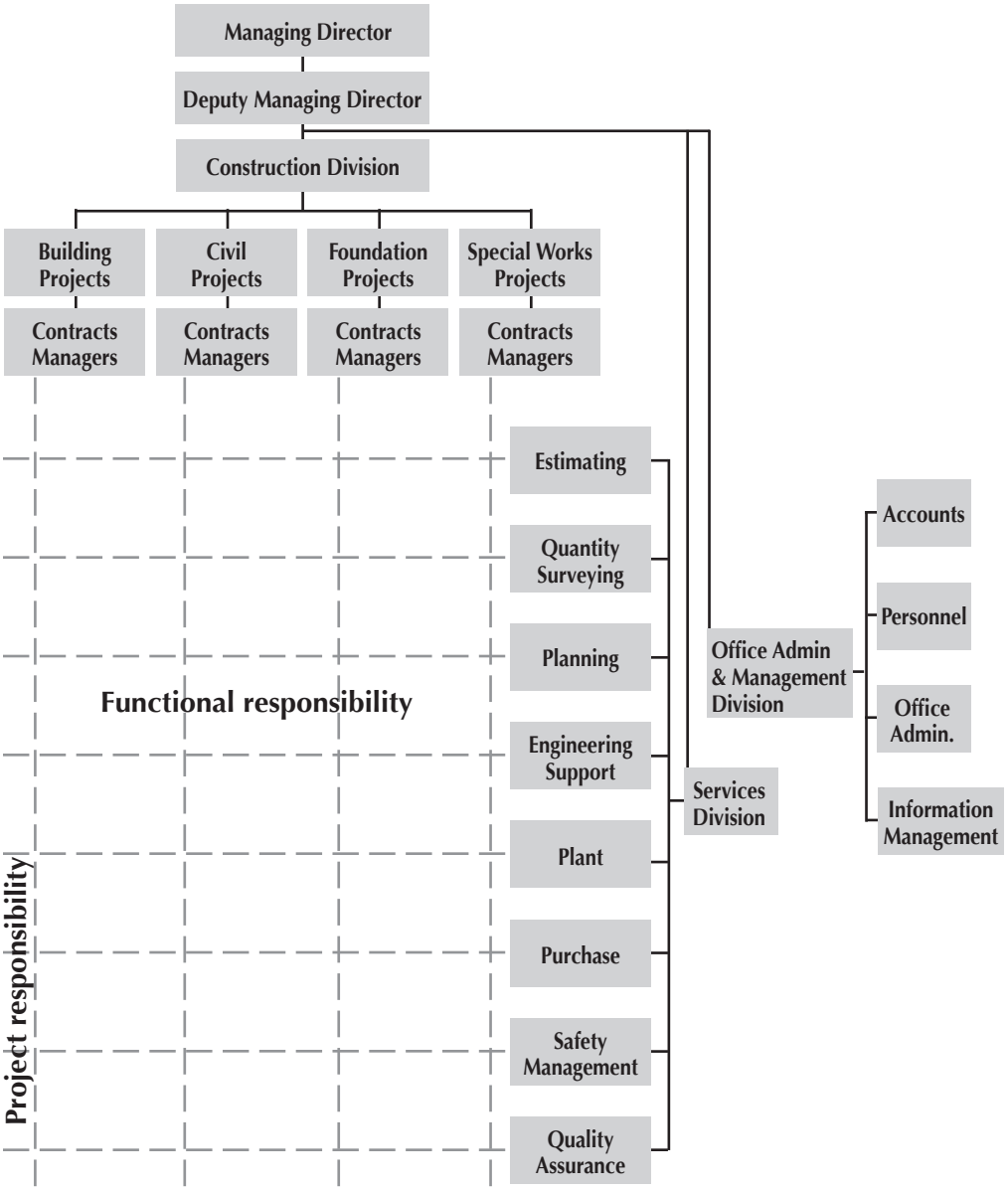

Fig. 2.1 A typical large contractor's head office organization.

2.2 ***The estimating department*** is responsible for preparing tenders for the company. It has to price a ***bill of quantities*** listed in the tender document. When pricing an item of work, it is necessary to consider the constituent parts (i.e. labour, plant, materials and overheads) in the estimation. It is also necessary to determine the parts of work that needed to be subcontracted. Assistance is usually required from the planning department to prepare a preliminary work programme and method statements for submission with the tender (section 2.4). In addition, assistance is needed from the purchase department for obtaining quotations of material supply and subcontracting work (section 2.7). After all items have been priced, the estimates will be forwarded to the company's top management who will add a profit mark-up.

2.3 The ***quantity surveying department*** is responsible for the assessment of work done and the subsequent payments of projects. It is also responsible for variations orders, subcontractor payments and claims for extra work. Another important duty of the department is the requisition of materials to be used in the project; in this respect it has to coordinate with the purchase department (section 2.7). Moreover, the department has to analyse the cash flow associated with the project so that the contractor is aware of his financial requirements. Usually, many of the quantity surveyors in this department are not attached to the head office but are placed on site (Fig. 2.2). The department is quite a big one in terms of the total number of staff. However, a small number of staff is required at the head office to coordinate site-based staff, to work on new projects, and to finish the unfinished works on completed contracts whose site offices have been closed.

2.4 The duty of the ***planning department*** is to plan and coordinate the works so as to make the most economic use of labour, plant and other resources. There are two stages of planning: ***tender planning*** and ***contract planning***. In the tender planning stage, it is necessary to liaise with the estimating department and to provide the latter with a preliminary work programme and method statements (section 2.2). When a tender becomes a contract, it comes to the contract planning stage. It is necessary for the planning department to liaise with the project manager or the site agent and the planning engineer on site (Fig. 2.2) and carry out a detailed contract planning exercise. Detailed work programme and method statements will be established during this stage of the planning exercise. Once the construction work starts, the planning and monitoring of the programme of work will be more in the hands of the site planning engineer.

2.5 The ***engineering support department*** gives technical support to the work sites as well as to the other departments in the head office. It is also involved in the investigation or research work associated with new construction methods or problems of an administrative/managerial nature which are particularly important to the company. Traditionally, the temporary work design, work study and cost control of a project are carried out on site by the site engineer (Fig. 2.2). However, there is a trend towards the centralization of technical functions at the engineering support department in the head office. The reasons for centralization are:

1. standard designs and procedures can be adopted
2. a single technical person/team can serve several sites
3. a head office department can easily access the company's computing facilities for engineering design, cost control and so on, which are usually kept at the head office only

2.6 The ***plant department*** functions as a servicing department in the company, providing plant support to work sites. Its duties are to coordinate all buying, selling and hiring requirements of plant and machinery, to maintain all plant and machinery, and to arrange their transportation to and from construction sites. It is also necessary for the department to liaise with the planning department and the plant engineer on site (Fig. 2.2) giving all information related to plant and machinery during the tender and contract planning stages respectively.

It is normal practice for a contractor to own only those items of plant which are either continuously used or difficult to obtain on hire. However, some very big contracting firms operate their plant department to make profit by letting out plants to other contractors. In such a case, the department usually owns a full range of construction plant. The plant manager (head of this department) will, unlike the former case, report directly to the managing director and works quite independently from the rest of the firm.

2.7 The ***purchase department*** obtains quotations on all materials and subcontractor procurement. At the tendering stage, the purchase department is responsible for liaising with the estimating department so that the necessary cost data are available to the estimator. The department always maintains a full list of the latest costs of materials and subcontracting works and stores it in the firms database. Once a tender is successful, the department will liaise closely with the purchaser on site (Fig. 2.2). Usually, the department invites material suppliers or subcontractors to submit quotations after receiving a

requisition from the quantity surveying department (section 2.3). There are four advantages for centralizing purchases at the head office rather than allowing individual site procurement:

1. a single purchaser can handle purchasing orders for several contracts and so bulk ordering, which is usually cheaper, is possible
2. the purchaser can obtain substantial discounts by building up long-term relationships and purchasing bulk quantities from suppliers
3. implementation of a computerized tendering and standardized cost reporting system is possible when all cost information is centralized
4. administrative support and computing facilities are usually better at the head office

2.8 A ***contracts manager*** is a staff member of the construction division of the company. The department is the most important department in a contracting firm, since the wealth of the company is generated by this department. A contracts manager looks after several projects at any one time. His duties include:

1. advising the project manager/site agent (Fig. 2.2) on how to organize their work in order to obtain maximum productivity
2. coordinating and working in conjunction with other servicing departments in the company
3. attending site meetings
4. liaising with clients

Because of his importance to the firm, a contracts manager can usually make specific demands on other services departments. He is classified as a member of the head office staff although he spends a lot of time visiting sites under his control. He is a middleman between the senior management of the head office and the site staff. His position demands him to be a man of high calibre. Contracts managers usually become top mangers in a contracting firm.

3. Organization of a Contractor's Site

3.1 The organization structures of 12 different contractors' sites in Hong Kong were surveyed. A typical site organization was derived and is shown in Fig. 2.2. This organization chart should be read in conjunction with Fig. 2.1, the typical contractor's head office organization. One should note the relationship between site personnel and head office staff.

In Fig. 2.2, it can be observed that project organization exists in a part of the chart, that is, the relationship between the general foreman and the foremen. Besides this, the whole organization is dominantly functional.

3.2 ***The project manager/site agent*** is the chief person representing the contractor on site. In some relatively small contracts, there is no project manager and the site agent is the top man, whereas in some large contracts, the post of project manager is established and under him is the site agent. The project manager is usually a very experienced person in construction with a very good academic background. The site agent is also a very experienced person but may not have the project manager's very good formal academic background.

Being the chief administrator on site, the project manager/site agent is responsible for directing and controlling all construction work. His main duty is to see that all work is constructed according to the requirements of the contract. As a leader of the construction team he must be able to demonstrate his ability to organize works and to make sound decisions. He should also possess some general sense of how a business is run and how to supervise people.

3.3 The ***works superintendent/general foreman*** is the key person in controlling the execution of works by mobilizing the labour force as required. Normally, the post of the works superintendent is not established unless the contract is a very huge one. A works superintendent/general foreman is responsible for issuing instructions to the foremen working under him. He advises the site agent about the requirement of materials and the plant engineer about the type of plant needed. He spends most of his time visiting every part of the site everyday.

The works superintendent/general foreman usually has extensive practical knowledge in various construction skills although he is usually not very well academically qualified. He is, however, a key person in transforming a set of construction drawings into finished structures. He should have the ability to read from drawings, to demonstrate to ***foremen*** and labourers how the work is carried out and to supervise them accordingly. A general foreman is usually promoted from foreman who have been working on site for a long time and have extensive practical construction experience.

3.4 The ***land surveyor*** is responsible for the setting out works and for making sure that works are constructed at correct levels. The land surveyor and his gangers and chainmen are the people who actually carry out such works. Sometimes, if the quantity surveyor is too busy, the land surveyor may help him in calculating the volume of excavation/ filling for the earthwork part of the contract. He must be a very careful person and must ensure that no mistake is made in setting out or in levelling works. Such accuracy is most important to the contractor as the latter cannot usually afford the financial consequences due to constructing works at wrong positions or wrong levels.

3.5 Other key persons in a contractor's site organization are covered in sections 2.3 to 2.7 of this chapter.

4. Organization of a Consulting Firm's Head Office

4.1 Six large consulting firms' head office organization in Hong Kong were surveyed. A typical organization structure was derived and is shown in Fig. 2.3. It is typically a functional organization (section 3 of Chapter 1). Each director has his own specialism. Besides engineering expertise, a director also looks after one or more areas of management, such as human resources or training, for the company.

4.2 When there is a new project, a design team will be formed. The team leader solicits specialist input from different departments which are headed by the directors. A design team can be as small as two or three persons, or as large as forty or fifty persons, depending on the size of the project.

5. Organization of a Consulting Engineer's Representative on Site

5.1 A consulting firm usually has a representative on site to supervise the contractor who undertakes construction works designed by the former. This representative is called the resident engineer (RE). Nine resident engineers' organization structures in Hong Kong were surveyed. A typical RE's organization was derived and is shown in Fig. 2.4.

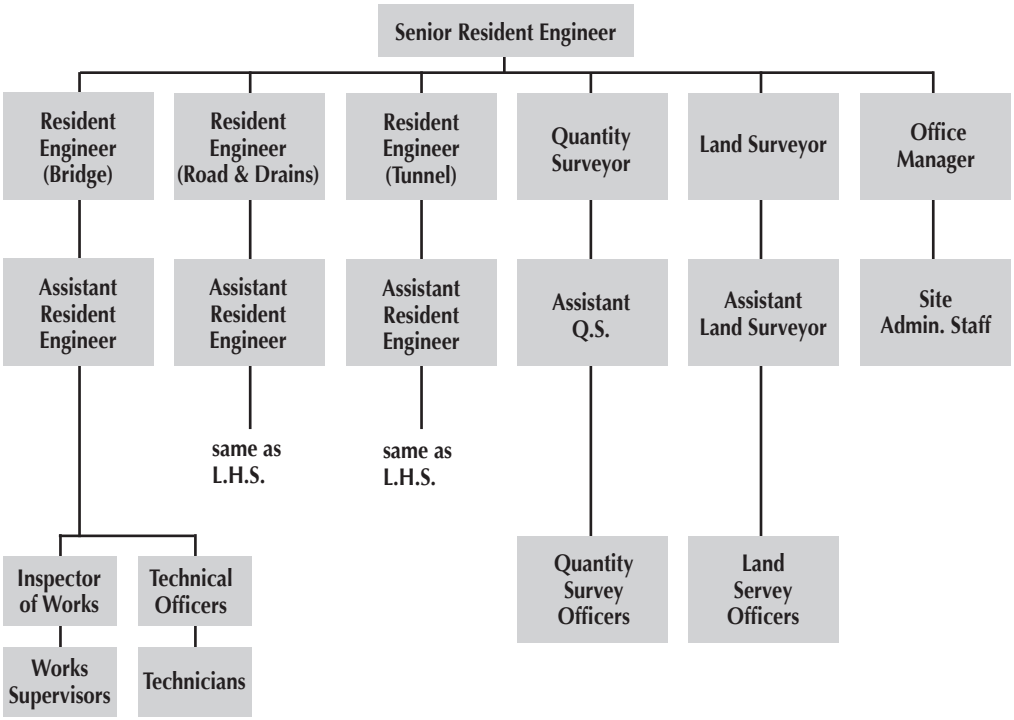

Fig. 2.4 A typical resident engineer's organization structure.

By comparing Fig. 2.4 with Fig. 1.3 of Chapter 1, one can see that the RE's organization is a matrix organization. It is task-oriented for each of the REs shown in the organization chart but is specialist-oriented for people such as quantity surveyor or land surveyor. The latter give their services to all the REs. Each RE has to look after a specific task.

5.2 The ***resident engineer*** is, as mentioned in section 5.1, an agent of the Engineer. He should always be responsible to the Engineer since his decisions may affect the responsibilities and obligations of the latter. Whenever there is any problem or dispute on site between the client and the contractor, the RE must act impartially. Neither the client's nor the contractor's opinion should influence the RE's decision. The basis of the RE's judgement should stem from his professional knowledge.

The main duties of an RE are to supervise the works carried out on site by the contractor and to make sure that the works are constructed according to the contract drawings, that the works completed are of good quality, that the contractor is fairly paid, and that a full set of records about the construction works completed is kept. He is usually a professional person with high academic qualifications, proper professional training and extensive practical experience in supervising construction works.

5.3 The ***inspector of works*** has the main duties of helping the RE to check the materials and workmanship provided by the contractor and to keep a daily report incorporating all details in connection with the actual progress of works. So, the essential requirement of a competent inspector, besides practical experience and technical knowledge, is the ability to judge quality and workmanship. An inspector of works is technically qualified (for instance, holding a higher certificate) and possesses extensive practical experience in various areas of construction. Sometimes, a contractor's general foreman with the appropriate technical qualification may become an inspector of works if the former wants to work for the RE instead of the contractor.

5.4 The ***works supervisor*** works under the inspector of works. His duty is to ensure that (by constant checking) the contractor's staff is constructing the works as specified in the contract by using the right amount of suitable materials. He should spend most of his time outside the site office observing and recording progress/production on the spot and ensuring that the contractor's foreman gives proper instructions to the labourers. A works supervisor should have some basic technical training and a few years of site construction experience.

10 NETWORK DIAGRAM

1. Introduction

A civil engineering project usually involves the implementation of a large number of interrelated activities. Careful planning and coordination is needed so that the activities can be carried out smoothly using minimum resources.

The arrangement of all the activities of a project in an appropriate sequence or set of sequences is called the ***programming of works***. This is a very important job in all kinds of construction projects. In this and the next few chapters a systematic method of programming will be introduced.

2. The Traditional Method

In the traditional method of programming, the project planner (usually the contractor) presents ***a programme chart*** (also called a ***bar chart*** or ***Gantt chart***). The activities involved in a project and the time taken for each activity is displayed in this chart.

Fig. 10.1 gives a typical example of such a programme.

In the past, the production of a programme chart depends very much on the intuition and experience of the planner. The traditional method of programming is not based on any theory. However, there are a couple of drawbacks that arise in this kind of approach.

Firstly a lot of details are missing in the chart. It does not indicate which critical activities must be finished on time so that the overall project will not be delayed. It therefore cannot help the planner to analyse the activities or make decisions about them.

The creation of such a traditional programme chart depends solely on the intuition and experience of the individual planner. The number of activities considered is therefore limited. Also, there is no objective, analytical or logical basis to produce the chart.

3. Network Diagrams

An improved method over the traditional method for the production of a work programme is the **critical path method**. This was introduced around 1957 to assist project planners to programme their work with the optimal use of resources.

Before the activities are analysed and the optimal resources found for a project, the project itself is first represented in a network diagram. In this chapter, we will see how such a network diagram can be drawn for a project. In the next chapter, you will see how the network diagram is analysed using the critical path method.

3.1 Producing an Activity List

To draw a network diagram for a project, the first step is to produce an **activity list** for the project. Table 10.1 gives an example of an activity list. This step is merely a brainstorming exercise. The activities thought of are not necessary listed in a logical order.

Activity	Description
A	Bulk excavation
B	Excavation to column foundation
C	Binding layer
D	Concreting of foundation
.	.
.	.
.	.
.	.
.	.

Table 10.1 An activity list for a project. The number of activities can be up to a few hundreds in a big project. The activities listed are not necessary arranged in proper order.

3.2 *Drawing the Network Diagram*

The next step is to arrange the activities in a logical order and represent them in a network diagram.

The following conventions are usually used when we draw a network diagram for a project. The kind of network we are drawing are called activity-on-arrow (AOA) networks.

An activity in a project is represented by an arrow with two small circles (called **nodes**), one at its head and the other at its tail (Fig. 10.2).

Fig. 10.2 An activity, labelled A, in an activity-on-arrow network.

Usually, numbers are put inside the nodes. Any number can be used to name a node as long as the number at the arrow head (i.e. end node) is greater than that at the tail (i.e. start node) of the activity. Fig. 10.2 shows a correct number entry while Fig. 10.3 shows an incorrect entry.

Fig. 10.3 An INCORRECT number entry for the nodes of a certain activity A.

So in general an activity is denoted by two numbers, i-j, where j is greater than i. The numbers i and j may or may not be consecutive numbers.

Activity A in Fig. 10.2 can also be called activity 1-2.

If there are two activities, activity A and activity B, and activity B can commence only when activity A is completed, then they may be represented as shown in Fig. 10.4.

Fig. 10.4 Network representing activity A followed by activity B.

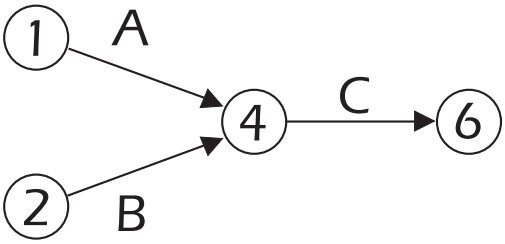

Fig. 10.5 Another example of a network.

Let us now consider Fig. 10.5. The network tells us that activity A (or activity 1-4) and activity B (or activity 2-4) must be completed before activity C (or activity 4-6) can commence. Activities 1-4 and 2-4, however, can be carried out simultaneously.

3.3 *Dummy Activities*

The following example illustrates one use of a ***dummy activity***. It is required to draw a network for a project which consists of activities A, B, C and D, such that A must be completed before C, and both A and B must be completed before D can commence.

The relationship between A, B and D can be represented as shown in Fig. 10.6. However, activity C is difficult to be added to the diagram — C cannot start from node 5 since the completion of B is not a necessary requirement. Then, how can we add activity C to the diagram?

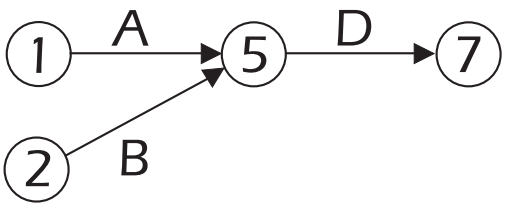

Fig. 10.6 Network representing A, B and D, but how about C?

The method is to invent an activity 5-6, a dummy activity, with no time duration and no cost incurred, so that activity C can start from node 5 and at the same time activity D can be drawn in to satisfy the requirements (Fig. 10.7).

Note that the dummy activity is drawn in as a dotted line.

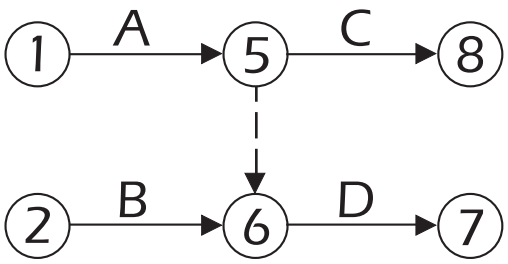

Fig. 10.7 Network for the problem showing the dummy activity 5-6.

The dummy activity does not take any time to complete, nor does it use any resources — it is used only to show the logic (or sequence) of the network.

Consider another situation in which a dummy activity is used. In Fig. 10.8, activity A is denoted by 1-3 and activity D is denoted by 5-7. Activities B and C, however, are both denoted by 3-5, which is not allowed in the network diagram convention. To rectify this situation, dummy activity 4-5 is introduced in the network so that the logical sequence is retained while at the same time each activity is represented by two unique nodes (Fig. 10.9).

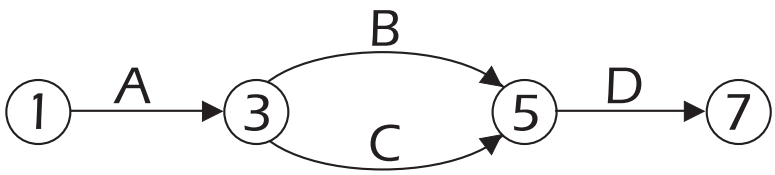

Fig. 10.8 An incorrect network diagram for activities A, B, C and D.

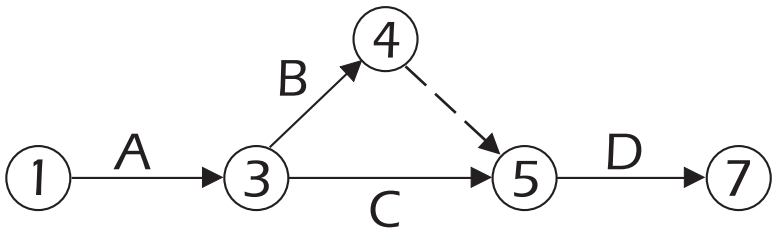

Fig. 10.9 A correct network representing activities A, B, C and D after dummy activity 4-5 has been introduced.

In this revised network, activities A, B, C and D are denoted by 1-3, 3-4, 3-5 and 5-7 respectively. Each activity therefore is uniquely denoted by two numbers.

4. Examples

4.1 Example 1

A group of workers is preparing to erect two pylons. The activities involved are:

A Obtain material
B Obtain concrete mixer
C Dig hole 1
D Dig hole 2
E Mix concrete
F Set up pylon 1
G Set up pylon 2
H Pour concrete into hole 1
I Pour concrete into hole 2

Pouring concrete into a particular hole must be done after the concrete is mixed and the corresponding pylon is set up. But before mixing the concrete, the workers have to obtain the material and the concrete mixer. Also a hole must be dug before the corresponding pylon can be set up. Because of limited labourers, only one hole can be dug at a time. Draw the network diagram for this project.

Solution

We first draw the complete activity list (Table 10.2).

Symbol	Activity description
A	Obtain material
B	Obtain concrete mixer
C	Dig hole 1
D	Dig hole 2
E	Mix concrete
F	Set up pylon 1
G	Set up pylon 2
H	Pour concrete into hole 1
I	Pour concrete into hole 2

Table 10.2 The activity list.

To draw the network, start with activities which do not have to follow any other activities. They are A, B and C (Fig. 10.10).

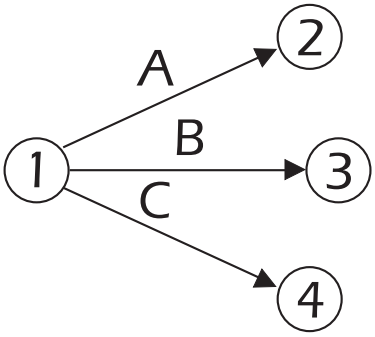

Fig. 10.10 First part of the network.

Then the other activities are drawn into the network diagram as shown in Fig. 10.11.

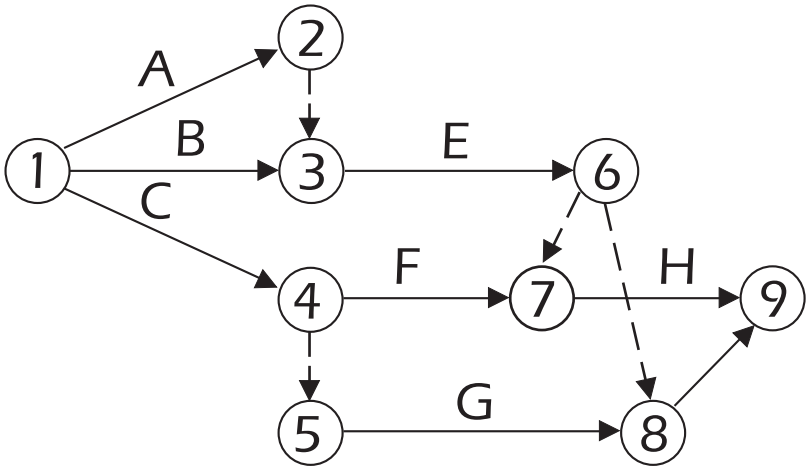

Fig. 10.11 The complete network.

4.2 Example 2

Draw the network represented by the activities in Table 10.3. The project begins with Activities A and B and ends with K.

Activities	Precedes
A	C
B	C,D
C	E,F
D	I,G,H
E	I
F	I
G	J
H	J
I	K
J	K
K	–

Table 10.3 The second column gives activities which follow those in the first column.

Solution

Notice that the activity list is different from what we have had. However, the network diagram is drawn in a similar way (Fig. 10.12).

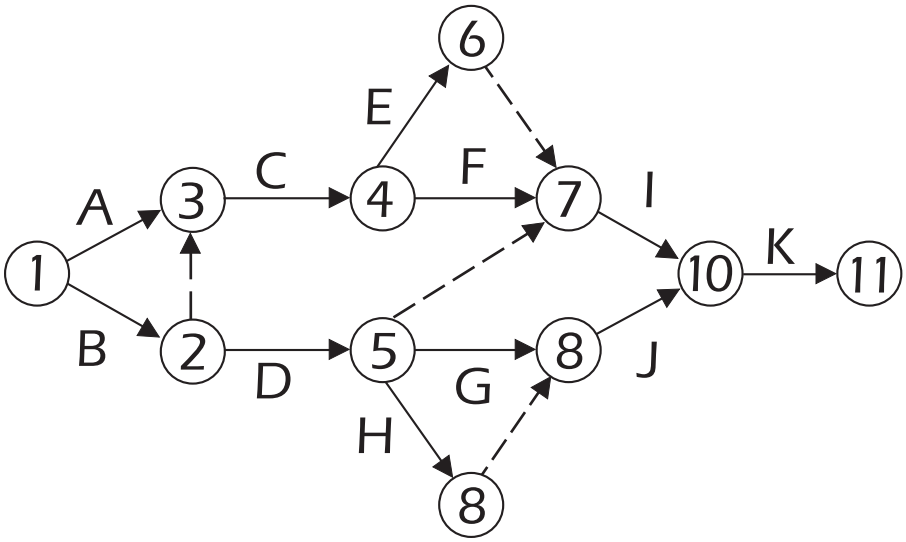

Fig. 10.12 The final network diagram.

Note that the examples in this chapter are for illustration purpose only. They are therefore oversimplified when compared to actual situations in construction projects. In reality, tens or sometimes hundreds of activities are involved in a project and the networks developed are much greater in size and complexity. With these larger networks, computer programs have been developed to draw and subsequently analyse them.

The analysis of network diagrams will be discussed in the next chapter.

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