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CONTROL OF CONSTRUCTION CONTRACTS

Analysis of systems for the control of progress, quality and cost of construction to the client, based upon six cases in building or civil engineering in the UK.

VOL. 1

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ABSTRACT

Six civil engineering and building projects under construction have been observed in order to compare theory and practice, and thus draw conclusions on how Clients and their management teams may control construction effectively.

It has been reported and the six studies have shown that during construction as problems occur decisions taken to tackle them result in changes to one or more of the independent variables cost, time and performance.

It is therefore argued in this thesis that if these variables are to be controlled to the Client's benefit:

- clear responsibilities, duties and authority to make decisions should be given to the members of project management teams.
- a project control system should be set up which will help the management team to perform those duties.
- both the management team and the system should be organized to suit the particular project and Client.
ACKNOWLEDGEMENT

The author would like to acknowledge the help of organizations and individuals for access to their projects, information and advice.
## CONTENTS OF VOLUME 1

1. **INTRODUCTION - ACKNOWLEDGEMENT**  
   Page No. 1

2. **PROJECT CONTROL STRATEGY**  
   Page No. 4

   2.1 **THE NEED FOR PROJECT CONTROL**  
       Page No. 4

   2.2 **DESCRIPTION OF PROJECT CONTROL SYSTEMS**  
       Page No. 8

       - **DEFINITION OF A PROJECT CONTROL SYSTEM**  
         Page No. 9

       - **GOALS OF A CLIENT'S PROJECT CONTROL SYSTEM**  
         Page No. 10

       - **PRINCIPLES OF PROJECT CONTROL SYSTEMS**  
         Page No. 12

       - **MODELS OF PROJECT CONTROL SYSTEMS**  
         Page No. 22

       - **LIMITATIONS IN THE PROCESSING OF THE SYSTEMS INPUT INFORMATION**  
         Page No. 26

   2.3 **THE NEED FOR RESEARCH**  
       Page No. 40

3. **CASE STUDIES**  
   Page No. 41

   3.1 **SELECTION OF PROJECTS**  
       Page No. 41

   3.2 **METHOD**  
       Page No. 44

   3.3 **PROBLEMS**  
       Page No. 47

   3.4 **LAYOUT OF VOLUME 2**  
       Page No. 49

4. **INFLUENCES ON THE WEIGHING OF THE CLIENT'S GOALS - (TIME COST PERFORMANCE)**  
   Page No. 50

   4.1 **NATURE OF PROJECT**  
       Page No. 50

       - **PROJECT TECHNOLOGY**  
         Page No. 50

       - **PROJECT'S RISKS AND RISK ANALYSIS**  
         Page No. 59

       - **PHASES OF A PROJECT**  
         Page No. 72

   4.2 **CLIENTS**  
       Page No. 79

       - **THE CLIENT ROLE - TYPES OF CLIENTS**  
         Page No. 79

       - **GOOD VALUE FOR MONEY**  
         Page No. 85

   4.3 **ENVIRONMENT**  
       Page No. 91

   4.4 **CONCLUSION**  
       Page No. 94

5. **TYPES OF CONTRACTUAL RELATIONSHIPS DETERMINED BY THE CONDITIONS OF CONTRACT**  
   Page No. 95

   5.1 **PAYMENT SYSTEMS**  
       Page No. 97

   5.2 **ORGANIZATIONAL ARRANGEMENTS**  
       Page No. 107

       - **THE TRADITIONAL CONTRACT SYSTEM**  
         Page No. 108

       - **OTHER TYPES OF CONTRACTS**  
         Page No. 120
<table>
<thead>
<tr>
<th>CONTENTS (Continued......)</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.  ORGANIZATION OF THE CLIENT'S PROJECT TEAM</td>
<td>133</td>
</tr>
<tr>
<td>6.1  PROJECT MANAGEMENT TEAM</td>
<td>133</td>
</tr>
<tr>
<td>6.2  CHOICES IN FORMING THE PROJECT'S MANAGEMENT TEAM</td>
<td>143</td>
</tr>
<tr>
<td>6.3  SIZE AND STRUCTURE OF PROJECT TEAMS</td>
<td>150</td>
</tr>
<tr>
<td>6.6  PRACTICE AND CONCLUSIONS</td>
<td>155</td>
</tr>
<tr>
<td>7.   CONCLUSIONS - RECOMMENDATIONS</td>
<td>158</td>
</tr>
<tr>
<td>7.1  CLIENT'S DEPARTMENTS RESPONSIBILITIES AND DUTIES</td>
<td>161</td>
</tr>
<tr>
<td>7.2  ORGANIZATION OF THE PROJECT'S MANAGEMENT TEAM</td>
<td>164</td>
</tr>
<tr>
<td>7.3  PROJECT CONTROL SYSTEM</td>
<td>167</td>
</tr>
<tr>
<td>8.   FUTURE RESEARCH</td>
<td>170</td>
</tr>
<tr>
<td>9.   BIBLIOGRAPHY</td>
<td>172</td>
</tr>
<tr>
<td>10.  APPENDIX 1</td>
<td>184</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

The objective of this research has been to observe control techniques in use on six civil engineering and building projects, under construction and to compare them to published recommendations and theories in order to:

a) Produce information and recommendations for the Clients, and their management teams, on the design, operation, of control systems for the construction of civil engineering and building projects.

b) Make proposals for future research.

Decisions by many parties to a project can affect its cost, time schedule, and standards of quality. In the early stages several departments in the Client's organization may be involved in specifying requirements together with consultants, specialist advisers, inspecting authorities etc. Many more parties are usually involved in construction, particularly Contractors or internal construction departments, sub-contractors, material suppliers and other public authorities.

At all stages decisions may therefore have to be planned and controlled, but up to the placing of contract(s) for construction, the decisions may determine much of the cost of a project but there is not yet the commitment to the main expenditure and to parties employing physical resources. After that commitment there follows a rapid increase in the rate of expenditure and organizational complexity. Surveys of industry state that this is when the greatest problems of control begin and that it is the Client who suffers the most acute effects.

It was therefore decided that because of the limited resources (one full-time researcher available for twenty-four months) this research would concentrate on the control of projects for their Clients during construction. In trying to establish the influences on the setting of the procedures for control, the researcher had to discuss decisions which were taken prior to the award of the contract(s).

In Chapter 2 it is argued that there is a need for better control and that a control system will assist the Client's management team to manage the construction in accordance with the Client's objectives. Suggestions as to how such systems should be designed, stated in books and papers, and the limitations of these systems are reviewed in Chapter 2.

The remaining chapters are based on publications and data from the six projects and are focussed on those factors which should, in the author's view, be considered when a system is set up, because they are likely to effect the system's effectiveness.

Chapter 3 outlines the method of research.

Chapter 4 contains an examination of:

- The influences of a project and its Client natures on the Client's objectives and choice of type of contract.
- The influence of the nature of Client project natures, and environmental changes, on the project's progress.
Chapter 5 is the analysis of potential advantages/disadvantages and obligations for the Client of types of contracts used in industry.

Chapter 6 contains an examination of the ways a Client's project management team may be organized.

Chapter 7 contains conclusions and recommendations on the management of people and the control of information during construction.

Chapter 8 gives suggestions for future research.
2. PROJECT CONTROL STRATEGY

2.1 THE NEED FOR PROJECT CONTROL

Better control of the costs and progress of construction projects, large and small, has been repeatedly stated to be the outstanding need of building, civil engineering and heavy construction in industry in Britain and abroad. Increases of costs of at least 30% over the amount expected at the start of construction are reported to be common, inflation apart, and any delays add to the costs. NEDO (1970) on large industrial sites; NEDO (1970) on construction in civil engineering since Banwell; NEDO (1975) on the Public Client and the construction industries; NEDO (1976) on engineering construction performance; World Bank's annual reviews of project performance audits, (developing countries); Maulin (1979) on successfully accomplishing Giant Projects.

Wearne (1973) in his book on principles of engineering organization, states that engineering projects depend upon an investment of resources for a specified objective; irrespective of whether the objective of the project is to suit a change in the market or some novelty in the equipment and structures forming a system. This view is also held by Thompson (1981) who in his book on Organization and economics of construction states that the Owner of a capital project invests money in the realisation of that project in order to either provide a service or produce goods.

Delays, extra costs or poor quality can obviously reverse the commercial or social justification for a project. Ideally all projects should therefore be completed to the quality specified, within programme, and within predicted costs. Peters emphasized this
during the 7th international cost engineering congress in London (1982) when he stated that "often a particular project is chosen because it forms part of an overall plan of optimum cost effectiveness. The choice of one option over another can be seriously affected if projects overspend the original sum that made up the economic analysis".

In practice the completion of projects within budget and programme is rarely achieved.

Elliot (1974) in a book on control of engineering projects states that in his experience the decision as to whether or not to proceed with a project must be taken very early in the project life cycle. Thus, the accuracy of the cost and time estimates upon which the decision to proceed is based is not very high e.g. with a one in five chance of not being wrong by more than ± 33%.

Warnock (1979) in his contribution to a multi-disciplined study of problems and solutions to Giant Projects states that "if everything in life was certain, if escalation did not exist as a brutal reality of economic considerations, if no variations from the plan could be anticipated, the project capital cost based on which the project was approved could simply be projected out to completion at the same target level. The course of the project from initiation to completion however is rarely entirely protected from either variations or unexpected influences." His recommendation is therefore that the management team have to try and limit variations to those worth their total cost.

Barnes (1978) in his paper on human factors in project cost control states that cost estimates are more often lower than higher than the
final costs. He believes that this under estimation may be attributed to two reasons, both related to human nature:

- "It is human to expect a task to be simpler than it actually is. Our vision of a job leaves out the ration of unexpected and unpredictable interruptions it will in fact experience. Our mental images are only sketches of the main shapes which omit the effort consuming detail."

- Heads of departments, project managers etc. have an interest in there being projects to manage. Would Concord or the Sydney Opera House have been authorized in the first place if the original forecasts of cost had been accurate?"

In a study of fifty public sector buildings and civil engineering contracts NEDO (1974) it has been concluded that trying to complete projects within the original budget did not always mean good value for money for the Client. The working party which carried out the study is of the opinion that some projects had failed to give value for money for the Owner although these had been completed within the officially set cost yardsticks. The reasons given for the working party judgement ranged from projects which were inadequate to perform the purpose for which they were built, to high contingencies which were still paid to the Contractor when the final accounts were closed.

It is the author's view that aiming at building a project within the budget and programme should be the management team's objective. Whether they achieve it or not should not be the measurement of their success because:

- A project is only a means to an end. The end may be a public demand or a commercial market, but the predictions of either may change during construction and therefore require changes to
- Design decisions are based upon predictions of the site conditions, availability of materials, use of special services, etc. and may have to be changed as definite information on these is obtained.
- Construction may be delayed by poor productivity, disputes, weather conditions, and faults of suppliers and other parties.
- Budgets or programmes may have been over optimistic because of reasons attributed to human nature.

All construction involves these risks. The extent that the above and inflation affect a project varies from project to project. Their effects have tended to become increasingly serious because of:
- High costs of finance and therefore of delays.
- Economic pressure to design to minimum cost that discourages the inclusion of spare capacity.
- Greater specialization in materials and techniques that reduce the flexibility of construction sequences and methods.
- Changes and delays disrupt planning and productivity and so cause claims, disputes and unwillingness to cooperate in contractual and industrial relations.

Methods of control are therefore needed to help managers to cope with these problems.
2.2 DESCRIPTION OF PROJECT CONTROL SYSTEMS

It is the author's experience that Client's project control systems may be resented by the Client's in-house engineering team, if it exists, as well as to outside professionals, consultants contractors, employed by the Client for two reasons:

- Employees may view project control systems as a means of reporting on them with the purpose of providing evidence to their superiors in relation to their success in fulfilling their duties, i.e. people may feel that they could be disciplined or their promotion prospects could be threatened;

- Professionals tend to believe that such systems are a waste of money for the Client. In their view a closer involvement by the Client in the implementation of projects, as well as vague design briefs and later changes of the original design brief obstruct the professionals from carrying out what they know best i.e. design and built projects.

The author feels that such misinterpretations may be avoided if answers to the following questions are provided, which is what is being attempted in this chapter:

a) What is a project control system?
b) What does it control?
c) What should the objectives be? (examine the limitations, benefits and how they may be best achieved).

The findings are based on written or verbal views of people who have been involved with the implementation of projects as well as the author's own experience.
DEFINITIONS OF A PROJECT CONTROL SYSTEM

In the Shorter Oxford English Dictionary control is defined "to check or verify and hence to regulate".

Beer (1966) in his book on decision and control, defined it as "... to make situations behave according to certain desired performance criteria".

Bhandari (1978) in his paper on interaction of information flow with CM systems expresses the view that all too often the term "system" becomes synonymous with computers. In his opinion a system can be any combination of manual or automated procedures designed to record and analyse data and present useful information.

Burger and Halpin (1977) in their paper on data base methods for complex project control described project control systems as the combination of methods by which an organization plans, operates and controls its activities in order to meet its goals and objectives utilizing the resources of time, money, people, materials and information.

Snowdon (1977) in his book on the management of engineering projects, states that in some industries, notably the construction and some types of manufacturing industry which have to set their stall out for specific and complicated tasks, the words Project Management are used to identify the control of that project.

The author agrees with Snowdon that while the words "Project Management" should be used to denote the achievement of an objective by
the creation of a new or the modification of an existing asset (e.g. building a plant or a facility), the project control system is the means of carrying out this achievement. By control the author therefore means action to influence the work for a project in order to achieve an objective. A project control system is a management information system which assists the management to decide on action to control. Its main elements are planning, monitoring and decisions leading to action for control.

Planning and budgeting before and during construction are the obvious means of guiding decisions on how to achieve objectives. Monitoring of performance is the means of predicting what will be achieved. Control in action to alter the trends inferred from monitoring.

GOALS OF A CLIENT'S PROJECT CONTROL SYSTEM

Clients would like their projects to achieve the following goals: Low cost; high quality; rapid completion.

Smith etc. (1975) in their paper on contractual relationships Snowdon (1977) and Barnes (1978) share this view but they also point out that in reality these goals are never completely obtainable because they are mutually exclusive. More cost usually buys better performance while cost and time are related in a more complex way. This complex relationship is also supported by the EDC building steering group which examined the construction times in the UK building industry by studying a number of cases. One of their findings stated in the NEDO (1983) faster building for industry is that: "The general belief that speed costs money is quite unfounded. Fast building is possible without sacrificing either cost or quality."
The customer must want it and choose a building team which will understand and share this objective.

This finding seems to be referring to the overall construction periods allowed for in the contract by the Client. The group substantiated this opinion after having observed that where contractors were asked for both competitive cost and time the tender results did not suggest a direct link of trade off between construction times and cost: often the same tenderer offered the lowest for each.

The author believes that the group’s statement is true in some cases but difficult to prove especially as the contractor's offer is determined by other influences besides the cost - time relationship. The relationship between time - cost is equally complex during the construction period when the management team has to decide whether to accelerate the works of a critical activity, at an additional cost, following an unexpected delay.

It follows therefore (especially because of the optimistic cost time performance estimates, based on which projects are authorized), that to meet these three interrelated goals it is necessary at least for one of them not to be tight. (Barnes (1978)). For example a contingency included in the budget may help to eliminate the risk of time overrun without having to sacrifice quality.

Barnes (1978) illustrates (Figure2.1) in a simplified way the attitude of the individual who is responsible for the project's management, during its implementation, toward the three interdependent variables. The individual may be positioned anywhere within the triangle depending on the importance the Client attaches to any of the variables.
For example the army commander wants the river bridged by a certain time. The cost in men machines etc. is not important and the load carrying capacity can be anything above the minimum requirement. The person in charge should therefore be located near to the time and performance angles of the triangle.

In conclusion the objective of the project's control system should be to assist the management team to continuously balance the cost time performance in accordance with the Client's wishes. The basis of control is the authority given by the Client to alter budgets programme or quality standards.

PRINCIPLES OF PROJECT CONTROL SYSTEMS
Birrell (1980) in his paper on construction planning beyond the critical path says that the major objective of planning should be a tool by which to control the actual process. In construction the feedback information on what is happening in the actual process, in relation to the plan for the process, in the control system.
Wearne (1973) defines the purpose of planning as the prediction of a sequence of choices before choosing between them, particularly to anticipate problems of:

1. Critical activities - the activities in the work for the project which in sequence will govern the time required to carry out the project, the duration for each of these activities usually being planned on the basis of the predicted value versus the predicted cost of various methods of work and concentrations of resources.

2. Interfaces - the relationships between different groups' activities for a project, usually requiring detailed decisions on where, when and how they can fit together.

3. Safety - the specification of precautions required for safety as distinct from economy, particularly important in the erection and testing of urgent, novel or large projects.

4. Uncertainties - resources possibly needed for critical activities may have to be ordered in the course of a project, though it may be known that these will be affected by subsequent changes in the objectives of the work required.

Paulson (1975) in his paper on project planning and control stated the consequences of starting a project with inadequate planning or after having planned it to the slightest detail. It is his view that starting a project without adequate planning is like going on a long car journey without maps or some preparation for the cost involved i.e. the project is going to be a disaster. Equally if a lot of time and effort is spent so that plans to the slightest detail are prepared it will be disproportionately expensive (as compared to the project's construction cost). It will also prove distrustful as it is likely to fail its basic purpose (i.e. to provide accurate data) and it is likely to inhibit human judgement.
and reasoning as well. Noon quoted by Wearne (1973) also recognises that expenditure on a control system can be excessive or insufficient. He points out that research of the control of projects have not produced evidence to indicate how much can usefully be spent on planning and monitoring. He therefore suggests that "we can be guided by conclusions from experience that certain symptoms indicate that a control system is faulty". Symptom of control projects are listed in Table 1.

These lists are not exhaustive. The table was assembled by H R Noon based on the statements of engineers and managers attending management courses. It includes the likely results of insufficient or of excessive planning and control. Action to alter a system is probably needed if it shows most of the symptoms listed in one quadrant of this table.

Bhandari (1978) concludes that "the economics of management information systems require constant balance between the value of information input to, accumulated in and retrieved from the system and the cost of designing, installing and operating it".

Besides the danger of over/under planning and control authors have also stressed the importance for the project control system to act in a dynamic way.

Huot (1982) in his paper on strategy management in large projects presented in the 7th International Cost Engineering Congress said that the system dynamics theory is based on two basic principles:

1. An information feedback system exists whenever the environment
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<th>UNDER PLANNED</th>
<th>OVER PLANNED</th>
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<tr>
<td>Plans and budgets not available.</td>
<td>Plans out of date or the projects run the PERT.</td>
</tr>
<tr>
<td>Few routine reports.</td>
<td>Few progress reports, all unrelated to plan.</td>
</tr>
<tr>
<td>Meetings only in crises.</td>
<td>Meetings triggered by crises.</td>
</tr>
<tr>
<td>Cash flow problems</td>
<td>Staff complain of lack of direction.</td>
</tr>
<tr>
<td>Staff complain of lack of direction, or erratic work loads.</td>
<td>Management involved in detail.</td>
</tr>
<tr>
<td>Management dominated by personalities.</td>
<td>High proportion of tenders lead to orders.</td>
</tr>
<tr>
<td>Many projects have priority.</td>
<td>Many projects have priority.</td>
</tr>
<tr>
<td>High proportion of tenders lead to orders.</td>
<td></td>
</tr>
<tr>
<td>Poor relations with customers, particularly because of poor deliveries.</td>
<td></td>
</tr>
<tr>
<td>Poor, erratic profits.</td>
<td></td>
</tr>
<tr>
<td>No enthusiasm apparent.</td>
<td></td>
</tr>
<tr>
<td>Violent changes of direction.</td>
<td>Many forms and reports in evidence.</td>
</tr>
<tr>
<td>Plans and budgets not available.</td>
<td>Frequent formal meetings.</td>
</tr>
<tr>
<td>Extensive progressing activity not related to plans.</td>
<td>Little cash flow difficulty.</td>
</tr>
<tr>
<td>Frequent detailed meetings.</td>
<td>Staff tend to be low calibre, leave work on time.</td>
</tr>
<tr>
<td>Cash flow problems</td>
<td>Top management enthusiasm for systems.</td>
</tr>
<tr>
<td>Staff complain of frequent job changes.</td>
<td>Programme and progress reporting at high level.</td>
</tr>
<tr>
<td>Staff of low calibre. 'Low level' personalities dominant.</td>
<td>Poor tendering success rate.</td>
</tr>
<tr>
<td>No top management support for systems.</td>
<td>Good relations with customers.</td>
</tr>
<tr>
<td>Customers exert pressure.</td>
<td>History of recent crisis and/or management changes.</td>
</tr>
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<td>History of delivery crises.</td>
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leads to a decision that results in action which affects the environment and thereby influences future decisions.

2. All systems present two basic behaviours: they maintain their equilibrium or they break it.

Huot believes that as a corollary to this theory it follows that:

1. The structure and the nature of feedback loops control an "action stream" that will change the behaviour of the system.
2. A knowledge of both policy and information results in an ability to derive the resulting action.

Two principles are contained in these statements:

- we can only control the future
- the system must act as a two way communication.

Paulson (1975) has also emphasised the importance of those principles. He believes that action for control may only be taken if the management team looks forward into the future; receive information as the works progress make assumptions about their implications and take action accordingly. He has pointed out that:

- A number of Clients and Contractors during construction, operate systems which concentrate on documenting how the job has progressed so far but little or no provision is made about future needs or implications. The project they undertake are usually completed slowly and inefficiently.
- Systems with slow feedback systems or limited information have also proved as disastrous as trying to drive a car with all the windows covered in paint.

The author has come across a number of such situations, especially in the housing industry. Construction has to stop several times due to
lack of money because of two or three-fold budget increases; as a result of design changes initiated by the Owner or Architect in order to improve the building's aesthetics without prior evaluation of their cost consequences.

Bhandari (1978) states that a system cannot act or think for management, but can shape thoughts and assist in the evaluation of situations. Such a system should be designed for management at various specific levels and it should supply information in most useful quantities and at reasonable frequencies. Management success depends to a large degree on the versatility of the system, what information is wisely chosen and how it is effectively utilized. Bhandari also expresses the view that thorough and precise collection of facts, data and information as a preparation for two way communication is absolutely essential. One way communication i.e. sending and not receiving, is no communication.

Wearne (1974) in his book illustrates this two way flow of information with the simplified diagramme illustrated in Figure 2.2.
Burger and Halpin (1977) in their paper on data base methods for complex project control point out that one very important segment of the overall system design is the development of a data capturing mechanism. They suggest that every attempt should be made to capture the data at the source and in the format most common to the users of the system. They also state that existing data processing systems are too rigid in the preparation of reports are redundant in the collection and manipulation of data and make it very difficult to produce reports with information content crossing the boundaries of several departments, each one of which has the objective of solving specific operational objectives.

Bhandari (1978) supports this view. In his experience there are far too many organizations that have been apparently successful in developing systems that have failed to generate useful information. These systems may generate reports that are measured in inches rather than pages, but fail to provide useful information to those managers who are fortunate enough to receive those reports. His suggestion is that the scope and operation of every system should be reviewed every year in order to ensure that the system is continuing to meet the management's needs for information.

Paulson (1975) also emphasises that reports should be received by the various management levels on time so that if necessary corrective action may be taken, and should not be bulky if they are to be read. His suggestion is that managers responsible for specific areas of works should receive sub-reports with cost time detailed progress information of the works they are responsible for. Managers responsible for the overall management should receive summaries of the overall progress as well as logically coordinated reports to back them up.
He also recommends that reports for control purposes should contain:
- major variances from planned or budgeted items in order to indicate which activities are more in need of attention than others.
- forecasting and trending based on which management can have a clear vision ahead and be able to anticipate problems before they arise, i.e. reports should look to the future as well as document the past.

Paulson warns however that when a control report indicates that something is wrong with an operation i.e. high variances from budget and/or programme are registered, management should first investigate, find and understand the reasons behind the symptoms reported. This way the management will not take corrective action merely for the sake of making the job conform to the original plans (which may be obsolete for the reasons explained previously.

Barnes (1978) believes that in practice control action is triggered off by variances from pre-set targets less often than the text books and company control manuals suggest. He recognises that recording of costs to date is important because it provides data for accounting purposes and helps managers to forecast the cost of the remaining works. His advice is that variances should only be used to monitor the total project. If used at the working level they interfere with good decision making because they lead lower level managers to apply their mental energy to justifying the reasons they did not achieve the outputs the estimators had foreseen instead of trying to influence the future. His experience is that effective control is achieved when all the management levels work together to achieve the balance of the cost
time performance variables in accordance with the Client's priorities. He identifies four management levels each one of which plans its activities for a certain period as shown in Figure 2.3.

Each manager makes a plan within the outline defined by or agreed jointly by his superior and communicates the result to his junior. Thus forecasts are based on the best available information about recent current and future estimates. Barnes believes that this style of control fosters cooperation instead of conflict and brings control where it has most influence i.e. at the point of decision making.

The major conclusion which may be drawn from the above views is that the control system by itself will not manage the project, but it will assist the project's management team to take control action and
ensure that it is implemented.

Setting out a team which can successfully carry out the management of the project in accordance with the Client's goals is therefore the most important task.

- Cohesion of objectives within the team will be achieved when all its members are carrying out specific tasks which will benefit the projects overall objectives.

- Friction within the team may be avoided when its members are motivated to work collectively towards the solution or anticipation of problems, instead of individually trying to defend their performance.

The objectives of a project control system should be:

- to ensure the flow of information and decisions among the management levels.

- to contribute to the cohesion, harmony and motivation of the team members to achieve the projects overall objectives.

The principles which determine that a system achieves the above objectives may be summarized as follows:

a) The system should be reviewed regularly to ensure that it still fulfils its objectives or whether it shows any signs of over/under expenditure.

b) The system will be dynamic if:

   i) A two way flow of information or decisions taken is maintained among the management levels

   ii) Management tries to control the future and not the past

   iii) The targets of each management level are revised as works progress, in consultation between any two successive departments, so the cohesion of objectives is maintained.
Individual management levels should be allowed however the initiative of achieving them.

c) Standard procedures should be set up in order to determine:
   - the way input data is collected, by whom, and the people, the timing, nature and quantity of information they should receive in order to make decisions.
   - the way such decisions will be communicated to the people who are responsible for their implementation.

MODELS OF PROJECT CONTROL SYSTEMS

A number of authors have published flow charts in order to illustrate how project control systems should be modelled.

Paulson (1976) and Bhandari (1978) have published the most comprehensive and very similar to each other, such models the author has come across.

The model illustrated in Figure 2.4 reproduced from Paulson's paper is designed to fulfil the following objectives:

1. Provide an organized and efficient means of measuring, collecting, verifying and quantifying data reflecting the progress and status of operations on the project with respect to schedule, cost, resources, procurement, and quality.

2. Provide standards against which to measure or compare progress and status. Examples of standards include CPM schedules, control budgets, procurement schedules, quality control specification working drawings.

3. Provide an organized, accurate and efficient means of converting the data from the operations into information. The information system should be realistic and should recognize: (a) the means
of processing the information (e.g. man versus computer); (b) the skills available; and (c) the value of the information compared to the cost of obtaining it.

4. Report the correct and necessary information in a form which can be interpreted by management, and at a level of detail most appropriate in the individual managers or supervisors who will be using the information.

5. Get this information to the correct managers and supervisors, i.e. those in a position to make best use of it.

6. The information must be received in time so that, if necessary, corrective action may be taken on those operations that generated the data in the first place.

In keeping with the principles of management by exception, the following two objectives should be added:

7. Identify and isolate the most important and critical information for a given situation.

8. Give it to the right person as quickly as possible for his considerations, decisions and action.

The flow chart models the operations, and assesses and structures the project information for use by an ideal Project Management Organization for analysis and decision making with feedback control appropriate for a multi-million dollar project. The authors also suggest that the system may be used during the projects design and construction phases irrespective of whether these phases are separated or overlapped.

In the flow chart, the project is initiated according to a predefined plan (box 1) and operations get underway (box 2). The plans also
become reference standard for control purposes (box 5). As operations continue, external factors (box 3) such as recently imposed standards or newly available materials in design or bad weather, strikes, procurement delays, foundation excavation problems or even unexpectedly good conditions on the site, may cause the course of operations to differ from the plan, or may provide opportunities for improving on the plan. The operations underway generate indicators or progress work in place, time, money, or resources expended) which may be measured (box 4) and fed as data into a system (box 6) to produce information for decision makers. In this information processing system, reference is made to planned standards (box 5), such as schedules and budgets, to show deviations, variance and trends. This information is analyzed and made available through reports (box 7), which may be sorted for future reference (box 8) or given to engineering managers and supervisors for their further analysis and decision-making (box 9), or both. They combine and compare this information with their own knowledge, experience, policies, and other qualitative and quantitative information and judgement (box 10) in order to produce new or modified plans for continuing and controlling the project operations (box 11).

This is a feedback control system. It operates continuously throughout the life of a project. Associated with it is a feedback time. Ideally, the time through parts 4, 6 and 7 should be as short as possible so that engineering managers and supervisors can receive accurate and up-to-date information in time to make decisions and formulate plans of action so as to have maximum impact controlling those operations, which are generating the information in the first place.
In a small project it is possible to short-circuit the path from box 2 to box 9 and provide direct feedback. A master builder who works with his own tools in constructing custom suburban homes is a common example of this. If something is wrong, he knows about it immediately.

In a large project, such as the design and construction of a rapid transit system or a nuclear power plant, direct feedback to the decision makers of all information on all activities is no longer possible. One needs a staff and an organized system to measure, process, analyze, and report the most important information to the decision makers. In engineering design and construction this staff consists largely of scheduling engineers and cost engineers. Nevertheless, the goal remains to provide feedback to decision makers in minimum time to maximum impact in controlling operations. Needless to say, however, it is here that the industry is experiencing some of its greatest difficulties.

A major need in project planning and control is to significantly improve and expedite the operations represented by boxes 4, 5, 6 and 7 on the flow charts in order to help resolve these difficulties and improve the quality of information available to decision makers. On larger projects, some improvements are being made through computer applications.

LIMITATIONS IN THE PROCESSING OF THE SYSTEMS INPUT INFORMATION
The accuracy and reliability of the methods used for the planning and processing of the systems input cost and time data during the construction phase have been questioned by a number of authors.
The main problems arise because of:
- the inbuilt limitations of the bar charts and CPM/PERT/Precedent networks which in the author's experience are the most popular methods of time scheduling.
- the separate monitoring and processing of time and cost data during the project's construction.

Limitations of bar charts and networks as time planning and monitoring tools
Harrison (1981) in his book on advanced project management outlines a number of disadvantages which in his view limit the applicability of bar charts:
- The bar charts do not show interrelationships between the activities on large projects and this can lead to problems in coordinating the work.
- There is a physical limit to the size of the chart which limit the size of project that can be planned using this technique.
- It cannot easily cope with frequent changes or updating since each change necessitates the redrawing of the chart.

Galoway and Nielsen (1980) in their paper on schedule control for Professional Construction Management projects conclude that scheduling is a tool for managing a construction project of any size. Based on their observations of two projects in USA they point out that networks prepared by the Contractor and approved by the Client can be used towards the minimization of delays and resolution of disputes.

Birrell (1980) in his paper on construction planning beyond the critical path point out however that the majority of the contractors fail to use CPM/PERT as a basic management technique. (This statement
is based on "a study of project planning and progress control practices in the Canadian construction industry" by the Canadian Construction Association Business and Contractor Relation Committee January (1974). His view is that some contractors provide a CPM/PERT in their tender at the request of the Client — they usually employ an outside consultant to do it and pass the fee to the Client — and continue to manage the project in their own more appropriate manner.

The Associated General Contractors of America in their manual for General Contractors on CPM in construction also suggest that the basic critical path network technique is neither a true model nor the best approximate model of the construction process. Birrell believes that the failure of the CPM/PERT to be adopted by the construction is because its concept was developed by the USA defence industry where due to national security reasons cost control and efficient use of resources carry a low weight. In construction each contractor is very interested in the efficient use of his resources on all the projects he is working on i.e. put simply for those who control the construction resources, minimum consumption of resources on a construction project is more desirable than minimum calendar duration of the whole project.

Roderick (1977) in his paper on the examination of the use of critical path methods in building also agrees with Birrell's views. Based on observations of practices adopted by the building industry he concluded that although CPM have been used increasingly by the building industry they have not proved to be as effective as it was expected. Based on sampling observations of on going building projects he identified two reasons because of which the contractors networks did not accurately
predict the operations on site:
- The estimates for the activity durations were grossly optimistic.
- The activities did not proceed in consecutive way, instead they developed concurrently.

Oxley and Thompson (1980) on their paper on "critical path success or failure?" based on four case studies and questionnaires sent to 115 contracting firms, conclude:
- that CPM is used to good effect particularly in large companies but it is no panacea.
- for many firms complexity is one of the two main factors for deciding to use CPM. The second factor is the imposition of network planning by contract terms.

They also found that the most common cause of failure or the main reasons for not using it are:
- better methods available for certain types of construction e.g. line of balance for repetitive construction.
- bar charts are adequate for simple projects.
- networks are more difficult and costly to update than bar charts and the supposed benefits are not achieved in practice.
- difficulty of implementation at site level where the bar chart is considered to be superior (more popular with Agents and foremen).
- difficulty of applying CPM throughout an organization.

Harrison (1981) outlined a number of problems with CPM/PERT techniques which are related to human factors i.e. lack of training and skills by the managers who are expected to take advantage of them:
- difficulties in communication
- difficulties in monitoring and controlling progress
the fact that by itself a network and its associated time analysis
is not an operational plan or schedule.
- there is a widespread misinterpretation of the concept of float.

Aims of cost control systems
Barnes et al (1981) in their article on "Perfect cost control - the gap
between theory and practice" stated that in the construction industry
few systems for cost control do more than record costs. Such systems
seldom do more than raise the question of whether a need for a decision
exists, and in many instances they are deceptive even in this narrow
function. As a result action control remains in the decisions of
managers, taken with the use of their own experience to help forecast
the outcome of the alternative actions they are considering.
The authors recommend that a system designed for the purpose of pre-
dicting instead of just recording costs should be built up in ten
steps. (From the project's conception to the construction phase).
Step 1 - Agree objectives and relate performance to an order of cost
Step 2 - Establish and refine estimates of costs
Step 3 - Cost consequences of design decisions
Step 4 - Base estimates on the method of construction
Step 5 - Establish contingency funds
Step 6 - Allow for inflation
Step 7 - Monitor progress against control estimate elements
Step 8 - Re estimate the final cost
Step 9 - Actions must take into account cost consequences
Step 10 - Evaluate the cost of design changes during construction

The conclusion that can be drawn from these recommendations, if a
system is to be used for control purposes, are:
I Base statements should be related to the method of construction (and not to the cost of the finished product) and the person in overall charge during the construction should be appointed as early as possible (Step 4).

II Payments are index linked but they should be related to a date price (base prices) for the purpose of comparisons with budget or forecasts of returns on completed projects (Step 6).

III Over emphasis on progress versus cost estimate elements can lead to failure of cost control (Step 7).

IV Good managers assess cost outcomes in minds or on paper before making decisions, (especially design changes during construction). Good systems must support them by helping to make cost outcome forecasts quickly and as accurately as possible. (Steps 8, 9, 10).

V Contingency funds should be established before the commencement of construction. (Step 5). Their purpose will not only be to finance unexpected cost increases, but also to be a means of exercising control of costs by whoever is authorised to use them.

The need of a fully integrated cost/time control system is therefore evident. The question however is:

"Is it achieved? Can it be achieved?"

Problems in achieving integrated cost and time control

Sears (1981) in his paper on "CPM/Cost an integrated approach" says that CPM and bar charts are designed to operate independently of cost control.

Networks and bar charts are made up of activities. An activity is defined as a unit of work which takes place in a specific location.
and has a finite time duration.

In contrast cost control is based on cost accounts of functional items which have no duration or location implications; except to differentiate between complexities of work within the same account.

The consequence is that time and cost variables are planned and controlled by specialists allocated to independent departments.

Sears, based on his experience from the management of large projects, states that the independent processing and control of cost and time have the following disadvantages:

- When a delay due to an unexpected cause occurs (strikes, weather etc.) both acceleration of the works or allowing the completion date to slip may involve additional costs. If the Client's priority is to complete the project at minimum cost, the cost control operating independent of time control will not show which of the two alternatives will result in minimum costs.

- Duplication of efforts.

- Errors due to lack of communications, especially in large sites where even regular meetings are not possible due to the distances involved.

Panayiotacopoulos (1977) in his paper on "Cost time model for large CPM project networks" states that to date all attempts to develop and use one accurate project cost-time curves for CPM curves have run against few major obstacles:

The arbitrary shapes of the cost time relationships for the project's activities and the rapidly increasing computational costs in relation to network size. In order to cope with those two difficulties he has proposed the following methodology.
"Depending on a network's structure, either the project cost-time curve for the whole network is obtained or the network is reduced to an equivalent smaller one; other existing schemes can then efficiently be employed, thus eliminating the great diseconomies of scale for computational costs associated with large networks. The basis of this analysis is the realization that almost all large project networks can be decomposed into nonoverlapping large segments, with such a structure that an efficient algorithm can be construction to develop a segment's cost-time curve when the cost functions for the activities are arbitrary. Proceeding from node to node like a shortest-route algorithm, the suggested analytical procedure allocates some available time to the various activities in a way that minimises the total network cost. Computational costs increase at decreasing rates with network size, while the procedure is simple enough for hand calculations by the average engineer."

Sears also claims to have developed a system where cost accounts and activities are matched in each of the following ways:

I. One to one relationship with distribution being uniform.
II. Two or more activities to one cost account with a uniform distribution.
III. Two or more cost accounts to one activity with a uniform distribution.
IV. Any combination of II and III
V. Any predefined non-uniform relationship between activities and cost accounts.
VI. Any discontinuous or undefined relationship theory evaluation of progress.

A number of University researchers including the above, consultancy
firms, contractors, have claimed to have developed fully integrated cost/time control systems. The author however has not come across any articles where the success or shortcoming of those systems have been substantiated based on the lessons learned from their use in real projects.

The British experience

In Britain the most commonly used document for the control of payments from the Client to the Contractor during construction is the Bill of Quantities (B of Q).

The ICE (1976) "Civil Engineering Procedure" say that the B of Q is a detailed bill of approximate quantities (computed by the Engineer) which includes brief description of the work to be undertaken, against each item of which the Contractor has entered a unit rate or price. The contract price is the aggregate amount of the various quantities priced at the quoted rates. During the performance of the work, the actual quantity executed under each item is measured and valued at the quoted rate. Provision is made for valuation and adjustment of rates for varied or additional work.

The Joint Contracts Tribunal (JCT) for the standard form of Building contract in their "Guide to the Standard Form of Building Contract 1980 Edition", provides conditions of contracts for B of Q's with quantities (i.e. quantities are not admeasured) and with approximate quantities (i.e. admeasured).

Barnes (1977) in his book on measurement in contract control, points out that changes to the originally planned work during construction
changes to the total contract's cost which are unrelated to changes of quantity.

The implications for the Client are that:
- Disputes arise, claims follow, a number of people spent a lot of energy and time in justifying or refuting them.
- The Client never knows whether the final settlement reflects the actual costs to the contractor or the contractor has made excessive profits.
- Claims invalidate financial control based on cash flow forecasts or profit and lead to delay in finalizing payments.

In 1960 the Building Research Station (BRS) based on the findings from two previous lines of research into site costs and site management recognized that whilst the use of quantities represented the finished work, and adequately reflected the cost of the building to a Client, it had little value to the builder in reconciling the cost of production or the method of construction. Existing methods were insensitive to the complexities of design; clients did not receive the greatest benefit from efficient designs, and there was little incentive for the architect to improve the 'buildability' of his designs. BRS considered that there needed to be a greater emphasis on drawings, planning techniques and in revealing, at tender stage, the site operations necessary to construct the proposed building. The scope of the Bill of Quantities, restricted to tendering and technical accounting, could be greatly enhanced. To demonstrate their philosophy a new form of documentation was devised - The Operational Bill.

A. The Operational Bill

Operational Bills separate the work into labour, plant and materials
requirements for gangs of men. These operations are not grouped by trades, as in a conventional bill, but are listed in the order in which work is likely to be executed. This order, shown by a precedence diagram, can form the basis for such activities as planning, project control, feedback of costs, bonusing and the payment of interim certificates. Materials are in a form suitable for ordering and buying.

Locational information is given by title, coding in the precedence diagram, the description of the works and by drawings. The function of the precedence diagram is to outline the production sequence, to relate the estimates to outline planning and to provide an index to the documents. It does not dictate the production sequence or affect production control.

Compared with the conventional Bill of Quantities, more information is required from the architect at the design stage in order to make judgements about the construction process and thence to produce the bill, but less information is required thereafter.

B. The Transitional Bills

BRS believed that Operational Bills were the optimum solution but that the step from existing practice was too great. Several transitional forms of documentation, eventually named Bills of Quantities (Operational Format), were proposed, to aid the evolution from existing forms to the Operational Bill. This format, often referred to as activity bills, analyses work into operations although unit price rates are calculated using conventional methods.

Despite the extensive dissemination programme by the BRS, and the
recognition of industry that the existing B of Q were not satisfactory, industry did not use the operational bills or its derivatives.

Lansley (1983) "Case studies of the constraints to the application of construction management research" summarized the reasons industry did not adopt the bill as follows:

1. Professionals, especially QS's, objected to the bills because:
   - their fees would have to be increased because of a higher work load.
   - their relationship with the Architect would become more demanding.
   - QS's would be held responsible for dictating to contractors through the choices made in structuring the operations and sequencing the work.

2. Contractors and sub-contractors despite an acceptance of the concept; the main problem appeared to be in using the estimators knowledge of measured rates and in pricing the job against an outline programme of work. Contractors wanted more control over the sequencing of the works.

3. BRS did not provide any guidance on how to develop a suitable cost feedback system.

4. Need for training of the professions for their new responsibilities. BRS did not see it as their role to provide such service.

It therefore appears that the bill was not accepted because it pre-conditioned revolutionary changes in the existing relationships, duties and responsibilities of members among the Design Team and the Contractors.

The author accepts however the validity of the argument, put forward by a number of QS's he discussed the subject with, that a serious dis-
advantage of the bill was its inflexibility to incorporate design changes initiated by the Client or Architect during the construction phase.

The Civil Engineering Standard Method of Measurement (CESMM) published in 1976 improves the possibility of fulfilling the objective of step 4 (B Aims of cost control systems) mentioned above, because:
- it makes possible the transfer of much of the clerical work associated with B of Q's into a computer.
- It gives the option to the Contractors to include in their priced B of Q Method Related Charges.

As Barnes (1977) explains, in commissioning civil engineering works the Client buys the material left behind, but only hires from the Contractor the men, the machines and the management skills. It is logical to assess their values in the same forms as the origin of their costs. It is illogical not to do so if the Employer is to retain the right at any time to vary what is left behind and if the financial uncertainties affecting Client and Contractor are to be minimized.

The method-related charges are divided into charges for recurrent or time related cost elements (maintaining site facilities - operating major plant etc.) and charges for elements which are neither recurrent nor quantity related such as temporary works, bringing major plant to site etc. If the Contractor enters a cost under method related chartes he is entitled to full payment whether or not the method originally stated has been held to, as long as there have been no contractual changes.
The author has not come across any published research findings which indicate to a degree which contractors are using method related charges or their effectiveness when used i.e. their contribution towards avoiding or settling faster financial disputes.
2.3 NEED FOR RESEARCH

Statements, techniques and theories of how projects should be controlled, principles which should determine the design of control systems and how decisions should be taken are abundant in textbooks and published papers.

What is not known is the extent to which each is used and with what results. As Wearne (1976) said in a discussion on a paper presented by D Paterson (1975) "what is difficult is learning from projects that go well. It seems that many engineers and their employers do not review completed projects for that purpose and those who do, do not usually publish the conclusions".

The author agrees with this view. A number of published papers on project control systems used during the construction of projects do not contain:

- examination of the influences on the design of such systems,
- analysis of their contribution or limitations in solving problems,
- conclusions on the changes the authors would introduce if they were to embark on the same project again.

The researchers therefore felt that a study of the above by observing a number of on-going projects would produce information which may help management teams to complete projects in accordance with the Client's goals.
3. CASE STUDIES

3.1 SELECTION OF PROJECTS

Projects were selected to cover:
- as wide a range of types of building and civil engineering projects as possible.
- public and commercial building projects.
- projects which were free of extraordinary circumstances.

The choice was limited by the reduced amount of work in the construction industry. Thus only management contracts, and contracts based on the ICE and JCT condition were observed.

The six selected projects, were the following:

PROJECT A

Was the culverting of a brook in a restricted site. The Owner was a provincial University. The design and supervision of the works were carried out by the Metropolitan Council of the City. (Client). An ICE 5th Edition contract for 20 weeks was awarded and the Client's Principal Engineer was named as the Engineer. The Client also appointed a part-time Resident Engineer.

The control of the project was carried out in accordance with procedures already established by the Client.

PROJECT B

Was the structure for an urban transport system, built over a period of 10 years at the approximate cost of £280 million.

Owner/Client was the Passenger Transport Executive (PTE) of the county.

The project was designed by five firms of Consulting Engineers and
Contractors were appointed to carry out the works.

Because of the project's complexity, a consulting engineering firm was appointed as a project coordination team (PCT). The computerized control system set up by the PCT reflected the project's complexity. Control actions were decided by a Management Group consisting of the Client's Directors and the head of the PCT. One of these Directors was appointed as a Project Manager.

PROJECT C

Was the expansion and refurbishment of the terminal building of a regional airport. The works were carried out in four phases over a period of 28 months under one contractor at a total cost of £6.73 million.

Owner/Client was a consortium of two County Councils and one Metropolitan Authority represented by the Airport Director. The Airport Director was responsible for the airport's operation.

One firm of Consulting Engineers was appointed by the Client to manage the design and construction. A senior partner was named as the Supervising Officer and a Resident Engineer was employed to lead the site staff.

The Conditions of Contract were in accordance with JCT with quantities.

PROJECT D

Was the erection of a road river concrete bridge and the construction of the approach roads. The works were carried out in two phases over 177 weeks at the total cost of approximately £14 million.

Owner/Client was the Council of the County in which the project was located. The Client was represented by the Deputy Executive of its
in house Engineering Department.

A firm of Consulting Engineers carried out the design and supervision of the works. A senior partner of the firm was named as the Engineer and a senior Resident Engineer was appointed on the site. The contract was in accordance with the ICE 5th edition.

PROJECT E

Was the construction of a conference centre to international standards in the centre of a city. It was expected to be completed in approximately 6 years at a cost of £50 million.

The Client was a public authority. A Project Manager was appointed by the Client on the site. Under the Project Manager the management team consisted of the Design Team's leader (Supervising Officer) the Resident Engineer and the Management Contractor. Approximately 100 sub-contractors were appointed for the supplies and construction. The computerized control system set up by the management team reflected the project's complexity.

PROJECT F

Was the building of a supermarket at a cost of £1.72 million in approximately nine months. Owner/Client was an expanding retail sales company. A member of the Client's personnel called Project Manager, was in liaison with the Design Team and Management Contractor. Leader of the Design Team was the Architect. The control of costs and time were the responsibility of the Quantity Surveyor and Management Contractor respectively.
3.2 METHOD

The collection of data was carried out by the method suggest by Blau and Scott (1963) in their book on Formal Organization: "direct unstructured interview exemplified by asking ... a wide range of questions, is most useful during the early stages of research, when information is desired on the range and variety of problems ... Once the specific questions and hypotheses that are to guide the research have been formulated, the investigator may choose the direct interview in a more systematic fashion ... ".

To plan questions to guide the interviews, a set of hypotheses was drafted which the information obtained was to test. Comments on the hypotheses and proposed questions were obtained from other academic groups and consultants in construction management. The usefulness of the question was also tested on Project A which was used as a pilot case study.

After initial enquiries for access, the arrangements for observing each project were specified formally in an exchange of letters with the Owner or representative stating the objectives, proposed method and a procedure for protecting confidences. After that all links were through the Client's Project Manager (in the case of projects E and F), Resident Engineer (projects A, C and D) and Project Coordinator (project B).

Additional information was also obtained from other members of the project's management teams when it was necessary or possible. For example because of the complexity of project E's control system, the system was also discussed with the Quantity Surveyor and the Management
Contractor's Project Manager.

The methods used for the collection of information were interviews, guided by the prepared questions, the study of documents and discussions, touring the site etc. In the case of project F the author was allowed to attend the management team's monthly policy meetings. The author had therefore the opportunity to discuss informally before or after those meetings general or specific views about the project with individual members of the Management Contractor and Design Team.

The hypotheses and questions were not sent to the host organization or individuals who were being interviewed, but they served as a guide to the author when questioning developed into a discussion.

Initially with the Project Managers or Resident Engineers the discussions were informal. The starting point was a statement of objectives and procedures written by the researchers, but at that stage views of the participants on problems with control based on their previous experiences were also discussed. A series of monthly interviews were carried out in each case and information was sought on:

- Project objectives, scope and programme
- Client
- Responsibilities, managerial and contractual
- Expected problems
- Set procedures and reasons for the choice of the system
- Origin of actual problems, action on them and the effects of the control system, or perhaps on the control system
- Comments on all the above.
Reports stating what the researchers understood to be the facts were drafted after each interview. These were sent to the person interviewed as a private draft for their corrections. An agreed version was then produced also as a private document. Outstanding questions then became the subject for the next interview.

The researchers' comments and predictions, as well as information which the person interviewed wished not to be attributed to him were recorded separately in an internal private draft.

On completion of each case study the researchers produced a single report summarizing the reports agreed during the observations. This report was then sent to the hosts for their final comments. These finalized reports are contained in Volume 2 of this thesis and they have formed the basis for the drafting of the recommendations and conclusions which appear in the following chapters.

These procedures follow established methodology and are in accord with the notes for the guidance of management research issued by the British Institute of Management.
3.3 PROBLEMS

The researchers were aware that the information they were seeking was sensitive to the people and organizations who were going to provide it; after all nobody likes to admit that some of his decisions were wrong or that the organization, on which he depends for employment, is not run efficiently.

The researchers were therefore prepared for:
- unwillingness from people to cooperate
- distortion of some sensitive facts.

Much to the researchers surprise no difficulties were encountered in getting people's or their organization's agreement to cooperate or discuss sensitive information (some of which was recorded in the internal private drafts, and it is used in our conclusions but it is not connected to any case study).

The researchers experience with peoples attitudes and project management also helped them to identify and encourage the interviewees to discuss sensitive issues, especially as the interviews became less formal.

Problems did occur with project B. The examination of the system's effectiveness was not completed to the researchers satisfaction as it became clear that the interviewees were not willing to participate any further mainly for the following reasons:
- The project's complexity made its understanding (in the limited time of the interview) difficult, and therefore more meetings than expected were required.
The project was almost completed and a lot of the information sought had taken place some years earlier. The interviewees felt that their comments could be damaging to their relations with the Client.

All the participants of the remaining projects agreed that they also had benefited from the interviews because they had had a chance to reappraise actions they had already taken and the methods they were using. For example in project D the Resident Engineer as a result of the interviews, changed the presentation of the report slightly in order to give a clearer picture of the reported information.
3.4 LAYOUT OF VOLUME 2

The finalized single reports for each case study are included in Volume 2.

Each report is divided into seven sections.

The project's purpose, technical description its total cost and construction time schedule are contained in section 1. The aim of this section is to show a picture of the size and technical difficulties involved with the project.

The Client's nature, objectives and attitude towards the project as well as other influences, such as the source of finance, which may influence his objectives are described in section 2.

The project's management structure, management organization (i.e. delegation of authority to members of the management team) and the type of contracts awarded to suppliers, contractors, sub-contractors are described in section 3.

The project's control system is described in detail in section 4.

The effectiveness of the system is examined in section 5 and 6, by analyzing the problems encountered during the project's construction, their causes and implications, and the way the system helped the management to tackle them.

The potential improvements of the project's control system, management organization and comments on the choice of type of contract as suggested by the participants appear in section 7.

The chapters which follow in this Volume have been formulated in the same sequence as the reports in Volume 2. Their aim is to discuss elements which in the author's view have a determining influence on the formulation and performance of control systems. The conclusions in each chapter are based on publications and the findings of this research.
4. INFLUENCES ON WEIGHING THE CLIENT's GOALS
(TIME - COST - PERFORMANCE)

4.1 NATURE OF PROJECT

PROJECT TECHNOLOGY

Methods of project organization and control can be expected to vary with the type of project, depending on whether the work is mainly civil engineering or mainly building construction. Differences were listed by NEDO (1978) in a review of flexibility in the industry as follows:

I Building works are usually more labour intensive while civil engineering more plant intensive.

II Building works require a major proportion of skilled tradesmen, a secondary proportion of semi-skilled and unskilled labourers and a small proportion of skilled and semi-skilled plant operators. Civil engineering works require proportionately more general and semi-skilled labourers and skilled plant operators and less skilled tradesmen.

III The building industry uses a larger range of materials than the civil engineering industry.

IV The size and composition of the labour force and the plant employed on a building site are determined by the site's size, location, design and size of the project by the quantities and proportions of processed and manufactured materials and prefabricated units in construction, and the method of construction.

In civil engineering the method of construction is more likely to be determined by the anticipated technical risks e.g. large excavations, temporary works, etc. The projects' location is also likely to result in large secondary works such as access roads, temporary accommodation for the work force, jetties for loading and unloading of the
construction materials.

The types of project characteristic of these two sectors of construction are indicated in tables 4.1 and 4.2 as produced for the NEDO study. As Thompson (1981) and others have pointed out, these two sectors and the heavy engineering sector of construction tend to have some common managerial problems but also some distinct methods of contract organization and practice in project control:—

I For most building projects the Client normally employs an Architect to manage the project's design and construction. The Architect may in turn utilize the services of an independent structural engineer and a Quantity Surveyor.

II For most civil engineering projects the Client engages the services of a civil engineer with expertise in the specific type of project. It is normal that the same engineer undertakes all the design and supervision of the Contractor(s). Contractor(s) as in the building are only employed to construct the works.

As a result of these differences:
- Each sector requires its own professional consultants (familiar with the features of that sector) who can design the project and manage the construction, and provide the required resources (labour, plant, management expertise) to carry out the works.
- The relationship between those specialists and their responsibilities during construction are determined in each sector by the dominant specialist. Thus, in most of the UK building projects, Conditions of Contract are drafted in accordance with JCT 1980 and the Architect is the leader of the Design Team and is named as the Supervising Officer during construction. In UK civil engineering
<table>
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<tr>
<th>Market sector in DOE statistics</th>
<th>Examples of building structures</th>
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<tr>
<td>New Housing</td>
<td>All dwellings</td>
</tr>
<tr>
<td>Public non-housing new work:</td>
<td></td>
</tr>
<tr>
<td>Gas, electricity, coal mining</td>
<td>Sub-stations, showrooms, pithead buildings etc.</td>
</tr>
<tr>
<td>Railways, air transport</td>
<td>Stations, terminals, hangers etc.</td>
</tr>
<tr>
<td>Education</td>
<td>Schools, colleges, universities</td>
</tr>
<tr>
<td>Health</td>
<td>Hospitals, clinics, welfare centres etc.</td>
</tr>
<tr>
<td>Offices, factories, garages,</td>
<td>Offices, factories, garages, shops</td>
</tr>
<tr>
<td>shops</td>
<td>Water works, pumping stations etc.</td>
</tr>
<tr>
<td>Water</td>
<td>Theatres, post offices, sports grounds, fire stations, museums, prisons, barracks, libraries etc.</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Factories warehouses etc.</td>
</tr>
<tr>
<td>Private non-housing new work:</td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>Offices, shops, hotels, cinemas, garages, farmbuildings, churches, etc.</td>
</tr>
</tbody>
</table>
| **TABLE 4.2**  
**Grouped Examples of Civil Engineering Works**  

| **Site investigation** | Boreholes, trial holes and shafts, etc., for the purpose of evaluating the bearing value, shear strength, permeability, etc. of the strata explored |
| **Foundations and underpinning** | To support heavy superstructures such as tall buildings, bridges, etc., and heavy machinery such as turbo-generators, rolling mills, etc. by distributing and transferring the forces imposed by the loads carried, or already being carried as in the cases of existing structures subject to settlement or subsidence, on to and/or into the ground beneath by means of direct bearing foundations, piles, cylinders, caissons, mass or reinforced concrete, chemical consolidation and injection, etc. |
| **Transportation** | Airways: airports and runways, etc.  
Highways: roads, motorways, etc.  
Railways: surface and underground.  
Bridges: road and rail (longspan: arch, cantilever and suspension), (shortspan: arch, beam girder, cantilever, portal, etc.).  
Shipping: docks, harbours, jetties, marine terminals, wharves, lighthouses, etc.  
Waterways: canals, locks, channels, riverworks, tidal barriers, aqueducts, etc. |
| **Sea defences** | Sea walls, breakwaters, revetments and groynes etc. |
| **Drainage, sewerage & sewage disposal** | Main and subsidiary soil and surface water sewers, sewage treatment works and pumping stations, effluent outfalls, storm relief works, etc. |
| **Water supply** | Dams and reservoirs, filtration and purification plants and pumping stations, elevated water tanks, pipe-lines, etc. |
| **Electrical power** | Generating stations (hydro-electric, coal and oil fired, nuclear, pumped storage, etc.).  
Sub-stations, switchgear, etc., and work in connection with overhead power transmission lines, underground cables, etc. |
| **Tunnels** | Driven in various strata and conditions for underground railways, sewers and interceptors, water supply, cables and pipe lines, etc. |
| **Industrial** | Heavy foundations and piling, services and engineering structures such as ore bunkers, conveyor and service culverts, in connection with the construction of steel works, gas works, coal mine headworks and shafts, and large manufacturing plants, etc. |
projects the ICE 5th Edition revised in 1979 is used as the guide in drafting the Conditions of Contract and the Engineer (a civil engineer) is in charge of the Design and of construction. These are by no means rigid rules however. In the case of project C for example (which was a building project) the design and construction were managed by a firm of civil engineers. (Supervising Officer was named as one of the senior Partners of the firm), specializing in the design and construction of airports.

The author believes however that offshore structures should be classed as a third sector of construction projects. This is because the method of construction is unique to those projects due to the nature of the works and the hostile environment in which they are built, thus specialized consultants and contractors are needed to design and manage the construction of the works. This type of construction projects have not been examined in the framework of this research; thus the findings of this Volume only apply to civil and building construction projects.

PROJECT'S RISKS AND RISK ANALYSIS

Pilcher (1975) in his book on the appraisal and control of project costs states that "very few investments of capital are made under conditions of certainty, that is, where the outcome of the investment is known with some degree of precision. If a decision is made in circumstances where it is possible to predict from historic data the probability or chance that a particular outcome will occur no matter how great or small that chance is, then it is said that the decision is made under risk".
Heeman (1976) in his paper on the effects of risk and organizational complexity on project management draws a relationship between the choice of a contract and the project risk by stating that: "the degree of risk in a project is recognized in contractual terms by having varying forms of contract other than fixed price".

Wearne (1976) in his paper on urgency, uncertainty complexity and organization analyses the three characteristics of risk (complexity, uncertainty, urgency) which distinguish one project from another and could decisively influence a Client in his choice of strategy.

I Complexity

Heeman (1976) says that "complexity is used to describe the means of communication control, alignment and motivation between different groups or organizations connected with the project. Complexity is therefore directly related to the number and types of interfaces occurring in a project".

Heeman sees an interface as a discontinuity which is caused by:

- Differing technologies i.e. civil, structural, mechanical, electrical etc.

- Different companies of sub-contractors and suppliers who in theory, all work to the same end but all have differing loyalties and they manage their work as a project of its own right.

- Interfaces between the differing departments in the Client's organization and in the main contractor. Although it is often assumed that an organization is a single entity with a single purpose, in real life this is not the case. Thus interfaces with hidden departmental motivations do exist, which must be allowed
and controlled in the same way as the more obvious ones of contractor and sub-contractor.

Heeman concludes that:
- Interfaces are of prime importance in a project because they are discontinuities over which information must be passed in a form which is intelligible and unmistakeable to both sides. The type of information which must pass in both directions includes a range of technical and contractual information (cost, progress etc.).
- The interfaces between technologies, companies, sections or groups must all be managed and coordinated if the project is to be completed within the limits of time, cost, and resources.

Wearne (1976) states that "complexity is not simply proportional to the size of a project or the number of different functions or organizations employed on it. It also depends upon the pattern of relationships in making decisions viz. which functions work in parallel rather than in sequence, and which are repeatedly involved". He therefore suggests that a flow diagram showing the sequence of relationships between specialists etc. (required for decisions from the start of a project to the completion of its commissioning), is a convenient way of depicting this.

The author agrees with the causes, conclusions and assessments of complexity stated above, but believes that there are two more causes of discontinuity:
- Interfaces not only between the Client's departments but also between the Client and the project's users (as in project E)
- Interfaces between the Client and owners of property the Client has
to take over. (e.g. the allotment tenant of project F and relationship between the Client and British Railways in Project B).

The effects of the latter were outlined in a study by Rothwell et al (1975) in observing the management of an urgent public works project. The project consisted of the raising of some sections of the river Thames flood protection defences. The Client (GLC) had to gain access to many properties which were not owned or controlled by the GLC. The consequences were that:
- negotiations on access and compensation were required
- the flood protection provided by the project had to be to a consistent standard set by the Client, and yet details for each property were dependent upon agreement with the owners of the properties as well as with other statutory authorities, such as boroughs, public utilities etc.

It is the author's experience that failure to draw flow charts, and thus establish the lines of communication between the Client and the project's management team at any moment during the project's implementation, (let alone when the project's implementation is decided as Wearne suggested) is the rule and not the exception. This view is also endorsed by the findings of this research.

In the projects observed either the management relationships between Client's management team were in accordance with the Client's standard procedures or special management teams and Client relationships were established. (Depending on whether the project was standard or unique for the Client's activities. Projects A, D, F are of the first category while B, C, E were of the former category.)
In both cases the management team either dealt with a number of different Client's departments or Users (with conflicting expectations), or with one member of the Client's organization whose departments' expectations were not always in line with the Client's expectations.

In project B for example the Client had no control over the activities of British Railways, although he financed the budget for those works. The result was cost increases in the budget allocated by the Client to British Railways, and delays to the Client's overall programme because of industrial relation problems and lack of control on British Railway's allocation of resources.

In project C the Airport Director's expectations were not in line with those of the Client. Thus works were omitted and reintroduced after the contractor's appointment and a number of design changes were initiated by the Client which resulted in cost increases. Full use of the Management Team's expertise was not always made as in the case of the Operators desks or when leases were awarded to various Users. As a result of the direct lines of communication which existed between the Airport Directors and some members of the Design Team (Architect) quality decisions were taken, with cost and time implications, which were communicated to the Resident Engineer and eventually the Supervising Officer in retrospect.

A similar problem was also observed in project E where some of the Users had direct access to members of the Design Team since the early stages of the projects' design. A year after the first package was let it was realized that requests for design investigations by the Users increased the Design Team's work load considerably and besides
the additional design costs there was a danger that slip-ups to the
out-to-tender schedule were likely to occur. The Client therefore, at
the Project Manager's request, decided to stop such links by notifying
the Users that all such requests had to be filtered through the
Supervising Officer. The lack of a manager for the completed building
also caused problems of communication between Client and Users and some
decisions were delayed.

In project D the Airport Director who was also responsible for the
project's future maintenance gave priority of performance over cost.
This quality improvement which would reduce future maintenance were
approved not because they were cost effective but because the
Director in charge of maintenance anticipated that future cuts in
his budget were more likely to affect the department's maintenance
budget.

Reduced maintenance cost was also the priority of the Project Manager
of project F who was also responsible for the maintenance of the
Client's buildings. In the case of project F the author found it
difficult to establish whether during the project's construction
phase there was a direct line of communication between the
Planning Manager and Design Team or whether the Planning Manager
could ask the Design Team to investigate design changes without
the Project Manager's prior knowledge. (The diagram in Appendix 7
is based on the Project Manager's account).

The author has also observed, during his work in industry, that
serious problems occur when the supervision of the design and
construction is the responsibility of different departments of the
Client's organization.

A clear lesson of the above observations is that it is in the Client's interest to:
- Define lines of communications within his departments likely to be involved with the project.
- Establish lines of communication between Client and the Users.
- Identify interfaces with statutory bodies or owners where property is likely to be effected by the project and coordinate with them.
- Establish lines of communication between the Client and the project's management team; preferably through one person who has the same expectation from the project as the Client and is informed of changes to the weighing of the Client's goals.
- Ensure that authority is delegated to the management team leader and that the duties and responsibilities of the team members are clearly defined, as suggested in Chapter 6. Thus problems resulting from friction within the team, such as those described in section 5 of the case studies in Volume 2 may be avoided.

II Uncertainty

The predictions of what is to be done in carrying out a project may be uncertain. The initial definitions of objectives may also be uncertain. In either case decisions on how to proceed may therefore have to be changed as work for the project is under way.

Wearne (1976) suggests that uncertainty should be assessed in budgeting and planning because he believes that "... the sensitivity and reliability of data have to be assessed for this, and that uncontrolable external variables should be distinguished from internal innovations,
mistakes and changes of mind''.

Heeman (1976) says that uncertainty is a risk to the outcome project measured in terms of uncertainty of performance, timeliness, resources used or costs. He believes that risks due to uncertainty can be attributed to two causes which are partly complementary:
- The risk due to technical innovation which can vary from a research project (i.e. high risk of not achieving success), through to substantial scaling up of known plant and process to minor variations on previous projects.
- Risk due to uncertainty in making estimates of performance, time resources or cost, due to lack of past experience and/or data. The estimating risk at the low end can often be given confidence limits because the estimate is made up from fixed price quotations and well recorded data. At the other end of the risk scale, one is either in danger of extrapolation beyond the validity of experience and data or just plain "questimating".

Parsons (1963) in his paper on what in unexpected in construction states that inherent in every construction contract is a certain unavoidable element of risk or uncertainty. Parsons makes a distinction however between normal risks or uncertainties, and unexpected ones. He defines the unexpected, in a broad sense, as "a change in the general scope of the works contemplated by the contract and specifications, either as a result of a major change in design or unknown or latent conditions that involve either an increase or decrease in the cost of or time required for the performance of work". Thus he categorises the unexpected into: latent, changed, unknown conditions.
Baldwin (1971) in his paper on the causes of delay in construction, compiled a list of causes in order to obtain a consensus of the major risks in construction. Engineers, Architects and contractors were invited to study the list and to rank the risks in decreasing order of importance. The results indicated that weather, labour and sub-contractors were the major concerns.

Byrne (1972) in his paper on the responsibilities of the Engineer and the Contractor under fixed price construction contracts describes several risks the contractor encounters during the construction of claims. (Similar problems could also be present in all heavy civil engineering):

- unusual weather, floods and pestilence, either due to inadequate existing data or because the conditions with a low probability of occurrence prevailed.
- labour and construction equipment costs.
- unknown physical features, probably the most serious and most frequently encountered risk during underground works.
- insufficient funds due to slow appropriations or action by the Client's financing source.
- recording and preserving archaeological finds.
- the hazards due to changes of laws etc. after the award of the contract.

Douglas (1963) in his paper on how should the Engineer cope with the unexpected in construction draws attention to the risk of design errors mainly due to the immense number of drawings, specifications and tender documents, by saying that "no firm with a long history or wide practice can say that it has not had experience with that problem."
No one is perfect... and in fact, a business founded on the anticipation of perfection in defiance of the laws of human fallability would itself soon fail".

This point was also endorsed by the findings of this research as all the project teams interviewed in this research have mentioned a number of design errors or wrong assumptions such as duplication of items in the B of Q, drawings, inaccurate specifications etc. The Clients in most cases seemed to be aware of the major ones, and indeed they accepted their existence. Their consequences were corrected by issuing Variation Orders which were usually covered by the Engineer's contingency of the provisional sums included in the B of Q.

The majority of the problems which were observed can be classed as unexpected e.g. ground conditions, inclement weather, design changes initiated by Client, delayed decisions by Client, strikes etc.

Extensive research has been carried out in order to develop techniques by which risks can be identified and their consequences quantified.

Fraser (1979) in his study on risk minimization in giant projects defines the term risk analysis as the term which engineers use to describe the probability calculations which they can make in order to find or justify a preferred choice of materials, methods or routes, and risk management as a very widely used term, used by the insurance industry, and referring to the necessary calculations needed to make an economic choice of whether to insure or not. Fraser also outlines the following aspects to be considered in relation to these terms:

- The event i.e. what might happen to the project.
The degree of probability i.e. how likely the event will occur.

- The amount at stake i.e. the total loss or losses, which would result.

Thompson (1981) expresses the view that "mathematical techniques may aid the assessment, but such approaches depend heavily on the judgement of the analyst" Thompson believes that at its present state of development use of this technique for financial appraisal is relevant only to major projects. A view also held by Heeman.

The author believes that risk analysis can be useful during the:

- Project's appraisal i.e. when the project's risks of not achieving the expected returns are investigated, especially when alternative solutions or projects are evaluated.

- In estimating an upper and lower limit of the budget the Client should reserve for the project i.e. errors of the single price prediction mentioned in chapter 2 are avoided and thus the Client is more aware of the likely cost he is committing himself to. It is also possible that the contingency sum for the tackling of unexpected risks included in the budget may be estimated as a part of the risk analysis.

The author also believes that trying to identify possible problems prior to the commencement of the construction is more valuable to the management team for controlling the construction, than spending energy and resources trying to quantify them, especially as most of the problems likely to be encountered are likely to be unexpected.

In the projects discussed risk analysis using statistical means was
not used either in the period prior to tendering or in choosing among alternative solutions when problems were encountered.

What the author was able to observe however was how technical risks were minimised by carrying out preliminary site investigations, as Douglas (1963) suggested, and how the anticipated effects of complexity and uncertainty of the project influenced the establishment of the project's management organization and the setting up of the control system.

a. **Site Investigation** Douglas (1963) states that "the engineer has a fundamental duty to minimize the unexpected in construction by gathering comprehensive information concerning existing pre construction site conditions ... Many problems have been caused by lack of comprehensiveness in this area of the Owner's (who is not willing to pay the additional cost) and the engineer's (who fails to pursue the Owner of their importance) responsibilities".

The importance of gathering preconstruction site information was also highlighted in the findings of the case study observations. Ground conditions, different to those anticipated were encountered in all the projects, except E., with varying cost and time implications. Site investigations are carried out when technically they are an essential part of the design (as in projects B, D and E) but their thoroughness depends on the size of the project time available and geographical spread.

In project F for example no preliminary investigations were carried out because of the way the Client chose the sites and the limited
time available. The drainage and foundation problems caused a 30% increase of the budget, which raised questions about the project's feasibility and delayed the completion by 4 weeks, i.e. the Client committed himself to the project on a grossly underestimated cost estimate, and the management team was faced with unexpected increases of its workload which disrupted the flow of information. In project A, because of its small size, no investigations were carried out and the cost of the design changes was covered by the budget contingency. In project E extensive site investigations were carried out, because of the technically difficult foundations, and thus no serious ground problems were encountered.

Problems encountered in projects B and D were mainly due to ground conditions different from those which could reasonably be interpreted from the findings of the ground investigations e.g. the buried wall by the foundation of pier N in project D, which had been missed by the borings.

Their cost consequences in project B were covered by the contingency. The delays were difficult to evaluate because they were overshadowed by the delays due to industrial relations and Government interference.

In project C there were no ground problems but preliminary investigations could have found the existing telephone, gas etc. lines and thus later delays could have been avoided.

b. Uncertainty - Complexity Heeman believes that the risks due to a project's uncertainties and complexities can be represented as a matrix because of their interaction.
The X axis represents the increasing uncertainty in the success of the project in terms of technical performance, time and cost.

The Y axis represents the increasing complexity in terms of the number of interfaces between sections, departments, companies involved in a project.

Thus in the X axis project's will range from:
- minor variations of previous projects
- through scaling up of known technology or processes
- to full development of new equipment or processes.

(Heeman is referring to chemical plant projects but the same principle can be applied to all types of civil engineering or building projects e.g. repetitive, large scale, vulnerable to technical innovation etc.).

Complexity on the Y axis will range:
- from a single department project within one company
- through one involving a client, a main contractor and his sub-contractor
- to a project which in itself comprises a number of subsidiary organizations or projects.

Thus depending on whether a project is identified as low or high risk, Heeman makes recommendations in relation to management organization and control.

In the case of projects B and E, because of risks involved due to their size, complexity, uncertainty, complicated designs, and time
available, the management teams tried to predict and allow for in the contingency the effects of the risks due to urgency and complexity, using their experience with other projects, and by holding meetings with the Engineers etc.

In the remaining projects some forecasting of the possible effects due to complexity (normally of a number of sub-contractors) was attempted in some cases before an activity was about to commence; more often the site managers tried to tackle problems as they occurred based on their experience or personal judgement. The risk involved in the remaining works were considered before a certificate of partial completion was issued, as in the case of projects A, C and D.

The Resident Engineers of project C and D however recognized the importance of forward planning, in anticipation of the effects of risks and complexity, as explained in paragraph 7 of both case studies, in Volume 2.

III Urgency

Wearne (1976) says that "urgency can be assessed on a scale representing the value of time saved in completing a project in the way indicated in Figure 4.1. This can be applied to a specific section of work or to a project as a whole".

Three conditions may be distinguished on the curve:

a) Minimum cost. This is the condition of zero urgency. It is the characteristic of expenditure when little or no financial return expected from the completion of the project. Urgency has therefore no financial value. A faster speed of completion may be desirable socially, but in practice the pressure on administrators controlling such projects tends to be such that they have to plan work to be done for the least capital cost, time is
therefore no money.

b) Minimum time. The duration of carrying out the work at the fastest speed, usually set by physical limits such as space, crane speeds, time for an undercoat of paint to dry etc. This is the characteristic of an emergency. At least temporarily, saving time has complete priority. In effect time is priceless.

c) Optimum cost-time (Commercial urgency). The duration of costing more than the minimum by the amount equal to the value of the time saved, but discounting the latter sum over a period between expenditure and pay back. In effect the commercial urgency point may lie anywhere on this curve since the value of time varies during a project and differs from project to project.
Project A was a minimum cost project. The Owner's objective was not to exceed the budget. The Resident Engineer's objective was to ensure that the design specifications were observed and that the budget was not exceeded.

The project described by Rothwell (1975) and project E were minimum time projects, as both had to be completed by a certain date:

As a result:
- one of the reasons the Client of project E chose to award a management contract (although the Client had never used such a contract before) was to shorten the construction phase.
- the contracts awarded by the GLC were the same type as for the rest of the projects the GLC undertook, but a special management team was set up to tackle the risks due to the project's complexity and urgency.

The author also believes that:

a) The Client of a minimum time project should be aware that he is vulnerable when he has to negotiate rates for the acceleration of the works following a time delay (as in the case of project E following the liquidation of the sub-contractor when the Client had to negotiate new rates with the suppliers and sub-contractors). The Client is also vulnerable to pay demands from the labour force (the works of Olympic stadiums are often reported in the press as interrupted because of industrial disputes). The capital cost of a minimum-time project is therefore likely to be greater than if this project was not urgent.

b) Because of the limited time available, design errors, undefined
relationships etc., are to be expected i.e. the risks due to uncertainty and complexity are likely to be higher.

In the case of commercial projects (third category) the Client's choice of type of contract and management organization, and the management team's decisions when problems occurred seem to be similar to those of either of the other two categories. This is because:
- cost-time optimization cannot be calculated due to the lack of time and cost integration (as discussed in chapter 2).
- change of priorities by the Client during construction.

Project F is such an example. The Client believed that completing the project in the minimum time possible was financially advantageous, but no fixed date had to be met (as in the case of the next project the Client undertook which had to be opened before Christmas in order to meet the season surge in demand). Thus a management contract was chosen because the Client believed that under such a contract the construction is quicker (although the Client was advised by the Design Team that a conventional contract was a cheaper way of building the project); all efforts during the construction phase, spearheaded by the Management Contractor were aimed at completing the project in the minimum time. Neither the choice of the contract nor the acceleration decisions were made following a cost benefit analysis but simply on the assumption that the time saving returns are higher than the additional construction cost.

Project C was treated by the Client as a minimum cost project while to the Airport Director it was a commercial project. During stage 3 of the contract the Airport Director, in consultation with the Supervising
Officer, and Resident Engineer, fixed the opening date and thus after this decision the project could have been classed as a time limited and therefore potentially a minimum time project.

Projects B and D could also be classed as commercial projects. Besides the infrastructure improvement which was the purpose of both projects, the Client of B expected a revenue, and the Client of D was paying for diverting the buses from the unsafe existing bridge. In both cases however the projects were treated as minimum cost projects. Meeting the budget was the objective of project B's management team, solutions to problems during project D's construction were decided with minimum cost in mind.

It can therefore be concluded that while in the first two categories decisions are aimed at minimising the time or cost, in the third category decisions are subject to the Client's goals. These goals are dependant on the Client's nature, project finance and environmental changes.

PHASES OF A PROJECT

Wearne (1966) states that the term project is used to cover the work from the initial study of market demand until the resulting structures and equipment are in use. He shows the sequence of the various project's stages to have a circular form as shown in Figure 4.2.
Thompson (1981) also states that the project's life span is divided into three distinct stages, appraisal, engineering and operation, and that the engineering stage consists of three overlapping phases, design construction and commissioning.

Warnock (1979) expresses the view that the project's cost is decided to a large degree by decisions taken during the appraisal stage by stating "At the end of the appraisal stage the plan for the project is accepted in its broad conceptual terms, estimates are refined, schedules are decided, economic viability is established and "bankability" is accepted at a sufficient high level of confidence.... When the project is released and the engineering stage commences, months or years after the commencement of the appraisal stage, during the project design phase refinements of engineering and cost estimates may now have led to some reduction in demand for capital funds.... the scope of variation however diminishes as the design progresses".

Warnock also points out that during the design phase, depending on
the risks due to the project's uncertainties, the type of contract is decided and the contingency sum which will be used by the leader of the management team to tackle problems during the construction phase.

Warnock recommends however that for large projects, a close integration between the design and construction management elements ".... Subdivision of the overall project into work packages with clearly defined interfaces will enable those elements requiring an early start or advantage procurement to proceed.... The main objectives of the contract package approach are to limit commercial risk and enhance competition".

Lemby (1981) studied in detail the experiences gained and the problems encountered in connection with ongoing cost steering and control during the construction of the first two nuclear power plants in Sweden. His conclusion is also that the cost of a project is to a large extent determined in the first stage of the work (appraisal) during which the most important decisions are made, as shown in Figure 4.3.
Fig 4.3. STEERING EFFECTS
Curve 1 shows, in principle, how the possibilities of reducing cost within the scope of previous decisions gradually diminish. During the latter phases of the project there is not much that can be done to diminish the total cost. On the other hand, the consequences of disturbances of different types can be minimised by thorough and persistent resource planning and job preparation including double-checking of all changes by means of carefully drawn up alteration routines. Curve 2 shows how, in principle, the accumulated amount invested in the project increases with time.

In conclusion:
- decisions during the project's appraisal stage determine to a considerable degree its cost and the time span within which the contract may be completed. Design refinements during the design phase may produce some further cost savings.
- in large projects overlapping of the design and construction phases is preferable.
- if the Client decides to abandon the project prior to the appointment of the contractor (or of the first contractor) the cost will be relatively small, as opposed to the loss he will have to incur later due to the rapid increase of expenditure during the construction phase.

The author agrees with the first conclusion. It is important to note however that reappraisal of the chosen alternatives may be advisable especially when the appraisal and design cover a long time span, and the previous assumption may have to change. In project D for example the feasibility had to be repeated due to a shift of emphasis from urban motorways to public transport.
The author believes that the design and construction project phases are usually overlapped to various degrees. For example, the detailed design is usually completed after the Contractor's appointment. Phase overlapping however is only of interest to the project's construction control only if design decisions with cost and time implications are expected to be made during the project's construction e.g. architectural finishes, provisional sums.

Dividing the work into a number of contracts is desirable, especially in large projects, because design choices are taken on the basis of more realistic data; but it should also be remembered that it increases the project's complexity, because of the number of contractors involved.

Our research has shown that the degree of overlapping of the engineering phases depends on:

- the weighing of the Client's goals. If time has priority over cost, as in the case of project F, the design was overlapped to a high degree with the construction. At the other extreme when minimum cost is the objective, as in the case of project A, the design is first completed and approved before the contract was put out to tender.

- the project's size. In project B for example, due to the size of the works they were phased and divided into discrete packages and thus the project's design and construction had to be overlapped. Advanced procurement of materials was also carried out.

The author agrees with the view that the Client should reappraise his project prior to the commencement of construction, when he may decide to abandon the project with a relatively small financial loss.
It is the author's experience however that this reappraisal seldom happens, mainly because Clients are reluctant to abandon projects after the design has reached an advanced stage; projects are usually reappraised as a result of restraints on the Client's capital, as in the case of project B.

For projects which are unique to the Client's operations, the degree of overlapping of the engineering phases is important because it influences the timing of decisions relating to:
- the choice of the type of contract, and the setting up of the project management organization.
- the commencement of the formulation of the control procedures and of the design of the control system.

In the case of projects B and E members of the management team for the project's construction were appointed approximately a year prior to the target date for the commencement of construction. The formulation of the control system was one of the main aims of the appointees. The framework of the system for both projects was ready by the time the construction commenced. The procedures were finalised and agreed approximately a year later.

In projects A, C, D and F the type of the contract had been decided at the beginning of the design phase and the management team was appointed, or in the case of C, set up, after the appointment of the contractor. The project control procedures were in accordance with the systems used by the Engineer etc. for all the projects they undertook; except in the case of project D where reporting had been influenced greatly by the experiences of the Resident Engineer.
4.2 CLIENTS

THE CLIENT ROLE - TYPES OF CLIENTS

The PE Group in their studies of public sector building and civil engineering projects for NEDO (1974), state that the Client's role (i.e. input in the project's management) should be:

a) to define the scope and objectives of the project
b) to decide on priorities
c) to decide on method of proceeding
d) consequently, to create a brief for the designer
e) to monitor both the design and construction phases
f) to resolve conflicts on either stage by reference to the purpose and priorities already defined
g) to react swiftly in such matters as consideration of variations.

The Group observed the following differences in the attitude of public and private Clients in the UK towards the management of construction projects:

- The types of contracts awarded in the public sector are conventional contracts. In some projects, such as housing, the contractor is involved at an earlier stage of the design phase; however they are virtually all package deal projects in which the design/construct organization takes over complete design responsibility rather than advising the design team as Banwell had envisaged.

The view that Public Clients are not as flexible as the Private ones appears to be applicable world wide. As Smith et al (1975) stated that "The type of contract used by the Public Client is usually restricted by government laws and regulations but a Private Client can use any type of contract he can negotiate".

- In the public sector, payments to the contractor are made promptly,
but the final settlements are long delayed due to administrative reasons on the Client's behalf and the contractors tardiness in presenting and agreeing their final accounts.

Both the public and private sectors are cost-conscious. In the case of the public sector their prime concern is return on investment and this allows them to be repetitive to large variations in price, providing there is a sound commercial reason.

Time however is of the utmost importance in the private sector, since finding the right market conditions is becoming more and more difficult, costs are increasing fast and letting conditions are unfavourable. Quality is also important to the private sector, if the building's Owner is to secure tenants.

In the public sector time and quality are also given priority in prestigious projects where target dates have to be met, as in project F, or in emergency projects, as the GLC project described by Rothwell et al (1975)

Private Clients tend to be more closely involved in monitoring their projects than are Public Clients. This may be attributed to the organizational complexities of the public Clients, due to their fragmentation between various individuals and departments.

The PE group states that ".... the end user is generally represented by a committee of elected members, which transmits its wishes to a permanent officer. In turn he has to cooperate with officers in other departments who are of equal or even more senior status. Unless cooperation is particularly good between the parties, there is real danger of confusion and poor communication of the basic aims of a project".

Clients of construction projects can therefore be distinguished into two categories, based on their sources of finance and legal...
status. Both of those elements determine to whom the Client is accountable, and to which degree.

a The Public Clients such as Government Departments, Local Authorities, Nationalised industries. Public Clients are accountable to the public or a public body since a sizeable part of their finances in taxpayers money in the form of direct grants and subsidies. The type of projects they undertake tend to be "minimum cost projects" and "emergency projects". Nationalised industries may undertake commercial as well as minimum cost projects, depending primarily on the nature of their business and secondarily on the political views of the government. Public Clients undertake building as well as civil engineering projects.

b The Private Clients main finance is usually obtained from private sources. Private Clients vary from a private person who wants his home to be built or a building for commercial purposes, to a group of individuals or public liability companies which will build a commercial project (projects). Usually projects built by Private Clients, with the exception of heavy plants (chemical etc.), are building projects.

In the University of Reading study (1979) on "UK and US construction industries; a comparison of design and contract procedures" it is concluded that "The attitude of a Client towards buildings not only varied according to whether he was a primary or a secondary constructor (see below) but also depended on his profit margins (i.e. primary Clients tended to become more involved with the project management). A highly profitable company for which a building is only incidental to its objectives will adopt a different approach for procuring a building from a company with very low
profit margins).

In this study, Private and Public Clients are distinguished into primary and secondary, depending on whether the project is a means to an end or the end for the Client's activities.

- primary constructors. They are those organizations whose prime aim is providing construction facilities. In the public sector, this includes the property departments of various government departments (e.g. Clients of projects A, D and E). In the private sector it includes property developers and hotel developers (as distinct from hotel operators).

- secondary constructors include manufacturing or retail companies whose expenditure on construction facilities is a small percentage of the total turnover of the organization (such as the Client of project F).

In the NEDO (1983) booklet it is suggested that the degree of the Client's input into the project's management should increase if:

- the project is highly specialized or unusual compared to the rest of the projects the Client implements, as in the case of the GLC project, or project E.

- speed has priority over cost. The EDC believes that the construction industry's performance, in the UK, varies from firm to firm and that "...the industry will not offer generally quick design and construction unless it is pressed to do so". This belief which influenced the Clients of projects E and F to appoint a management contractor in the project's management team.

- the Client is experienced in the management of construction projects. As the EDC points out "...some Clients have an almost continuous building programme and a high level of inhouse
expertise, while others will build once a decade or once a lifetime.

In conclusion:
- the Client's definitions of priorities and objectives (goals besides the uniqueness of the project are also influenced by the Client's nature.
- the procedures of project management and the Client's input into management decisions should be determined by the project's nature and uniqueness and the Client's goals and experience, but they also appear to be restrained by the Client's nature.

The author agrees with the above conclusions but also believes that the Client's experience, size and nature need closer examination.
- An experienced Client is expected to have a better understanding of the problems involved with construction projects, and therefore he can provide a positive management input.
On the other hand existing inhouse departments add to the project's complexity and standard procedures of contracting and control are in use which may not be suitable for the particular project.
- If the Client is inexperienced then he will need advice from a professional such as an Architect etc. If this relationship is built on mutual trust and confidence then the Client's inexperience may not prove such a handicap. In project C for example because of the good working relationship the Resident Engineer had with the Airport Director, decisions to accelerate or decelerate works or change the contents of the construction phases were taken quickly and a number of claims and delays were avoided. The author would like to emphasise however that such relationships of trust can only be built on a personal level between the people who are authorized to make decisions and are responsible for the every day management.
The author believes that the Public Clients are hesitant to adopt new types of contracts, or change existing procedures of awarding contracts settling final accounts etc. due to their accountability to the public. Public Clients are exposed to public criticism by MP's newspapers, Parliament etc. and to a retrospective check on the use of public money by public auditors who have very little relationship or knowledge of project management. Safeguards in order to protect the decision makers have therefore been presented, such as laws or procedures (e.g. accept the lowest tenderer) which in the author's view does not always benefit the project and they tend to slow down the decision making process, e.g. the choice of the management contract for project E was not due to projects risks but was only made when the Client realised that under a conventional contract there was a high possibility that the target date could not be met.

Private Clients are either accountable to a small number of owners (or one person) or in the case of public liability companies to a large number of share-holders.

In the first case the degree of flexibility and quick decision making will depend on the personal relationships between the Owner(s) and the project's management team.

Public corporations are in theory accountable to their share-holders,
represented by the Board of Directors. It is widely accepted however that the power of control of the firm remains with the management. Galbraith (1977).

It is therefore expected that decisions will be made more quickly, following direct consultation with the top management when it is required.

Private Clients with inhouse design and supervision teams do suffer from problems because of complexity as much as Public Clients. This point was also made by the Project Manager and PMR of project F. They both pointed out that because the Client did not have an inhouse team, decisions would be made quicker as opposed to some of their large competitors where the types of contracts and contractual procedures were more bureaucratic.

The author also believes that one more restraint on the employees of Public Clients is their difficulty to define what is "good value for money for the Client" when a minimum project is implemented.

GOOD VALUE FOR MONEY

Snowdon (1979) in his paper on project management states that "Mere achievement of a project does not necessarily mean that it was successful. In fact most projects in retrospect have some shortcomings. It may be stating the obvious to suggest that establishment of criteria for success renders achievement more likely. Nevertheless it is a fact which is usually overlooked".

In the NEDO (1976) booklet on the professions in the construction industry it is stated that "Value for money depends on achieving the right balance between capital cost, running costs, project duration,
quality in all aspects, durability and adaptability ... If value for money could be defined and evaluated, it might provide a strong incentive to all participants in the construction process to achieve it. .... It is also hard to evaluate the degree of success or failure in achieving value for money. Since each project is unique, a judgement has to be taken in every case about what is the right balance between the contributory factors to value for money".

The PE group (NEDO 1974) suggests that defining value for money in the private sector is straightforward while in the public sector such a definition is more complex. "Value for money in the private sector is to obtain a good return on the invested capital. Cost per square meter, functionality and quality are likely major factors, together with the time taken to complete the project, so that the investment can bring a return at the earliest opportunity. In the Public Sector, concepts of value for money are largely determined in relation to official cost yardsticks .... Value for money in the public sector is thus an indefinable entity which must stem from the conceptual planning of the designer working to the brief of the Client.

The negative effects of the public sector's yardsticks, mainly cost yardsticks, are also emphasised in the NEDO (1976) booklet ".... cost yardsticks incorporate a rationing element i.e. the conscious choice to limit standards, with the intention of making a fixed amount of resources spend further than they would otherwise .... initial cost yardsticks tend to degenerate however into an attempt to hold costs static in an inflationary era. ....work is thus delayed when tenders exceed the yardsticks and means are sought to circumvent the systems
.... attention is focused on initial costs, sometimes at the expense of the other factors contributory to value for money, so that poor quality building results".

Both in the NEDO (1974) and NEDO (1976) it has been stated that "management competence during the design and construction phases is vital in maintaining the value for money designed into the original concept. Clearly variations and claims can erode value for money, as can poor control of quality during the construction period".

In the course of this research the author has observed that:

a) It is difficult to define value for money in the public sector where projects of minimum cost are concerned. In cases of minimum cost projects, as projects A, B, C and D, the Client usually considers value for money a project which was finished within the originally reserved budget. As problems were encountered design standards were lowered or the time schedule was allowed to slip. Thus an independent observer may question whether the finished projects are value for money for the Client e.g. projects finished within the budget but requiring high maintenance costs or built in double the time than planned, while in both cases an additional expenditure could have allowed the management team to achieve the originally planned standards or time schedule. The question arises however whether the Client can raise the additional capital.

b) Variations to the original design brief issued at the Client's request or indeed in order to counteract unexpected problems may erode the value for money based on the original assumptions, but changes in the conditions during the project's construction make them necessary.
In all the observed projects instructions to vary the works were issued either at the Client's request or to counteract unexpected problems. As these can affect the resulting value for money, the management team should try to monitor and control variations.

In projects B and E written procedures were prepared and agreed by the members of the team and the Client's representatives to determine the evaluation, authorization, issuing and monitoring of all design variations. Meetings served for discussing proposed variations, while the final decisions were taken by authorized member or members of a management team.

In project F there were no written procedures, but the frequent policy and design meetings and the MC's pink slips and monthly report ensured the tight recording of all the Architect's instructions. Some instructions with anticipated major cost/time consequences were evaluated prior to their issue.

In the case of projects A, C and D control of instructions to vary the works prior to their issue was left to the Resident Engineers. They used their discretion whether to consult with the Engineer/Supervising Officer prior to issuing a variation. Monitoring of the Engineers'/Supervising Officers' instructions was not as tight as in the case of project F. Both the Resident Engineer of C and D recognised the need for improvements in the monitoring and control of those instructions. (See sections 7 of projects C and D in Volume 2).

The conclusion the author has drawn from the above is that monitoring and control of instructions to vary the works is possible and should
be the objective of a project's control system; and that if variations are to be controlled attention must be paid to the following:

- The management team must be kept informed throughout construction of any changes in the Client's definition of value for money.
- Client initiated requests to vary the works must be evaluated (by the management team), authorized and issued on the basis of agreed procedures between the Client and the management team.

The appointment of a Project Director by the Client whose duties and responsibilities are discussed in Chapter 6 and 7 of this Volume, should ensure that the above objectives will be achieved. If a Project Director is not appointed, the authority of others to request a design change investigation and then approve it should be specified.

- The Client must be consulted prior to the issuing of instructions to vary the works due to unexpected problems and which are anticipated to have major cost/time consequences, except that the Engineer/Supervising Officer should be allowed to issue instructions which he considers unavoidable or urgent, and inform the Client.
- The Engineer/Supervising Officer should be allocated a contingency sum with which he can cover the costs of these exceptional instructions.

Evaluation of major variations prior to their issuing does not mean that an accurate quantification of the consequences can be produced. As was observed in projects B and E where computerised programmes were used, the indirect consequences due to interference etc. became apparent much later following an instruction to vary the works.
What the author is suggesting is that consequences are discussed (and the most favourable alternative for the Client is chosen) among the members of the team, and in the case of traditional contracts between the Engineer's site staff and members of the Contractor's site staff. An estimation of the direct costs, and perhaps a less accurate one of the indirect ones may be produced, but the Client should be aware that there is a risk that this may be exceeded. Insistence by the Client for the team, Contractor etc. to commit themselves, will be in the author's view met with either reluctance of the team, Contractor to produce such statements or with deliberate overestimations.
4.3 ENVIRONMENT

Stocks and Male (1983) in their report on "the Client's perception of contractual forms and procedures" state that an organization's environment can vary between stable and dynamic.

Mintzber (1979) in his book on "the structuring and organization" sees the dynamic environment as being the cause of uncertainty within the work of an organization. He therefore suggests that it is important for the organization to respond quickly to an environment which is becoming dynamic.

The influence on the environmental pressure on the project organization were also emphasised in the comparative study of the UK and USA construction industries conducted by the University of Reading (1979). "It appears to be extremely likely that the pressures imposed by the environment and by clients are systematically related to, and to a large extent justify, the different procedures adopted by the UK and US construction industries. This view can conveniently be described by regarding the construction process as consisting of three elements. The obvious and probably essential elements are the architect's and engineer's design roles and the role of the specialists who carry out the actual construction. The third element is the role of creating a project organization which enables the designers and constructors to work effectively, as far as possible in a controlled and predictable manner, while meeting demands for public accountability. Design and contract procedures give expression to the third element, which we may call organization".

A number of environmental differences between the USA and UK
construction industries and their implications are reported in the Reading report. The consequences of such differences which may be observed between any two countries can be summarized as follows:

- steady demand, achieved in large and rich markets, which encourages the creation of a variety of reliable firms because of the steady work flow
- inflation rates. High rates or rapid changes create uncertainty in the appraisal of projects, and in the prediction of the Client's and Contractor's cash flows. The effects of cost escalation of a contract have also to be considered in allocating the risk when the conditions of the contract are drafted (Perry & Thompson (1977) 'Construction finance and cost escalation').
- differences in prices of materials, create preferences for certain types of materials.
- high productivity may result in higher labour wages, but the overall unit costs can be lower.
- high interest rates can affect investment in construction projects but they can also affect the preference for time over cost (especially in the private sector).

Because all the projects observed were built in the UK, the author was not able to observe the influence of the environmental differences on the organization or choice of contracts.

What was observed however was the influence of the environmental changes on the Client's goals and choice of contracts. Project B for example was twice stopped as a result of government policy to curtail public expenditure.
Change in the market trends resulted in a decrease of demand for office space, by British Airways, in project C. In project D the Client's priority for low maintenance costs (their definition of good value for money) had to be curtailed half way through the construction following government policy for cuts in public expenditure.

Other environmental changes are due to changes of legislation concerning building regulations, taxation, policy on planning approvals and fluctuations in the demand the products or services the project is built to produce, sell or offer.
4.4 CONCLUSION

A project's construction success may therefore be vulnerable to expected or unexpected risks due to the project's size - complexity - urgency, the Client's nature, experience and definition of good value for money, and the possible changes of the economic environment.

The Client's attitude towards those risks should determine the construction contractual relationships i.e. the distribution of risks between the Client and Contractor, and the authority delegated by the Client to the management team to manage the risks undertaken by the Client.

The management team should then formulate a system in order to monitor and control the Client's risks.
5. TYPES OF CONTRACTUAL RELATIONSHIPS DETERMINED BY CONDITIONS OF CONTRACT

The ICE (1976) booklet Civil Engineering Procedures states that "the Conditions of Contract define the terms under which the work is to be carried out, the relationship between the Client and the Contractor, the powers of the Engineer and the terms of payment". i.e. the C of C specify the payment system to the Contractor and the organizational arrangements between the three parties involved (Client, Engineer, and Contractor).

Systems of payments and organizational arrangements used by the construction industry can be classified into three and four groups respectively. A project's Condition of Contract can therefore be formulated based on the principles of a combination of those two groupings which the author defines as the type of contract.

Confusion often arises in industry because a type of contract may be named after the payment system or the organizational arrangement. The author believes that confusion can be avoided if the type of a contract is defined by indicating both the payment system and organizational arrangement contained in the Conditions of Contract e.g. a traditional contract with B of Q or lump sum; a management contract with a target cost fee etc.

In the following paragraphs, based on the case studies and publications, the types of contracts used in the building and civil engineering industries in the UK, and their potential advantages/disadvantages are analyzed by examining:
a) the possible systems of payments

b) the possible organizational arrangements.

Similar types of contracts are in use in other countries such as the USA, Germany, India, Greece etc. as it appears in papers by Byrne (1972), Smith et al (1975), Warszawski (1975), Kettle (1976), Barrie (1976), Dressler (1980), Core (1980) etc. What may differ from country to country is the:

- degree of authority and responsibility delegated to each of the three parties

- the extent to which each type is used in each country.
5.1 PAYMENT SYSTEMS

The ICE (1976) classifies the following types of payment systems which are also used in the building industry:

A. Measurement Contracts

I  Bill of Quantities.

The Bill of Quantities contract is based upon a detailed bill of approximate quantities (computed from the drawings by the Engineer) which includes brief descriptions of the work to be undertaken, against each item of which the Contractor has entered a unit rate or price. The contract price is the aggregate amount of the various quantities priced at the quoted rates. During the performance of the work the actual quantity executed under each item is measured and valued at the quoted rate. i.e. under a unit price payment system the Client carries the price risk. The result is that the method of work is decided by the Contractor, unless a specific method has been specified and thus priced. A number of disputes may therefore arise when the Contractor after his appointment proposes a specific method which the Engineer etc. finds unsatisfactory.

Provision is made for valuation and adjustment of rates for varied or additional works. Major variations however usually result in a complete renegotiation, or negotiation of new rates. Thus as long as major variations are not initiated by the Engineer, the final cost of the project can accurately be predicted subject to the final measurement of the executed quantities.

Monthly quarterly etc. cash flow predictions are also difficult since the Engineer has no control over the Contractor's decisions when to do
the work, and due to the lack of integration of price cost and method of work (described in chapter 2). It is probable that the impact of those weaknesses on forecasting and control may be reduced with the use of method-related charges and if the Contractor is asked to submit with his offer a separate sealed envelope with a breakdown of his unit prices, as suggested by the RE of project D. (Volume 2 subsection 7.2a). This envelope would only be opened if the Contractor is awarded the contract, otherwise it would be returned to the Contractor.

It was observed in the research that B of Q also tend to suffer from errors due to duplications and omissions, and large approximations in the PC and provisional sums they contain. Such human errors are more acute in large contracts (e.g. project C, D and frame package of project E), and are attributed to the lack of coordination between the people who put the B of Q together and the short time available.

II Schedule of rates

The usual form of schedule of rates payment is a list of items of work covering the operation which a Client may want. No quantities are given. Sometimes the Contractor is invited to affix his rates to the items, sometimes to quote a percentage above or below rates previously entered by the Engineer. The Contract usually relates to a defined geographical area and to a stated period of time. The Contractor may be called upon to undertake any of the items of work anywhere in that area during the term of the Contract. Another form of this type of payment is applied to one specific project where speed in commencement of construction is of great importance. In this case a short list of the most important items of work is prepared,
complete with representative quantities. These items are priced by the Contractor and, if accepted, become the basis for negotiating prices for subsequent items of work as these become available.

A schedule of rates is best suited for repetitive work.

B. Lump Sum Payment

The description 'lump sum' is generally used to mean contracts in which a single payment is made when all the work is complete. It is not a precise description because it is also used where payment is made in instalments on the completion of defined stages of work or where a proportion of the total payment is retained during the 'maintenance' period of the contractor's responsibilities for defects after the project has been completed and handed over. In effect a JCT contract with a B of Q with fixed quantities is a 'lump sum' type as payment is made for each defined quantity of construction completed, but in practice this description is used to mean contracts with simple systems for payment of all or most of the contract price on completion of construction (as in the case of project C).

The attraction of lump sum contracts is that they are simpler to prepare and administer, particularly in not including a detailed B of Q. The JCT models offer the option of not including quantities. The same is possible with the ICE/ACE/FCEC model for civil engineering. Though not commonly thought of as a model for a lump sum contract, these conditions can be used in this way by changes to some clauses to omit references to a B of Q and insert a basis for payment of a lump sum or instalments. Lump sum payment are therefore not a radical alternative to the types of payment traditional to building and civil
In the USA and Middle East lump sum contracts were more popular than measurement contracts but in recent years there seems to have been a change in this trend as the argument that their advantages are less than their disadvantages.

Their advantages are the simpler basis of payment and thus the reduction of the costs of project management.

Their disadvantages are that:
- the contract's final cost is higher than under a measurement type of payment since the contractors responsible are expected to include in the prices most or all of the expected and unexpected risks and be paid for them irrespective of whether they occur.
- lump sum payments may attract gambling contractors of questionable financial and technical reliability and avert serious contractors. As Carr (1977) argues in his paper on paying the price for construction risk, "... lump sum contracts do not preclude risks for the Client but change them .... Reputable contractors might avoid a high risk lump sum contract, because they expect to be undercut by contractors who fail to see the risk or desire such a risk".
- there is no detailed basis for assessing contractor's claims.

Lump sum payments are therefore appropriate for low risk projects, for which the design is finalised before contractors are invited to tender. It was generally agreed for example that a JCT with quantities was not the right choice of contract for project C.
C. Cost-Plus Reimbursable

In using any of the above systems of payment the Client has to decide what he wants built and the project team have it designed in detail if Contractors are to be invited to compete to offer the lowest tender price for construction.

If what is to be constructed will be decided in stages during construction one choice for a Client of a project is to appoint a Contractor to provide the management, labour and plant likely to be required and then for decisions on their use to be made as design decisions proceed. The Contractor tenders prices for manpower and plant per hour etc. used but decisions as when to use them, order materials, employ sub-contractors etc. have to be agreed with the Client's representative. The costs of these are paid as used, plus either fixed amounts or a percentage for overheads and profit. Such payments are known as 'cost-plus' or 'reimbursable' contracts. In effect the Client is acting as his own Contractor in taking the risks of planning the use of manpower and plant.

Under some of these systems of payments the contractor is paid only for productive costs, and therefore has to repeat at his own expense construction work which is sub-standard. If work is experimental or hazardous (high risk) it is more usual to repay real costs unless the contractor has been negligent in following instructions.

This system of payments is therefore appropriate if what is to be built is uncertain until it is started and either completion is urgent or design decisions cannot be made except as construction proceeds. It is therefore most used for emergency or maintenance work.
Potential advantages:
- Construction can overlap design.
- Design can be changed as construction proceeds.
- The project team gain construction experience.

Potential disadvantages:
- Final cost and payments due during construction are uncertain.
- The chosen Contractor's prices for manpower and plant are likely to be high as he cannot plan to use them economically.
- Selecting between Contractors as the basis of prices does not commit the chosen one to use manpower and plant efficiently.
- Contractors may not allocate their best managers to such contracts, as they provide only a fixed profit and give individuals limited managerial experience.
- The project team has to be large enough to take part in planning the detail of construction and to check all the Contractor's costs.
- Changes of design are not discouraged by the threat of claims from the Contractor.

The best results of cost-plus reimbursable payments therefore appear to be obtained where the Contractor has ample resources to undertake unexpected problems and a concern to maintain a reputation with Clients or their representatives.

Mechanisms can be built into the Contractor's fee which will act as an incentive for the Contractor to manage his resources efficiently.

I. Cost plus percentage fee. The fee is a fixed percentage of the allowable cost. The Contractor's only incentive to restrain costs or
minimize the construction time span is a fear of damage to his professional reputation.

II. Cost plus fixed fee. The fee is a fixed lump sum usually based upon an agreed estimated cost. The Contractor in this case has a financial benefit in completing the job in minimum time because his time related overheads are reduced.

III. Target cost and guaranteed maximum fee. If what is to be constructed will be decided during construction but can be described at the start an alternative to the cost-plus reimbursable system of payments is one in which a 'target cost' for construction is agreed when entering into the contract and the Client and Contractor share the savings achieved or share the excess actual cost.

This is intended to give the Contractor some protection against uncertainties and an incentive to control costs. The problem is in defining the basis of the target. It is needed only if the work to be done is uncertain, but it must be defined. This system of payments is therefore appropriate if what is to be constructed can be at least approximately defined at the start and the uncertainties are in the time or sequence in which the Contractor can do the work as delays can be measured and their effects calculated.

A variant in this type of payment system is one in which the Contractor guarantees that the total cost to the Client will not exceed a specified amount. This has the advantage to the Client that the Contractor takes more risks, but it depends upon the project team being able to specify what is to be built before the contract is agreed.
In the USA the guaranteed maximum type of agreement is also known as an "Upset Price" contract.

Dayworks and convertible contracts may also be classified under the cost plus fee group.

**Dayworks**

Many larger contracts that are of the traditional type for the construction of defined work also include a "Dayworks" section requiring Contractors when tendering to give prices for the use of manpower and plant by the day or hour if ordered by the Engineer or equivalent. In effect these are a cost-plus section within the B of Q of a mainly traditional contract as described earlier. They have the advantage and disadvantages of a cost-plus reimbursable contract as described, but only come into effect if ordered.

Use of the Dayworks items in a B of Q is usually limited to emergencies and urgent but unexpected work.

**Convertible Payments**

If what is to be constructed is uncertain when it starts but should become certain part way through a contract can be written so that work up to a defined date or state of progress is paid for on a cost-plus or target basis but then may be converted to a lump sum or B of Q type of contract. The choice of whether to convert is usually the Client's.

The right to do so and the requirement on the Contractor to give firm prices when the detailed design is provided must be written into the initial agreement. In some cases the Client also has the right to
end the contract at that time, to be able to invite competitive prices from other Contractors; but in practice the change to another contract seems so likely to cause delay unacceptable to the Client that contractors don't expect it to happen. To achieve the purpose of such a contract the Client must therefore plan for an interruption to construction.

The advantages of this arrangement if achieved are therefore those of the cost-plus or target type of payment in getting work started when needs are uncertain, but also the advantages of lump-sum or a B of Q payment in limiting the remaining cost to the Client.

It can therefore be concluded that choice of a payment system for a contract will determine the Client's risk, Contractor's incentive and the Client's flexibility to introduce changes.

These relationships have been illustrated by Thompson (1981) as shown in Figure 5.1.
The significance of those relationships is that they may influence the choice of organizational arrangement between the three parties involved during the project's construction phase.
5.2 ORGANIZATIONAL ARRANGEMENTS

To consider possible organizational relationships between the parties to a contract, it may be useful to look at publications on achieving good relationships and cooperation between departments within an organization.

Snowdon (1977) states that the purpose of an organization is to facilitate the tasks of people and when several are involved to make it possible for their activities to be coordinated .... the purpose of setting up an organization is to permit people to undertake the work that they have to do in as efficient a manner as possible. The establishment of an organization implies that the necessary resources are brought into a relationship with one another and there is satisfactory communication or flow of information between them. It is also implied that the activities required are brought under satisfactory control to achieve whatever purpose is required.."

Snowdon (1977) believes that when the organization is established:
- the responsibilities of the participants should be clarified "No person can contribute to the maximum of his ability if he is not sure of the boundaries of the task he is expected to perform. If there are omissions or overlaps between adjacent areas there will be neglect or duplication .... Management of the project also demands that responsibilities are clarified also to make sure that action will take place on all the required aspects".
- special attention should be paid to problems of verbal and written communications "The golden rule is to remember that all communication is for the benefit of the receiver .... Too little breeds assumptions, which may be wrong; too much implies that some of it
is irrelevant and the receiver may fail to attach the right significance to some part of the message". 

- the timing and type of information should be decided e.g. technical (expressed in drawings, specifications, standards instructions or reports). commercial (e.g. conditions of sales, contracts, measurements, prices etc.) and administrative (e.g. letters memos and permits etc.).

These principles are important in the determination of the organizational arrangements between the three parties, as well as between the individual members of the management team which are examined in chapter 7.

Four types of contracts which are used in the UK and USA are examined below listing the potential advantages and disadvantages of each choice for controlling the quality, speed and cost of construction.

A. THE TRADITIONAL CONTRACT SYSTEM

In what is called the traditional system, worldwide, a building or civil engineering project is constructed by a firm of Contractors employed by the Client for that project, consultants having designed the project in detail and the Contractor being chosen after tendering in competition with others on the basis of drawings, a specification and other contract documents prepared for the Client by the consultants.

I Civil Engineer

The model for relationships between Client and Contractor for the construction of a civil engineering project in the UK is provided in
conditions of contract agreed by the ICE, ACE and FCEC. Revision of these Conditions and guidance on their use are the responsibilities of the SJCCC.

In these contracts a person named by the Client as 'the Engineer' has powers and duties to supervise the Contractor's work for the Client. The Engineer administers the contract and can also issue variation orders to the Contractors to change what he is committed to construct. Their contractual relationships in this system are indicated in Figure 5.2. The formal channels of communications between them are indicated in Figure 5.3.

As this system evolved in the XIXth century the consultant employed by the Client to advise on starting a project, designing it and preparing the contract documents was usually named as 'the Engineer'. More recently Clients have tended to name their Chief Engineers or other senior employees as 'the Engineer'. (As in project A.)

The quality of construction required is specified by the Engineer in the drawings and specification for a project. The Engineer has the contractual power and duty to insist that the Contractor endeavours to achieve what is specified. If this fails the Engineer may get sub-standard work remedied by others at the Contractor's expense.

The cost of construction to the Client is indicated by the prices in the tender from the Contractor. The actual cost can be greater or less, for these reasons:

- When tendering a Contractor is required to price the project in detail item by item in a bill of quantities prepared by the
FIG. 5.2. TRADITIONAL CONTRACTUAL RELATIONSHIPS IN THE UK

FIG. 5.3. COMMUNICATION CHANNELS IN THE TRADITIONAL SYSTEM

FEATURES OF TRADITIONAL TYPE OF CONTRACT

- Separate designer
- Single general contractor appointed when design is completed (although parts of the detailed design may be carried out after contractor's appointment)
- In the UK, measurement payment system or lump sum. Lump sum is more common in building (JCT with quantities) than in civil projects. Lump sum is more common in USA. Cost plus may also be used
- Negotiated professional fee for design consultants
consultant or cost advisers. The actual cost to be paid depends upon the actual quantities of each item ordered by the Engineer.

- The Engineer may order variations and decide prices for new items.
- The Contractor can claim for extra payment for Variation Orders and for some losses.
- An optional clause in these Conditions of Contract provides that the B of Q prices will be adjusted during construction according to the effects of inflation on the basis of indices produced independently for the industry.

Payment by the Client to the Contractor is normally monthly, on the basis of the Engineer's certificate of work completed and agreed claims, but less a proportion retained for a year after the completion of construction during which the Contractor is responsible for maintaining the work to the standards of the drawings and specification.

The Engineer has the power and duty to make decisions on the Contractor's claims. Disputes on any decision by the Engineer go to arbitration if requested by Client or Contractor. Settlement of the final cost to the Client may therefore be a year or more after the completion of construction.

Planning, methods of construction and progress are the responsibility of the Contractor, though proposals have to be submitted to the Engineer. The Engineer has the power and duty to grant the Contractor extensions of time for some causes of delay. As Reynolds (1980) explains in his book on the measurement of civil engineering work "The Engineer's representative (RE) has to watch and supervise the erection of the works (Clause 2 (i) of ICE 5th Edition revised January 1979)
and the work must be constructed, completed and maintained to the Engineer's satisfaction unless legally or physically impossible (Clause 13(i)). The Engineer provides the Contractor with design criteria to enable him to carry out his responsibilities. The Engineer ensures that the methods of construction employed will not adversely affect the permanent works and without reducing the Contractor's responsibilities, that the possibility of an unsatisfactory result is minimised".

The Contractor is responsible for the work of all sub-contractors, including any nominated by the Engineer.

Potential advantages:
- The Contractor takes the risks which a competent and experienced Contractor should be able to foresee and control and thus it is in his interest to try and carry out the work as efficiently as possible.
- One Contractor is responsible to the Client.
- The Engineer, his Resident Engineer on site, and the Contractor should bring to a project their accumulated experience of other projects.
- The detailed B of Q provides a basis for paying the Contractor precisely for work satisfactorily completed and for deciding prices for varied work.
- The system of relationships is well established and the ICE/ACE/ACE model Conditions are familiar to consultants and Contractors.
- Many consultants are represented in the membership of the ICE and the SJCCC and can therefore exchange experience, press for improvements in the Conditions of Contract and establish codes of conduct
Potential disadvantages:

- Construction does not start until the completion of most of the design, tendering, and agreement on the one contract for all the construction work.

- Client and Engineer have only indirect control of the quality and progress of construction.

- The final cost to the Client may be uncertain until a year or more after construction.

- The monthly cash needed by the Client to pay the Contractor depends upon the Contractor's decisions on when to proceed with each item in the B of Q.

- The Client's decisions on responding to external problems of changes in markets etc. tend to be separate from the Engineer's decisions on varying design to overcome construction problems.

- The self-discipline of the Client and project teams may be weak because of the Engineer's power to order variations. In particular, the initial decisions in design etc. which govern much of the cost of a project may be made casually by people who expect they can change their minds later without being accountable for the resulting problems.

- The separation of responsibilities for design and construction provides scope for disputes about the basis and the detail of drawings and B of Q.

- Any proposals from the chosen Contractor for improving the cost or speed of construction by design changes come after design is complete or substantially so.

- The standard methods for the measurement of B of Q items are not
directly useful to the Contractor in his budgeting or in controlling his costs nor to the Engineer in assessing the costs v benefits of proposed design changes or in deciding the validity of the Contractor's claims.

This type of contract is therefore suitable for projects having these characteristics:

- The Engineer has the experience to design for economic construction and consults pre-selected Contractors on this during design.
- Design is detailed before Contractors are invited to tender.
- Tenders are invited from Contractors pre-selected on the basis of their quality of management, technical performance, labour relations, financial resources and other current commitments.
- The Client will exercise self control over changes.
- The Contractors have confidence when tendering in the Engineer's use of his contractual powers during construction.
- Standards of work have priority over speed of completion.

The B of Q with approximate quantities used in this type of contract provides a detailed control of payments and a basis for settling claims, but is not a guide to economic decisions. This type of contract is used by public Clients. Commercial civil engineering projects are more often built under other types of contracts such as design and built, management contracts.

II Building Industry

The traditional contractual system for building construction in the UK appears to be generally similar to the above. In nearly all detail it is different.
The reasons why different systems have evolved may be these:

- Many of the promoters only once or occasionally require a building project, so that they do not accumulate experience of their role or have a continuing interest in the improvement of practice.
- Building design depends more on judgements of social and individual demands.
- Building construction is more the assembly of standard or prefabricated parts, and larger buildings usually include extensive mechanical and electrical systems.

Many projects require civil engineering and building work, structural engineering being a common need of both, so that the distinction is not absolute. The practice is to classify projects as one or other according to the dominant work and local variables such as the Contractor's available, their labour policy and links with other projects.

The models for the traditional relationships between Client and Contractor for the construction of building projects in the UK are provided by Conditions of Contract published by the JCT (previously by the RIBA). Several sets of model conditions have been agreed by the JCT, to provide alternatives for private and public Clients with and without the use of a B of Q. There are also options between a B of Q with approximate quantities, payment to a Contractor depending upon the finally measured quantities, and a B of Q not subject to this.*

The JCT models establish 'the Architect' or 'the Supervising Officer'

*The JCT describe their conditions of contract as 'standards' but the author believes that 'models' is a more accurate indication of their status in practice.
in a similar role to 'the Engineer' for design but with less power to control construction. Reynolds (1980) states that "the Architect designs the building and then only has the power, as expressly stated in the JCT Standard Form of Contract, to issue instructions to the Contractor. The Contractor is to carry out and complete the works shown, described or referred to in the contract Documents (Clauses 2(1) and 4(1)). The Architect is concerned with a concept of the usage of space and aesthetic considerations and less with the problems of execution. The building contractor is fully in control of the method employed in the erection of the building which is as much a management and a physical problem".

In detail the wording of the JCT is different to the ICE/ACE/FCEC model. Their potential advantages and disadvantages are broadly similar except that:
- The Clients of most building projects have little or no connection with each other or regular interest in the industry to enable them to gain experience from each other and to press for improvements in practice.
- Control over the Contractor is less.
- Variations can be expensive.

This type of a contract is therefore suitable for projects with these characteristics:
- The architectural, structural, mechanical, electrical and cost members of the project team work together and are subject to a project director. (See chapter 6).
- The design team consults pre-selected Contractors during design.
- Design is final before Contractors are invited to tender.
- Tenders are invited from Contractors pre-selected as the basis of the quality of their management, their experience of the type of project and control of sub-contractors, their financial resources and other current commitments.

- Standards of work have priority over speed of completion.

The B of Q used in this type of contract provides a detailed control of payments but not a guide for economic decisions. The JCT contract with a B of Q is therefore more common for public rather than commercial buildings.

**Sub-Contracting**

Most Contractors offering to construct a building or civil engineering project expect to employ other firms as sub-contractors to undertake specialist work or provide local services. Model Conditions of Contract make the right to do so subject to the approval of the Engineer or equivalent but state that such approval shall not be unreasonably withheld. The result is that much of construction is commonly sub-contracted and the 'main' Contractor concentrates on planning construction as a whole, financing his costs, and supervision of the sub-contractors. The Contractor remains responsible to the Client for all the work, but in turn has only indirect control of the speed and quality of each sub-contractor's part.

Contractual relationships are therefore more complex, but in practice the power of the Client or the Engineer etc. to influence the quality and speed of work is much the same whether a Contractor sub contracts it or whether he uses specialists within his organization, provided that the Engineer etc. checks that a proposed sub-contractor has the
expertise and resources for the work to be done and is entering into commitments to the main Contractor that are consistent as far as is economic with the commitments of the main Contractor to the Client.

The greatest complexity of design responsibilities but also the greatest reasons for employing a sub contractor occur in projects that include extensive electrical, mechanical or process plant or systems that have to be installed during construction. Usually the suppliers of such plant are also its designers, starting from specifications of the performance required, space available and data on connections provided by the project team, but responsible thereafter for design, supply, installation and testing to show that the plant meets the specification. In effect there can therefore be substantial design + build and usually lump sum sub-contracts within a main contract. In other countries it is more common for such work to be the subject of one or more contracts in parallel to the construction contract. In the UK the tradition has been to specify mechanical, electrical and other plant to be designed by its suppliers as a sub contract to the one construction Contractor.

As design decisions for the main contract may depend upon information from such a sub contractor, the practice has evolved of the Engineer or the Architect nominating this sub contractor before inviting tenders for the main contract, but normally making it a condition of the main contract that the Contractor chosen accepts the nominated sub contractor as if chosen by him. Nomination of a sub contractor prior to choosing the main Contractor is also used if needed to get components ordered to be supplied in time for installation during construction. The result of nomination for either reason can be disputes about the
responsibility for the choice of the nominated sub contractor is he is not achieving the speed or quality of work required by the main contract. project C. To avoid such problems the alternative for a Client is to use the management contracting system and appoint sectional Contractors for such work before any for construction.

Consortia and Joint Ventures

A partnership between two or more Contractors and perhaps others may be valuable to combine expertise and other resources, to achieve joint planning, and to share risks. Such partnerships are known as 'consortia' if established to obtain several contracts, for instance complex projects such as power stations. They are known as 'joint ventures' when established for one project.

In theory such systems are an advantages to the Client in providing a single contracting organization to undertake what would otherwise require several parallel contracts, but to achieve this the contract needs to make the members of the contracting partnership jointly and severally liable for their total commitment and each member needs to be large enough to be able to carry the risks of this liability.

A consortium or joint venture of Contractors can be employed as the Contractor in the traditional system or any of the alternatives reviewed in this Chapter. The potential advantages and disadvantages of doing so are as listed, with the additional advantage that the partnership can bring together the greater expertise and resources of two or more organizations. (As in project D).

Contracts employing a consortium or joint contractors are therefore
suitable for exceptionally large or complex projects. They are used by Contractors to obtain contracts that they might not obtain or be able to risk alone, particularly for projects overseas where the Client wishes one organization to undertake the financing, design and construction of a complete project.

B. OTHER TYPES OF CONTRACTS

In the NEDO (1976) booklet it is reported that fresh approaches to organizational arrangements have been stimulated in the UK by:

- efforts to improve integration between design and construction and to speed project completion. (Especially following Banwell's report in 1964.)

- Changing demands on the construction industries to produce more complex projects and to meet continuing programmes of work.

- Increase in the size of workload for which individual Client organizations are responsible, and growth in size of Contractor organizations.

- Requirements in some cases be overseas Clients for a design, construct and operational service as one comprehensive package.

In other words the move towards new organizational arrangements has been initiated by both the Clients and Contractors needs. As the Quantity Surveyor of the Management Contractor of project F pointed out "in times of financial uncertainty the Contractor prefers a lower risk/lower profit management contract to other types of contract."
I. Turnkey, Package Deal and Design + Build Contracts

An alternative to all the above arrangements is for one Contractor to be responsible for design and construction.

This is called a 'turnkey' contract when the Contractor undertakes to provide a complete industrial project that is tested and running before the promoter takes it over. The description 'package-deal' is used for a contract for a complete but relatively standard project such as building a warehouse. The description 'design + build' has more recently been coined for the provision of a bespoke building such as an office block.

Like all descriptions these are not precise definitions of responsibilities. All such contracts in practice vary in the extent that the Client specifies standards and initiates the design, and in the extent that the Contractor is responsible for testing and commissioning building services or other equipment and systems being supplied with a building before take over by the promoter. The common concept is that most of design and all construction are the responsibility of the one Contractor.

These are usually lump sum payments.

In many cases Contractors who normally undertake construction in the traditional system offer to undertake turnkey or similar contracts in partnership with consultants or companies who provide design services, or these are employed as a sub-contractor to provide design to the Contractor. This may produce some unfamiliar and unwelcome relationships between designers and Contractors; these need to be
Potential advantages:
- Simple contract between Client and Contractor.
- Design and construction are planned and controlled by one organization.
- Construction can overlap design.
- Final cost should be known before construction starts, but depending upon the extent that the Contractor takes all the risks.

Potential disadvantages:
- Changes in scope, design or programme by the Client after the contract is agreed can lead to expensive claims from the Contractor.

This type of contract is therefore suitable for projects that can be specified finally before agreeing the contract, and for projects where speed of construction is important. It is therefore commonly used for commercial projects. It is also common in contracts obtained by UK Contractors to construct projects overseas, particularly as the Contractor is often also responsible for financing the project.

Model Conditions for design + build contracts for buildings in the UK have recently been published by the JCT and the use of these on a project is now being observed.

II. Management Contracts

Management Contractor

Under what is called a management contract the Client employs a
Contractor called Management Contractor (MC) to plan and supervise, jointly with the members of the Design Team (DT) all the construction of the project. Advised by the MC and DT the Client agrees to the distribution of the project's works into a number of sequential packages. Each one of the packages is put out to tender in accordance with the construction programme (prepared by the MC, agreed with the DT and approved by the Client and the selected Contractor is called a sub-contractor.

Prior to their appointment prospective sub-contractors may be selected and screened by the MC and DT and the selection list is approved by the Client or the SO (depending on size of package as specified in the MC's Condition of Contract). The sub-contractors may be employed either by the Client or the MC. In either case there are a number of advantages and disadvantages for the Client. If the Client employs the sub-contractor directly.

Potential advantages:
- Defective warranties are issued by the Supervising Officer directly to the sub-contractor; which gives him greater power to press the sub-contractor to carry them out. (As under a traditional type of contract).
- No liquidated damages should be included in the MC's contract thus the MC's bond with the management team are stronger.

Potential disadvantages:
- MC will probably lose authority over the management of the sub-contractor.
- Additional work will be created in the Client contract department
which will have to draft, and administer a large number of subcontract's terms.

If default occurs it is important that a new sub-contractor is appointed immediately. If the existing selection/appointment procedures, as in the case of Public Clients, are lengthy, Clients are advised not to employ the sub-contractors directly unless they can revise these procedures to suit the need of a management contract.

The Client reimburses to the MC the actual cost of the work (i.e. the summation of all the sub-contract accounts and suppliers bills, all discounts being handed back to the Client). In addition the Client pays on an agreed basis the cost of the MC's on site overheads the level of which is agreed and monitored by the Client's Quantity Surveyor. Finally a fee is paid to the MC which covers his overheads and profit. The fee is one of the types described under the cost plus payment system and the choice should depend on the weighing of cost time performance by the Client.

In all the cases the author has known the MC is appointed on the condition that he and his subsidiary companies cannot bid for any of the sub-contracts.

The contractual relationships and channels of communication in this system are indicated in Figures 5.4 and 5.5.

The main difference between this and the systems reviewed earlier is that the construction work is divided between several contractors and only one or a few of them need be appointed for construction to start.
FEATURES OF MANAGEMENT CONTRACTS

- Management team is made up of client's senior members of staff, DT & MC. (One of the client's members acts as Project Director or Project Manager)
- Measurement or lump sum contracts for independent sub-contractors/suppliers
- Negotiated cost plus fee payment system for the MC
- Negotiated fees for members of DT
The responsibilities of the DT and the powers and duties of the Supervising Officer Engineer etc. can be as in the traditional system, but the model forms of contract need alteration to distinguish between the MC and a sub-contractor.

Potential advantages:
- The DT can draw on the MC's advice on construction. Thus the MC can be asked to provide advice on construction aspects of the design assessment of alternative choices of materials programming and planning. In reality however the DT may not seek the MC's advice (on choices of materials and alternative design choices). This is because the DT's members feel that the MC will try to direct them to solutions which are easier and quicker to build, but not necessarily of the desired by the DT quality. If a penalty clause is not precluded in the MC's contract, the MC's relationship with the DT may change which may increase his design input.
- Construction can overlap design, but each sub-contract is tendered upon final design. Thus the construction duration can be shorter.
- The MC can be used to provide common services on the site and so save duplication by the sectional contractors.
- The MC can take over the control of the works of a package if the sub-contractor goes out of business and thus minimise delays. (Only if the sub-contractors are directly employed by the MC).
- Few people outside the Client's organization need know of confidences about the whole project.
- The project can be terminated, delayed and design decisions can be delayed or changed by the Client with less cost implications than under a traditional type of contract. (Although there is a time cut-off beyond which such delays can be very costly).
- During the selection period, sub-contractors can be screened tightly and the DT can draw on the MC's nation-wide knowledge of the prospective sub-contractors reliability and performance. This does not happen when sub-contractors are nominated under a traditional type of contract;

- Discounts offered by the sub-contractors benefit the Client. (In the traditional contract the Contractor benefits but also takes the risk of selecting the sub-contractors.)

- The fragmentation of the contract into sub-contracts means better planning, monitoring and control of construction, by the project's management team, i.e. more accurate knowledge of committed expenditure, outstanding claims etc., better control of VO's prior to their issuing, and accurate recording following their issuing.

- The Client has the flexibility to adjust his annual budgets in accordance with external economic pressures on his finance, by delaying or accelerating the appointments of unlet non critical sub-contracts or adjusting payments towards the MC's fee.

Potential disadvantages:

- The Client carries the risks of the costs of the contractual complexities (e.g. failures of sectional contractors, interference between them etc.). It is therefore important that the Client is actively involved with the project's management decisions and kept informed of the progress which is not possible with inexperienced Clients; and it is difficult when a number of Users are involved or the Client consists of a number of departments which are likely to be involved with the project's construction.

- The final cost of the project is uncertain until all the major packages are let which could cover two-thirds of the construction
phase.
- The quality of the finishes may be sub-standard because the MC's Agent on the site does not have direct control over the sub-contractor's labour force.
- Some desirable Contractors (because of their experience with a specific type of works, reliability etc.) may not tender for a project where they will be supervised by another Contractor.
- Because of the tight out to tender schedule some packages, especially some of the major first packages, may be awarded on inadequate information which could result in claims.
- The management contract appears to be more expensive than the traditional contract because of the MC's fee and the higher fees that the DT should be paid (due to their higher costs under a management contract), which are not balanced by the discounts of the sub-contractors. The cost benefits due to better management of the works by the MC are difficult to evaluate if the financial value of earlier completion is not known.
- When delays due to the flow of information between the DT and MC occur friction within the Management Team may result.

Management contracts are therefore appropriate for projects which are urgent or where time has priority over cost, or only the initial construction work can be decided at the start. They provide flexibility in deciding the speed and scope of construction as it proceeds. In the UK they have been used more for commercial building projects but are now being used for public building projects as case E.

No model Conditions of Contract have yet been published for management
contracts in the UK, but a study of the results of some management contracts is being carried out for CIRIA and may lead to action on this. Currently the clauses of management contracts are either based on draft Conditions of Contract prepared by the MC for all the contracts they undertake or they are prepared by the Client in consultation with the DT specifically for a particular project.

**Project Management Contracts**

The description 'project management contract' is used in the USA when a Client hires a project team to combine the roles of a management contractor and the Engineer as reviewed above but not undertake the design. Firms specialise in offering such project management teams to Clients, drawing their staff to do so from contractors and consultants.

In such systems construction is carried out by Contractors under either one lump sum contract or a set of sectional contracts. The project management Contractor acts as agent of the Client in planning, agreeing and supervising these contracts. A B of Q contract could also be used.

Design may be the work of the Client's staff or consultants. In either case the project management Contractor acts as agent of the Client to plan, direct and supervise design.

This system should combine the advantages of management contracting and the powers of the Engineer provided that the project management Contractor is appointed at the start of design so as to be able to plan design and construction as a whole. The authority of the project
management Contractor over the Client's own staff also needs to be defined.

In the UK for large and complex projects, the works of which are designed and built in overlapping or consecutive phases, a firm of consulting Engineers may be employed to assist the Client with the project's management i.e. the firm does not undertake any design aspects.

In project B members of the firm and of the Client formed the Project Coordination Team (PCT). The PCT's function was to plan the works, monitor their progress and advise the Client's Management Group and Executive on the required medium and long term managerial decisions the Management Group and Executive had to take. Contractors were appointed under the traditional contracts in which a Senior Partner of the design consultants was named as the Engineer. One important diversion from the traditional contract was that the contingencies were not at the Engineer's or RE's discretion but under the control of the Management Group.

The building industry has been more responsive than the civil engineering, to the use of other types of contracts as Slack & Giles (1981) have stated in their paper on management in civil engineering, Financial Times, 30th June 1982, Building Methods and Management.

It is the author's view that one of the reasons this is so, is that even under a conventional building contract the main Contractor subcontracts approximately 60-70% of the works to specialists, as opposed to civil engineering projects where 30% or less is sub-contracted.
As the RE of project D pointed out the appointment of an MC would have yielded no considerable time or management benefits because the erection of the main bridge (approximately 70% of the works and critical to the overall programme) would have still been awarded as one sub-contract.

Some civil engineering projects for which specialised technology is required, such as processing, desalination plants, power stations etc., are constructed under design and construct or turnkey contracts.

In offshore projects in the North Sea, a Project Services Contractor (PSC) may be appointed who together with the Client's members form the Project Management Team.

This type of management organization was reported in papers presented in the 1980 European Offshore Petroleum Conference and Exhibition by Lauren, Gregg et al, Vicklund etc. Tasks the PSC undertakes include the cost and time planning, contract control, site management and general project administration.

The Client provides the design input required to achieve his required standards for safety, reliability and operability.

In conclusion the types of contracts reviewed in this Chapter differ in the extent that the risks of planning and controlling the construction are taken by the Client or by a Contractor. Defining the potential risks is therefore the starting point for advisors on decisions on the numbers and type of contracts appropriate for a project. This Chapter has been a limited review for the purposes of summarizing the
consequences of these decisions for the control of construction.

One common principle indicated in many publications and to which the author subscribes is that Clients are advised to limit a Contractor's risks to those that a competent Contractor should best be able to foresee and control. Contractors may agree to accept greater risks, but at a price to cover probabilities above the most likely. It is not only the cost of doing that that may affect the speed and quality of construction. It is the uncertainty of risks that limits a Contractor's ability to plan and achieve satisfactory work. This in turn can affect the motivation of managers and of all a Contractor's employees. That studies of communications amongst people on a site show are the greatest single influence on the results of a contract. Experienced Client's therefore conclude that it is in their interest to take themselves all the risks that cannot be better foreseen and controlled by Contractors.
6. ORGANIZATION OF THE CLIENT'S PROJECT TEAM

6.1 PROJECT MANAGEMENT TEAM

Placing of a contract is usually the start of relationships between the chosen Contractor's staff and Client's representatives who may not have worked together or met before. It is also the time of a change in the task of the Client's project team, progressively reducing their role as construction and site decisions become dominant.

Investigations have shown that project teams and Contractors' staff tend to regard their own function as central to a project and the other's as a service that should adapt accordingly. This can cause differences in attitudes to priorities and problems even if responsibilities are understood between them from the start. In practice the project team are likely to be first concerned with outstanding design questions, and the Contractor's staff with mobilising their manpower, ordering materials and planning, taking over the site and selecting sub-contractors. Relationships for the control of the work therefore tend to be considered too late for principles to be established and individuals meet each other before problems arise.

In the author's experience the failure to establish the management teams organization may have the following consequences:
- No one person has the information, time and authority to make decisions best for the project as a whole.
- Each party or department in the Client's organization solves problems to suit themselves.
- Each evolves their own planning, costing, budgeting and monitoring data in a form likely to be inconsistent with others.
- Problems that one party or department cannot solve alone are nego-
tiated with others too late to avoid delay and extra costs.
- These problems become the subject of disputes.
- Practice within and between organizations become formalized so that individuals believe that they cannot make improvements.
- Repeated failures of the industry to achieve economic results from expenditure on construction leads Client and government to add procedures that require the prior checking of the decisions previously left to project teams. These additional procedures can improve the planning of decisions, but they add to costs and the extra time they take worsens some problems.

Decisions are therefore most likely to be successful if made by one person who will be responsible for the results and who has the time and information to investigate the need for a decision and consider the possible choices. To achieve this, the management of a project requires attention not only to planning, budgeting, design, construction and relationships between all parties. It also requires attention to who uses control information to what effect.

All of this is agreed by many people in the industry and by experienced promoters of projects. The failures to apply what is agreed are probably due to:
- The haste to get work started that commonly follows the decision to proceed with a project. The quick start achieved is often followed by extra costs and loss of time because no one has ensured that all parties are working to consistent objectives and programme. Such wasteful hustling is a temptation to the Clients of projects large and small and not just on projects novel to the Client and advisers, probably because of a wish to demonstrate action to others less experienced in project economics.
- Some public authorities and commercial companies which have established procedures to control the appointment of consultants and Contractors do not also have procedures for deciding who shall control a project as a whole. One possible reason is that they are reluctant to impose controls that would limit their own freedom to change decisions.

- Few projects are reviewed systematically by their users to learn the technical and organizational causes of success and problems.

The aim of this Chapter is to examine the advantages in the appointment of a Project Director for any project to remedy the above, the influences which can assist or limit his effectiveness; and the consequent appointments and duties of the management team's members.

**Project Manager/Director/Coordinator**

In the NEDO (1976) booklet it is stated that "large and complex projects would merit the appointment of a Project Manager, where job consists entirely of ensuring the effective working of the total construction process; alternative for smaller projects a manager might handle several at different stages".

The title of Project Manager is used in the construction industry, but there are no published, agreed terms of reference which define the authority, duties and responsibilities the Client should delegate to a person with the title.

A number of authors have published definitions and recommendations concerning the Project Manager's role.
James (1981) in his paper on achieving the Client's aims defines the Project Manager "... as the person who will manage and give instruction to the other specialists engaged on the project, interpreting the Client's requirements and instructions and acting on his behalf".

The NEDO (1976) recommends that the Project Manager "should preferably be a professional, independent of the design team and could be an employee or a consultant".

This view is also endorsed by Cheesman (1981) in his paper on what is project management and who are project managers who state that "... when a Project Manager exists he should come from the Client's own organization or be appointed as an independent consultant separate from the design and construction teams as it is a rare man who can be totally impartial when they themselves are involved in other aspects of the project tasks".

In the NEDO (1976) booklet it is stated that "the requirements for the job are adequate authority, experience of the building or civil engineering industry, in design and construction, an analytical mind, the ability to lead, and sufficient knowledge of the Client organization to achieve quick decisions on problems which arise during both design and construction".

Cheesman defines the role of the Project Manager as that of "... the overall planner and coordinator but with authority to direct other team members having the necessary power to apply sanctions for non-performance". It is Cheesman's view that the Project Manager's objectives should be the following:
- Safeguard the Client's interests and represent him at all stages of the project.
- Establish and maintain procedures to control performance in terms of cost, time, quality.
- Facilitate communications between design and construction and ensure the availability of information.
- Maintain the project objective as the over-riding aim of all the organization and individuals involved in the project.

Harrison (1981) states the importance in determining the Project Managers relationship with the Client's Departments, Users etc. "Two principle characteristics of project management are the existence of dual responsibility and split authority ... Most managers in any organization are subject to several sources of power or influence ... Dual subordination may not be a good thing but as long as instructions are not conflicting there is no reason why a subordinate should not receive instructions from two people. The Project Manager determining what is to be done and by when, and the Functional Manager controlling how and by whom. The Project Manager is primarily concerned with time, cost and coordination and the Functional Manager primarily concerned with technical performance decisions". Harrison believes that when conflict arises either of the two should be clearly recognised as the one who must be initially obeyed. Any conflict must therefore be resolved by these superior managers. (Knight 1977).

It can therefore be concluded that if the Project Manager is to be effective in achieving his objectives his status within the Client's Organization and the management team should be defined.
The author believes that a manager's authority is derived from:

I. His powers delegated by the Client.

II. His knowledge of the subject and the power of his personality
   i.e. his ability to influence others, exercise his own discretion
   and get his own way.

The former can be achieved by clearly defining the Project Manager's
role objective responsibilities and duties and the latter through
careful selection of the right candidate.

Depending on the power to take action to control delegated to the
Project Manager, his role can vary from that of a Coordinator to a
Project Director. (As in the cases of projects B, E and F respectively).

A number of types of organizations with varying degrees of power dele-
gated to the Project Managers are described in books and papers e.g.
matrix, pyramid, circular (or global). Each of these choices has
advantages and disadvantages, and the author believes that in
choosing a specific type, the Client's nature, existing organization
and the project's nature should be considered.

The author's impression is that the title or description 'Project
Manager' is used in industry and public authorities for people who
are responsible for the coordination of projects but not authorized
to exercise control. A coordinator can achieve much through the
command of information and strength of personality, but if the person
in such a position has to obtain authority from others to make
decisions that affect budgets or programmes the control of a project
is likely to be slow and inaccurate. These faults can be avoided if
the person called the Project Manager has the support of one higher manager who has the authority and the time to understand the decisions required. In some cases the person called the Project Manager has to obtain control decisions from several higher managers who haven't that understanding. At worst, the group of higher managers have no agreed policy until required by a problem. Such divisions of authority and responsibility in Client's organizations are the cause of many of the excessive costs, delays and unsatisfactory projects which led to this research.

In conventional contracts in the UK there is rarely a person called Project Manager. Some of the Project Manager's responsibilities and duties are carried out by the Engineer and his Resident Engineer. The Engineer is in contract with the Client, through a senior member of the Client's organization who is usually kept informed on progress during monthly meetings and of any major design changes which may have cost/time effects.

In theory the Engineer has extensive powers under the ICE contract (see clauses 13, 14, 36, 39, 40, 46, 51 etc.).

However as the author observed and is being reported, in practice the Engineer's power is less. As it was stated at a conference reported on page 17 of the New Civil Engineer of 30th October 1980 "He (the Engineer) must act under the constraint of his Employer and the exercise of his 'independent' functions are subjected to serious difficulties ... In short the Engineer no longer has the confidence of the parties and is often unable to take the action required in the best interest of the works".
In view of this development the author believes this view was shared by the Resident Engineers the author has talked to, that the Client should become actively involved with decisions taken on the site i.e. appoint a Project Manager who will be in direct contact and have the authority to approve action for control as the works progress.

When other types of contracts are awarded Clients appear to recognize the necessity of full time Project Managers (as it was observed in projects E and F).

The choice of suitable people for this role has not been examined further in the framework of this research but the author believes that ideally the Project Manager should be appointed as early as possible (from the project's conceptual stage) and should have these characteristics:
- experience in the part of the work for the project where uncertainties are most likely to affect cost and speed of construction.
- ability to tolerate uncertainty in relationships and information.
- self control in the use of time.
- motivation to make the project a success.

The role therefore requires some of the qualities of a general manager.

**Planning and Cost Engineers**

In large and complex projects (such as project B) or in projects of all sizes built under non-traditional contracts, Planning and Cost Engineers are included in the Management Team.
In small or medium size projects built under a traditional Contractor (such as projects A, C & D):

- Planning of construction is considered to be the responsibility of the Contractor and thus a Planning Engineer is not included in the RE's staff. The Engineer may require the Contractor to supply the Resident Engineer with a programme indicating some completion dates of some activities and which in most cases become obsolete a few months after the commencement of construction (as it was observed in the case studies) mainly due to changes in the sequence of the works. Thus the Resident Engineer is not in a position to foresee as the works progress, whether the dates will be met, and thus try to prevent delays by asking the Contractor to take action and prevent the delays from occurring. Once the contract dates are not met, in theory the Engineer etc. can penalize the Contractor by invoking the liquidation damages for delayed completion clause included in the Contractual Conditions. In reality, in the author's view, aggravation is caused, lengthy negotiations resulting at best in certificates of partial completion issued to the Contractor, or extensions of the contractual period for reasons outside the Contractor's influence.

- Cost control as described in Chapter 2 is not carried out. Cost recording is carried out by the Quantity Surveyor (or an engineer), who is responsible for the interim and final measurements and the evaluation of claims. However the recorded costs are estimates and in the author's experience in some cases, deviations from the actual figures may be substantial. If a large number of Engineer's etc. instructions issued without informing the QS at the time of issuing, the number of outstanding claims, and in many cases the slow pace of final measurements.
It is the author's view that the above two positions (perhaps carried out by the same person answerable directly to the Resident Engineer) will improve the performance of the traditional site teams. This view was also expressed by the Resident Engineer of projects C and D. Their job descriptions are contained in sub-section 7 of projects C and D in Volume 2.

Lockyer & Partners (1971) in their report on the Training and development of Field Managers in Engineering Construction included job specification for Senior Planning and Cost Engineers which are reproduced in Appendix I of this Volume. The author feels that although these specifications were drafted for use by Contractors to define roles for their staff on large industrial sites, they are equally applicable to Client's project management teams. In the case of project B for example the function of the Senior Cost and Planning Engineers are very similar to those suggested by Lockyer & Partners. Different and more simple specifications may be appropriate for Client's project management teams, depending upon the project's nature and the type of contract.
6.2 CHOICES IN FORMING THE PROJECT'S MANAGEMENT TEAM

The author believes that if the project is to be successfully controlled, the Client should evaluate the alternative choices in forming his team. In many cases, especially when in house engineering department exist, project teams are formed using members of those departments without considering their ability to cope with the project's nature.

The review of the potential choices the Clients have and their advantages and disadvantages which follow is based on published reports and papers. Knight (1972), Wearne (1977) and on the author's experience.

Existing Staff in a Department

If a project is small in its demands on the time of members of an existing department and they have the expertise required for it an obvious arrangement is to form the project team by adding these tasks to their functions.

Potential advantages:
- Utilizes known people.
- Relevant internal experience can be used.
- Employees should feel that the project is theirs.
- Their employment is not temporary.
- The project experience is retained.
- The project is less obvious to competitors.

Potential disadvantages:
- Previous project experience may be lacking.
- The work to be done for the project may be underestimated and either
it or other work may not get adequate attention.
- Project objectives may be treated as secondary to established interests.
- Project thinking may be dominated by existing attitudes.
- Established routines and relationships may be inappropriate.

This choice is therefore suitable for a project which is relatively small and not urgent or novel compared to the rest of the work of the department, provided that a project director is named and given adequate time and authority. A team leader of the staff in the department allocated a project is unlikely to have this authority. If a project is exceptionally urgent, the head of department may need to be the Project Director and be freed of some other responsibilities.

Separate Temporary Team
The obvious alternative is for the Client to recruit temporary employees to form a separate team for the duration of a project.

Potential advantages:
- Puts emphasis on the project and its objectives.
- Can employ people with project experience.
- Can draw on new ideas and different experience.
- Avoids disturbance to other work.
- Helps keep project information confidential.

Potential disadvantages:
- Temporary jobs may not attract adequate people.
- May fail to use relevant data and experience available in the Client's established departments.
Requires planning of handover of the project to its user and definition of long-term responsibilities for results.

Management team may conflict with established departments over the use of common services or other resources.

Management team members need an incentive to end their jobs.

Project experience is lost.

This choice is therefore suitable for a project which is relatively novel or large, urgent, physically distant or exceptionally vital to the promoter's future.

If the leader of a team employed only for the duration of a project is expected to be the Project Director, he/she may need the regular support of a project board to resolve problems of authority and relationships with other departments, particularly with the users of the resulting project or others whose work is altered by it. Employing an outsider temporarily for this purpose is useful for precipitating problems and causing changes, but the person needs to be appointed before problems arise in order to be able to anticipate and help avoid them, rather than have to take a more limited role.

Consultants

Rather than recruit temporary staff a Client can employ one or more firms of consultants.

Potential advantages:

- Can use the consultant's experience of other projects.
- Can bring in new ideas and different experience.
- Avoids disturbance to the Client's other work.
- Team members have continuing employment.
- Team has an incentive to achieve a successful project.
- Team members can be changed as needs change during the project.

Potential disadvantages:
- Consultants interests may be different to the promoters.
- Consultant may move staff to other work.
- May fail to use relevant data and experience available in the Client's organization.
- Requires planning of handover of project for use and definition of long-term responsibilities for results.
- Project experience is lost.

This choice is therefore suitable for a project which is relatively novel, large or physically distant.

The Client should appoint a team leader to be responsible to the Project Director.

If a set of firms of consultants provide the team, each firm should appoint its leading person and there should be a separate team leader who is responsible to the Project Director for coordinating the whole team.

Appointing a consultant as Project Director requires the support of a project board, and is similar in advantages to those listed at the end of the previous section. As noted previously, appointing a consultant as 'the Engineer', 'the Architect' or 'the Supervising Officer' under some model conditions of contract gives that person some of the
powers of project director.

**Permanent Projects Department**

If a Client is a regular investor in projects the formation of a projects department is a means of achieving many of the advantages of the choices listed above.

Potential advantages:
- Puts emphasis on the projects and their objectives.
- Creates a group of people to develop project expertise, relationships and procedures.
- Can attract people with relevant expertise.
- Provides flexibility in allocating people to project teams.
- Their employment is not temporary.

Potential disadvantages:
- Project department interest may dominate decisions.
- May fail to use relevant expertise in other departments.
- May clash with them over the use of common services, etc.
- Requires control of priorities between projects.
- Requires planning of handover of projects to users and definition of long-term responsibilities for results.
- The project department may require an unusual proportion of senior managers in order to provide team leaders.

This choice is therefore suitable if a Client expects to proceed with a continuing programme of projects which are overlapping but not all simultaneous.
Interdepartmental Teams

In practice a combination of two of the above choices is found in which each project team consists of one or more members of a project department together with members of other departments that have relevant interests, expertise or resources.

Potential advantages:
- Can combine available expertise.
- All departments can feel the project is theirs.
- Can be flexible in utilizing manpower.
- Can extend individual experience, particularly in testing project team leaders.
- Creates a group to develop project expertise, relationships and procedures.

Potential disadvantages:
- May need means of matching project and other departmental motivation of individuals.
- Requires control of priorities between projects.

This choice is therefore suitable if a Client expects to proceed with a programme of projects varying in their timing and related to the interests and expertise of functional departments.

The team leaders need not be members of the projects department. They can be whoever is most suitable in experience and ability.

Forming a temporary management team from members of several departments can result in individuals being responsible to the team leader and to
their permanent head of department. This is known as a 'matrix' of management. Knight (1977). In it, ambiguity in authority should be avoided by defining various responsibilities. For instance if heads of departments are responsible for allocating adequate staff to project teams and for supporting them with specialist services and advice, and each team leader is responsible for detailed planning, budgeting and monitoring and reporting on these to the project director and the heads of departments. Decisions on the standards v costs of a project should be the responsibility of the project director. Decisions on priorities are the responsibility of the project board.

These relatively simple principles are needed in the complex conditions that several departments' resources are being shared amongst several projects. This is logical. It is most complicated choice amongst all listed here. As with the others, its success depends upon attention to how each project will be controlled.

**Choices**

Combinations of a projects department, interdepartmental teams and temporary employees or consultants staff have the potential advantages of each choice listed by us, but they have the additional disadvantage of demanding more of the time of team leaders and Project Director for motivating people, obtaining monitoring information and negotiating changes to programmes and budgets.
6.3 SIZE AND STRUCTURE OF PROJECT TEAMS

A common fault is that a management team is too small at the start of construction to be able to anticipate problems and is built up only as delays and extra costs are incurred. This appears to happen because decisions on appointing a project team are not made by the person who is to be responsible for achieving control. No one person is then responsible for balancing the costs and the expected benefits of expenditure on a management team. This is another reason why observations of practice lead to the conclusion that all authority over its budget once a decision has been made to construct a project should be concentrated in one person. Following this principle the Project Director should decide the size, build up, membership and duties of a project team and be responsible for the results achieved.

If a team of only two or three people is needed and all of them have experience of planning, budgeting and monitoring they may well work together informally and not require an organizational structure to define a division of work amongst them. Members of such teams are usually motivated because they can all influence the project as a whole and share the credit for the results. They can substitute for each other and absorb occasional changes of personnel without losing continuity of knowledge of the project. A small project team can therefore be economical and can motivate everyone working on their project.

A larger team needs attention to its structure to achieve economy and motivation. The lessons of studies of organizations is that efficiency and motivation are most likely if the Project Director plans the division of work in his project team, consultatively with them but
defining their roles formally, and re-plans it regularly during their project so that uncertainties are avoided and gaps and overlaps are remedied.

The members of a management team are likely to bring to it commercial, architectural, engineering, construction, administrative or other 'functional' expertise. It does not follow that they should have such functions in a team. There are these possible alternatives:

**Stage by Stage Responsibility**

Members of a management team can be made responsible for planning, budgeting and monitoring successive stages of a project. All or most of them may be members of the team throughout, but one is leader of one stage, another leader of the next, etc.

Potential advantages:

- The leader at any time can be the member of the team with the style of leadership and experience appropriate for the type of people and organizations employed at that stage of the project.
- The designated leaders of future stages can plan ahead for them as well as influence the current stage.
- Change of leader from stage to stage provides an opportunity to review objectives and needs for control yet retain continuity of knowledge of information, decisions and the reasons for decisions.

Possible disadvantages:

- Project objectives may be treated as secondary to the targets set for a stage of the work.
- The style of leadership required for each stage is not easily
agreed.

- The person appropriate by that criterion may lack experience of the stage of work, and vice versa.

Sectional Responsibility

The divisions of responsibilities in a management team can instead be by separate sections of a project, for instance particular buildings or distinct zones of a site.

Potential advantages:

- Each section can get attention as a whole and continuity achieved through design, construction, testing of services, etc.
- Individuals have a longer-lasting role in a project team and gain experience of all stages of work.

Potential disadvantages:

- The person or group within a project team made responsible for a section may lack experience of some of the work to be done in it.
- Common services and inter-connections need attention.

By Contractor Employed

The division of responsibilities in a project team can be allocated to correspond to the scope of each contract for construction, supply of equipment, etc:

Potential advantages:

- One person is responsible for relationships with a Contractor.
- Can utilize functional experience corresponding to the scope of each contract.
- Can correspond with responsibility for a section of a project for a stage of work.

Potential disadvantages:
- Project objectives may be treated as secondary to the terms of each contract.
- Overlaps between contracts, common services and inter-connections need attention.

**Functional Responsibility**

The division of responsibilities in a management team can be on the basis of individual qualifications and functional experience, so that an engineer in a team would plan, budget and monitor the engineering, an architect the architectural design, etc.

Potential advantages:
- Industry, public authorities, etc. are predominantly organized in functional departments, so that a corresponding system in project team seems natural to many people.
- For the same reason people with functional experience are the main source of recruits to project teams.
- Such a management team can utilize and maintain that experience, and best qualify its members for further work if they do not continue in a project team.
- Members of a management team with functional experience are accepted by functional departments as qualified to deal with them.
- One person in a team is responsible for relationships with a functional department.
Potential disadvantages:
- The members of such a project team may retain functional, attitudes and interests rather than accept the needs of a project as a whole.
- Functional experience may be poor training in coordination between functions.
6.4 PRACTICE AND CONCLUSIONS

The structure of management teams in practice is often a combination of two or more of the principles summarized in the above sections, but division of responsibilities by section of a project and by functional expertise are the most common.

At the start of construction the coordination of all design can still be a large task, for instance if several departments or consultants have much detail to complete or substantial changes arise from site conditions or proposals from Contractors. Any of these are quite common at the start of larger projects. If they occur, one member of a management team may have to concentrate on planning and coordinating an extensive amount of urgent design work.

At the same time the optimization of design and construction speed and costs can then be considered between designers and Contractors, but as contractual commitments and construction costs are likely to be more important than design costs the control of decisions should be guided by team members responsible for sections of construction and each contract. Thus early in construction the team for all but small or finally designed projects may have to include some members concentrating on a stage of work such as design while most concentrate on a section of the site or on one of several Contractors.

In such a team some of its members may concentrate on functional roles over the whole project, for instance one may advise and check on the safety of special processes or of construction, one budgets as a whole, cash flow and financing, another contractual policy and tactics. Various functional roles may therefore be appropriate in a
management team which is nevertheless mainly organized to achieve the planning, budgeting, monitoring and coordination of sections of work and each contract for construction.

Functional roles in a team can be most needed early in construction, when expertise from other projects can be applied to guide decisions on policy and procedures. As the project progresses the particular detail and decisions made become the dominant influence on remaining decisions, so that functional expertise may diminish in value relative to knowledge of each section of work or contract.

During construction a management team therefore logically becomes centred on the supervision of sections of site work on each of several contracts. The risk of this is that problems tend to be viewed as unique to the project. To see that relevant specialist experience is used, the designers and other functional departments should remain formally responsible for reviewing reports from construction and subsequent stages.

So should advisers on safety, contracts, etc., not only to utilize their expertise, but also for them to learn from the results and for them to know when involved earlier in a project that they will also be required to report on the eventual results.

A common problem in appointing a management team is that people appropriate in functional experience and in abilities to lead and motivate others may not have adequate knowledge of methods of planning, budgeting and monitoring. Experts in planning techniques may be available, but as a service on the use of systems and data processing rather than to join a project team to plan the work and monitor its
progress in detail. And experts in cost advice may be available, but as a service on the use of systems and predicting costs rather than to join a management team to estimate and monitor costs in detail. One member of a management team may therefore best be appointed as a project planner, and one a project cost adviser. In effect they become functional experts in a team, to concentrate on planning and cost advice on a project as a whole. Doing so can be particularly valuable to check for gaps or overlaps between the members of a team who are concentrating on stages of a project, particular sections or contracts, or specialist functions, but this can cause doubts or conflicts on who is an adviser and who is responsible. For this reason roles should be defined in project teams. In particular attention should be paid to the roles of a planner and a cost adviser in a complex team.
7. CONCLUSIONS - RECOMMENDATIONS

In essence this research has shown that if the Client is to achieve value for money from a project the setting up of a construction control system should be as prominent in his management strategy as decisions on responsibilities for design and the supervision of construction.

In Chapter 2 and 4 it has been argued that any recommendation directed at better control of construction must be based on the principles that:

- A project is a means to an end for the Client
- Clients, projects, and the environment in which they are built have unique features.

The implications of those principles are that no one standard way of organizing design, construction and control is appropriate for all projects; nor is one way best for building works of any size and another for civil engineering of any size. It therefore follows that Clients in choosing their management strategy should take into consideration the Client's and project nature and the environmental features or anticipated changes.

As a result of this research the author has identified two elements which in his view are essential, besides luck, if the project's management team is to maintain effective control:

a. Management of people
b. Communication of information and decisions made

Attention should therefore be paid by the Project's Director, Engineer etc. at the very early stages of a project's design to the:
- responsibilities of the Client's department
- organization of the project management team
- setting up of a control system to assist the management team to carry out its duties.

The recommendations which follow under the above three headings are based on the findings of Chapters 2 and 6 and the cases described in Volume 2.

The diagram 7.1 is an illustration of how the author believes the distinct roles and actions of the Client's project Board, the Project Director, the project's Management Team and Contractors ought to happen, following the decision to proceed with the project.

The author hopes that action as shown in this diagram coupled with the principles for control stated above and under the following headings will provide a check list of what is likely to be needed for project control.
Fig. 7.1 RESPONSIBILITIES FOR CONSTRUCTION

JCH/CSH/SW
13 May 1983
7.1 CLIENT'S DEPARTMENTS RESPONSIBILITIES AND DUTIES

Usually Clients of construction projects are public companies or local authorities. In any of these various departments within a Client's organization may have different interests in the project. It is also possible that Client and Owners or Users may be two or more different organizations (as in projects A and E), in which case as it was discussed in Chapter 4 conflicting decisions and interests may occur. For some large projects the Client may be a consortium or temporary partnership of several organizations in a joint venture. For smaller projects such as private houses it may be an individual, but usually this person is advised by an architect and perhaps others with different experience and interests. In nearly all the cases the Client is therefore more than one person and those involved may vary greatly in their interests, objectives, experience and knowledge of a project.

The common conclusion from studies of the completion of projects is that the authority for control of all stages should be defined at the start of a project and reviewed as it proceeds. It should therefore be defined by the Client when setting up the project team and before design and construction are allocated to consultants, Contractors or internal departments such as a direct-labour organization.

In Chapter 6 it has been argued that one person should have a command of information and the time and authority to use it to control the project. This person was named "the Project Director". This title is only an indication of the role. What matters is that individual in that role has the authority, information, ability and incentive to take action to achieve control. That person needs to have the time
to assess information on influences such as market changes that may affect the objectives of the project and information on the problems and trends of the progress of design and construction. Only rarely is an individual Client or the chief executive of the promoting company or public authority likely to have the time and the expertise to undertake all this. The authority therefore has to be given to someone who has the time and the ability.

If a project is urgent the Client needs to authorize the Project Director to make all subsequent decisions on adjusting objectives and overcoming problems of design and construction. Any checks on this authority are incompatible with urgency.

If a project has commercial objectives, decisions on the speed of construction and on responding to changes of objectives need to be weighed against the costs of construction and the subsequent running costs of the completed project. The Project Director may therefore be subject to all or part of the Client's organization for such decisions, particularly if several departments or a set of firms have stakes in the project. For this purpose a 'project board' might be required. This could consist of the whole board of directors or equivalent group who made the decision to proceed with the project or it may be some of these, depending upon the importance and risks of the project. The author believes that it should include the executive heads of every function that has some responsibility for the performance, costs and success of a project, to form a coherent steering group that reconciles all interests in the Client's organization and gives decisions to the Project Director on changes affecting objectives.
If the project is publicly rather than commercially financed a similar 'project board' may be needed to represent all who are accountable for the expenditure and the resulting project, so that any differences in objectives, standards and priorities are reconciled and coherent decisions given to the Project Director. A Cabinet Committee is an instance of such a project board for the rare case of a national strategic project. More often it is the heads of departments in a public authority who meet as a steering committee.

In all cases the project board expects to receive reports from Project Directors and make decisions referred up to them. In principle the project board may not have much to do if it is known in the Client's organization that such a board is established in order to see that the members of all departments accept the authority of a Project Director. In many cases the project board may therefore be an existing committee in a company or public authority and one of its members has the role of Project Director in addition to an established responsibility in the organization.
7.2 ORGANIZATION OF THE PROJECT'S MANAGEMENT TEAM

As reviewed in Chapter 6, a group of people or perhaps only one person may be employed by the Client of a project to carry out or supervise the work of completing design, planning, budgets, risk analysis and preparing contract documents following the Client's decision to proceed with a project.

Some or all of this team may have carried out or supervised design and other work prior to that decision, particularly to provide the proposals and estimates of benefits, costs and risk leading to selection of the project. On the decision to proceed, this team may need augmenting so as to have the capacity and expertise to produce or check design and other information in more detail than required earlier, gather and analyze data on cost and progress, and simulate the results of trends and choices for decisions by the Project Director. Not only are more people therefore usually needed. Attention to their organization relationships is also required because of their greater complexity and because they now have to provide a service for control decisions rather than project studies.

Project management teams can be organized in a variety of ways, particularly in whether and how they use consultants or contractors to design a project and contractors or direct labour to construct it. These alternatives were summarized in Chapter 6. Figure 7.1 illustrates the frequent arrangement that the Client has a project team of his own staff and employs consultants to design the project, draft contracts and supervise contractors who carry out construction. There may be only one consultant or firm of consultants, or there may be a set of them, for instance architects and consulting engineers plus
advisers on costs, special hazards, local conditions etc., depending on the complexity and novelty of a project and on the expertise and policies of Client and consultants.

More simply the roles shown for the project team and consultants may be combined, and separate site supervision needed only if the site is distant from them. Or a Contractor may be responsible for design and construction. The advantages of each type of contract were listed in Chapter 5. The diagram depicts a relatively complex but quite common set of relationships, for the purpose of showing a way of illustrating relationships and indicating what responsibilities should be decided and defined to establish a control system. The important principle behind it is that many functions can be delegated to a project team but the authority over changes in objectives should remain with the Project Director. The author believes that diagrams of this sort should be drafted by Project Directors when the decision is made to proceed with a project, to assist the Client in organizing the project and indicate the authority and responsibilities of all employed on it.

A separate project team leader is not shown in the diagram but may be required to lead the design of the project, coordinate and check design by others, and supervise the planning, budgeting and monitoring information systems. These can be the tasks of the Project Director, if the one person has the time and expertise, but the Project Director's essential task of control should not be confused with coordination of the project team. This authority to control should be defined so that it is not left uncertain or wrongly assumed to be part of the role of team leader. The tasks of separate team leader can then be defined by
the Project Director.

The project team may be provided by consultants, and in contracts for the construction of a project the team leader may be named as 'the Engineer', 'the Architect' or 'the Supervising Officer' as defined in model conditions of contract for construction in use in this country and published for use internationally. Under some of these model conditions the person named has powers and duties to order variations, grant extra time and agree extra payments to the Contractor. If these conditions of contract are used they give the person named as the Engineer etc. some of the powers of the Project Director. The author has argued however that some of these powers have been taken away from the Engineer and that it is in the Client's interest to appoint a Project Director even in the case of a traditional contract. The choice of these conditions of contract should therefore be considered at the start of actions to proceed with a project, as part of decisions on contract strategy, organizational responsibilities and how the project is to be controlled.
7.3 PROJECT CONTROL SYSTEM

The main objectives of control systems should be the monitoring of progress and committed expenditure; forecasting of future expenditure and progress; control of expenditure before the Client is committed; the flow of design detail information between Design Team, Client and Contractors; coordination of Contractors/suppliers after their appointment; forward planning to head off problems which are likely to affect the progress and costs of future works; and supply of enough information to help the management team to make decisions when problems occur.

The author believes that if a control system is to fulfil the above objectives it should be designed to:

a. Provide cost/time committed and forecasted information based on:
   - measurement of quantities as works progress
   - monitoring of committed PC and Provisional sums
   - adjustment of contingency sums
   - cash flows and time programmes for future works

b. Initiate action for control based on procedures set and agreed among the management team for the evaluation and authorization of:
   - award of new contracts (if works are to be built by several Contractors/suppliers)
   - design changes with estimated major cost/time effects
   - decisions for the acceleration on deceleration of the works following unexpected events
   - Use of major PC and Provisional sums prior to commitment of the Client.
   - adjustment of contingency sums.
Reports on the above items should be forwarded to various levels of the management team and Client organization at agreed times. Such reports can then be discussed during meetings at agreed dates.

Dates for formal/informal meetings to take place during construction should be agreed among the members of the team in order to:
- state progress and costs
- discuss the information required by the Contractor from the design team
- coordinate the Contractors (if more than one)
- decide to take action.

The number and frequency of meetings should depend on the project's size and complexity. Deciding on the participants in each meeting is important as it is preferable that the number of participants is kept small. The author believes however that it is important that all the members of the management team and the Client's representative(s) (Project Director etc.) should meet regularly in order to discuss policy matters and coordinate with each other.

One conclusion that may be drawn from the findings of this research is that in the case of large, complex, novel, urgent, projects such as B and E Client's recognise the need and are therefore willing to undertake the expenditure of employing people who will design and operate such control systems.

It is in the case of medium and small projects (such as A, C, D and F) where Clients may be hard to persuade that a system performing the above tasks is to their benefit and thus it is worth financing.
A management Contractor or consultant appointed by the Client, (whose fee is an additional expense to that of the Engineer or Contractor under a traditional contract) should set up and operate a control system which will ensure tight monitoring of committed expenditure and progress, as well as forward planning. Nevertheless, as it was observed in project F, the system may not be designed to embrace the Client's organization. It is therefore important that the Project Director ensures that the Client's departments do not obstruct the project's progress because they interfere with the management team or they delay information by establishing lines of communication within the Client's organization and keeping them informed on progress and consequences.

In the case of traditional contracts the author believes that the site staff will be assisted in the performance of their duties through better monitoring of committed expenditure and forward planning. It was therefore recommended in Chapter 6 that a Cost/planning engineer is included in the site staff whose duty will be to design and operate a system for monitoring and control of the construction. On smaller sites these may not be separate jobs, but it is clear from this study that the tasks of producing and using control information should be defined as someone's responsibility and that the role of "Project Director" is needed not only to take action to exert control but also to design and monitor the system of control.
8. FUTURE RESEARCH

The author believes that more research is required in order to increase the knowledge and understanding of operation and effectiveness of construction control systems. Such research should concentrate on the following objectives:

a. The better understanding of the processing of information, reporting and decision making, through:
   - Observation of a comprehensive set of projects from start to finish i.e. projects which cover a wide range of building and civil engineering works, of various sizes, new and remedial, with public and commercial objectives. The author believes that the researcher(s) should be attached to the management team. The researcher will then be in a position to observe events and more importantly the relationship within the members of the management team, instead of having to rely on information provided many times in retrospect by a member of the team.
   - Observation of the response, to the implications of problems and decisions taken by the Client's management team, by the Contractor's site team (not applicable in cases where the Contractor is a member of a Client's management team). The author believes that there is a lack of understanding between Client's management team and Contractors, and that relations and thus performance will improve if the understanding of the other sides of the operations objectives and philosophy is improved.

b. The study of the influence of more parameters than those examined, on the design and effectiveness of control systems by the:
   - Observation of projects of similar types and Clients, built under various types of contracts, to produce not only a
detailed account of potential advantages and disadvantages for the Client as in Chapter 5, but also models such as Figure 7.1 which will be suitable to each type of contract.

- Observations of projects built in different countries which will improve our understanding of the influence of location, culture and environmental factors, on project control. The author believes that the research will assist management teams to be better prepared to tackle the implications of environmental changes during construction.
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183
Overall job objective

To contribute to the productive and timely completion of the contract through the preparation, co-ordination and continuous up-dating of an overall programme for the site construction work.

Job responsibilities

(i) To review the relevant job instructions
The planning engineer will study and assess the planning already undertaken at head office, the specifications, drawings, definitive estimate or site budget, and target dates for the contract so that he is completely familiar with the work which has to be planned and the parameters within which he must programme it.

(ii) To review delivery information
He will review existing material and equipment schedules and obtain further delivery information from the relevant departments.

(iii) To assist in the broad plan for construction
He will assist the site manager, the resident engineer and engineers in the preparation of the broad plan for construction where this has not already been done at head office. In cases where he is provided with a plan from head office, he will check with the site manager, the resident engineer and engineers that there are no immediate alterations to the programme.

(iv) To prepare the site plan
He will prepare the site plan in accordance with the instructions passed to him by head office and the site manager and consistent with the requirements of the drawings, specifications, target dates and definitive estimate. In doing so, he will ensure that the plan will be consistent with the delivery times that have already been established for material and equipment and will inform the materials engineer and appropriate head office departments of the delivery times that will be required for other material and equipment. This must be done as soon as the requirements are established in order to provide the maximum lead time for the procurement and purchasing departments.

(v) To check the current validity of any programme previously prepared at head office
In cases where the site plan has been prepared at head office together with the relevant material and equipment schedules, the senior planning engineer will
check the information supplied with each department on site and at head office
to ensure that the data given is still current and that no changes have to be made.

(vi) To determine the manpower requirements
On completion of the broad plan, the senior planning engineer will assist the site
manager, the resident engineer and the industrial relations officer in assessing the
manpower requirements and the dates when such manpower needs to be available
on site. He will finalise the planned build-up of manpower and reassess the site
plan to ensure that they are both co-ordinated.

(vii) To keep all staff informed of the current plan
He must ensure that all staff and sub-contractors are made aware of the site plan
and appreciate the part they will need to play in its implementation.

(viii) To assist in the preparation of craft and section plans
He must provide any help and advice required in the preparation of the craft and
section plans and ensure that these are correctly co-ordinated with the site plan.

(ix) To determine the methods of reporting progress
He will liaise with the section engineers and with the cost engineer to determine
the most appropriate method of reporting progress and must ensure that such
procedures are fully understood by the section engineers and by those reporting
on the progress of sub-contractors.

(x) Progress reporting
He will liaise with the section engineers during the course of the work to ensure the
accuracy of progress reports and that they are sufficiently detailed for the system.

(xi) To update the site plan
Utilising the progress data, he will update the site plan and will inform all those
concerned when progress is falling behind the programme.

(xii) To review the expediting of material and equipment deliveries
He will maintain a constant check on material and equipment schedules to ensure
that the expected delivery dates continue to correspond to requirements. Any
expected delay in delivery should be checked with the materials engineer and
reported to the site manager when it appears that the site plan will be affected.

(xiii) To attend weekly site progress meetings
He will attend the progress meeting held each week by the site manager and report
on the current situation. He will note all changes in the forward plans and any
restrictions on progress.

(xiv) To incorporate additional work in the site plan
Work additional to the original requirements and all variations and revisions must
be incorporated in the site plan and the appropriate staff and sub-contractors
informed of any changes to their work load and any alterations to the targets
previously set. Relevant copies of the site plan that have been issued to the various
departments in the form of bar charts or other visual or written instruction must
be recalled, revised and reissued.
(xv) To ensure that staff work to the site plan
He must ensure that each department adheres to the site plan. Any departure or deviation from the plan must be checked with the department concerned so that the situation can be immediately corrected. Continued failure to pursue the work in accordance with the site plan must be reported to the site manager for a decision.

(xvi) To develop the knowledge and experience of staff reporting to him
He is responsible for the on-the-job training and development of any planning engineer, junior planning engineer or technical clerk appointed to work under his supervision. He must discuss any areas of strength and weakness with the site manager so that further responsibility, training or experience can be given.

Qualifications and experience required for the appointment
Senior planning engineers will be appointed from planning engineers, junior planning engineers and from field staff who have shown the necessary aptitude for planning work. They should have had some experience on construction sites in an engineering, craft or administrative capacity so that they are familiar with construction techniques and with the material and equipment which is used on site. They should preferably be of an educational standard equivalent to at least the General Certificate of Education 'O' level and possess the Ordinary National Certificate.

Skill, knowledge and experience required to fulfil the specific responsibilities of the position

<table>
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<tr>
<th>Skill, knowledge or experience</th>
<th>Cross reference to job responsibilities</th>
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<tr>
<td>1 Knowledge and understanding of the site organisation and communication system</td>
<td>General</td>
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<tr>
<td>2 Knowledge and understanding of head office organisation and responsibilities</td>
<td>General</td>
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<tr>
<td>3 Knowledge and experience of planning techniques</td>
<td>General</td>
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<tr>
<td>(a) Knowledge and understanding of network planning</td>
<td>General</td>
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<tr>
<td>(b) The ability to prepare and use bar charts</td>
<td>General</td>
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<tr>
<td>(c) Knowledge and experience of site manpower planning</td>
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(d) Knowledge of material and equipment scheduling techniques and procedures

4 Technical knowledge
(a) The ability to read, analyse and assess drawings, isometrics, specifications, etc
(b) A general appreciation of all crafts
(c) A general appreciation of construction techniques
(d) Knowledge of the contract specifications and drawings
(e) A general knowledge of the types of materials and equipment used in construction work

5 Detailed knowledge of the definitive estimate

6 A general knowledge of the delivery periods for items in common use

7 An understanding and appreciation of communication techniques

8 An understanding and appreciation of instructional techniques

9 Knowledge of methods of progress assessment

10 Knowledge of site costing procedures

11 Knowledge of available training schemes for planning staff
JOB TITLE: SENIOR COST ENGINEER
 RESPONSIBLE TO: SITE MANAGER
 SUPERVISING: JUNIOR COST ENGINEERS
 COST CLERKS

Overall job objective
To contribute towards the control of site efficiency and productivity through the preparation and maintenance of accurate records of all direct and indirect site costs, and by relating and comparing the data with the definitive estimate or site budget.

Job responsibilities
(i) To review the relevant job instructions
The senior cost engineer will make himself familiar with the drawings and the specifications of the contract and with the site plan. In particular, he will study the definitive estimate and determine the various codes under which the costs of the contract must be recorded.

(ii) To establish the costing system and procedures
He will establish the costing system and costing procedures where they have not already been laid down by head office.

(iii) To ensure that a reporting system is implemented
He must liaise with the resident engineer and with the planning engineer to ensure that a satisfactory reporting system will be implemented to meet the requirements of the costing system.

(iv) To agree the costing procedures
Where the detailed costing procedures have not been laid down by head office, he must submit the procedures he has designed to the site manager and to head office to ensure that they meet requirements.

(v) To ensure the timely and accurate recording of data by the supervisory staff
He will ensure that the appropriate supervisory staff understand their responsibility for providing accurate and timely reports on manhour expenditure in accordance with the agreed reporting system. He will particularly ensure that the correct cost codes are used.

(vi) To maintain accurate cost records
He will ensure that manhours expended and all labour costs are accurately recorded under the appropriate cost heads in the cost ledgers.

(vii) To relate costs expended to the estimate
He will relate the expended costs to those estimated in the definitive estimate or
Skill, knowledge and experience required to fulfil the specific responsibilities of the position

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1. **Knowledge and understanding of the site organisation and communication system**
   - General

2. **Knowledge and understanding of head office organisation and responsibilities**
   - General

3. **Knowledge of costing**
   - (a) Cost accounting
     - (ii) (vi) (vii) (viii) (xiii)
   - (b) Company and client code of accounts
     - (i) (ii) (v) (vi)
   - (c) Costing techniques and procedures, including cost forecasting
     - (iii) (iv) (vii) (x)
   - (d) Cost reporting procedures
     - (iii) (v) (viii) (ix)
   - (e) Detailed knowledge of the definitive estimate or site budget
     - General

4. **Technical knowledge**
   - (a) The ability to read, analyse and assess drawings, isometrics, specifications, etc
     - (i) (v) (vii) (x)
   - (b) A general appreciation of the working of all crafts
     - (v) (vi) (vii) (viii) (x)
   - (c) A general appreciation of construction techniques
     - (x) (vii) (viii)
   - (d) Knowledge of the contract specification and drawings
     - (i) (v) (vi) (vii) (viii) (x)

5. **Knowledge of the site plan and the reporting procedures associated with it**
   - (i) (iii)

6. **An understanding and appreciation of communication techniques**
   - (v) (vii) (xi)

7. **A general knowledge of the site financial accounts and wages system**
   - (xiii)

8. **Knowledge of available training schemes for costing staff**
   - (xiv)