
British Standard

Use of network techniques in project management

Part 1. Guide to the use of management, planning, review and reporting procedures

Utilisation des techniques de réseaux pour la gestion des projets

Partie 1. Guide pour l'utilisation des techniques de gestion, planification, révision et compte-rendu

Netzplantechnik im Projektmanagement

Teil 1. Leitfaden zur Anwendung von Management-, Planungs-, Überprüfungs- und Berichtstechniken

Foreword

This Part of BS 6046 has been prepared under the direction of the Quality Management and Statistics Standards Committee.

The aim of this guide is to be of practical use to the manager who wishes to use project network techniques as a tool for project management. A project manager meets many problems of which only some can be foreseen; even those familiar with planning and controlling projects will encounter unexpected difficulties and will often be forced into 'management by crisis'.

This guide is designed to draw attention to the problems that project management can resolve in advance, and does this by helping those involved to ask the right questions. Although the use of project network techniques is not a prerequisite for project management and many of the aspects discussed apply whether or not such techniques are used, the guide is principally concerned with their use. The guide deals in some detail with the circumstances under which project network techniques are appropriate and stresses the management problems that arise in their application.

The guide systematically examines the area of application of project network techniques in project management. It guides the less experienced reader logically through the more fundamental questions, while the structure enables those more experienced in project management to progress rapidly through to more advanced topics. The best way of using the guide is for the reader to acquaint himself with its structure and the sequence in which various problems are approached.

The guide concentrates on practical problems and possible methods of solving them. Being a guide to practice and application, it does not discuss theoretical aspects, neither does it provide detailed explanations: for such a purpose a number of textbooks have been written for a wide range of possible users. The reader's attention is drawn mainly to the questions that arise during project management and the use of networks. In particular, the general problem of communication, i.e. between different parts of the same organization and between different organizations, is stressed as is the importance of knowing the right questions to ask. The answers given here are a good guide, based on long and wide-ranging experience; they are, however, opinions and not absolute facts. As such, the views expressed should be

examined critically in the light of particular circumstances to which they are applied, as should all general interpretations. The main value claimed is that widely discussed and agreed answers to frequently met problems tend to be well suited for most situations and provide an authoritative basis, not to be disregarded lightly, for inter-organizational project management arrangements.

BS 6046 is published in the four following Parts.

Part 1. Guide to the use of management, planning, review and reporting procedures. The important functions and organization of project management, as distinct from general management, are emphasized. Descriptions are given of the involvement of management as the project develops from the initial planning of the project and review systems to the procedures to be adopted in setting the stages and frequency of project review and methods of reporting.

Part 2. Guide to the use of graphical and estimating techniques. Practical considerations for the estimation of values needed for the analysis of project networks are discussed. Guidance is given on the factors to be considered in choosing between activity-on-arrow or activity-on-node techniques. Network drawing methods for the presentation of the two types of network are discussed and recommendations given for the conventions to be used and the level of detail to be included as well as practical hints.

Part 3. Guide to the use of computers. Guidance is given on *when* and *when not* to use computers in conjunction with project networks. The different ways in which a computer may be used for processing project networks are described and assistance is given on how to select the actual computer package. This Part then refers to the purpose and significance of coding systems for use with project networks.

Part 4. Guide to resource analysis and cost control. This Part covers the use of resource analysis and project cost control as a natural extension to the use of time analysis in project network techniques. The two techniques are treated separately for the purpose of providing more effective management information.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Amendment No. 1
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Use of network techniques in project management
Part 1. Guide to the use of management, planning,
review and reporting procedures

Corrections

AMD 5111
November 1987

Clause 0.4
In paragraph 2, line 2 delete 'as duration' and substitute 'as of duration'.

AMD 5111
November 1987

Figure 1. Typical project management procedures
Delete 'Date collection and analysis' and substitute 'Data collection and analysis'.

AMD 5111
November 1987

Clause 2.1 Project initiation and client/contractor relationships
In paragraph 3, line 4, delete 'Subsequently' and substitute 'Consequently'.

AMD 5111
November 1987

Clause 2.5 Project review, reporting and communications
In paragraph 3, line 5, delete 'because you have made a decision, it is easy to assume that everyone else is aware of the outcome' and substitute 'because a decision has been made, it should not be assumed that everyone will be aware of it or its effects'.

AMD 5111
November 1987

Clause 2.6 Project cost factors and improvement potential
In the final line of paragraph 1 delete 'high' and substitute 'precise'.

AMD 5111
November 1987

Clause 5.1 General
In paragraph 6, line 9, delete 'in situation' and substitute 'in the situation'.

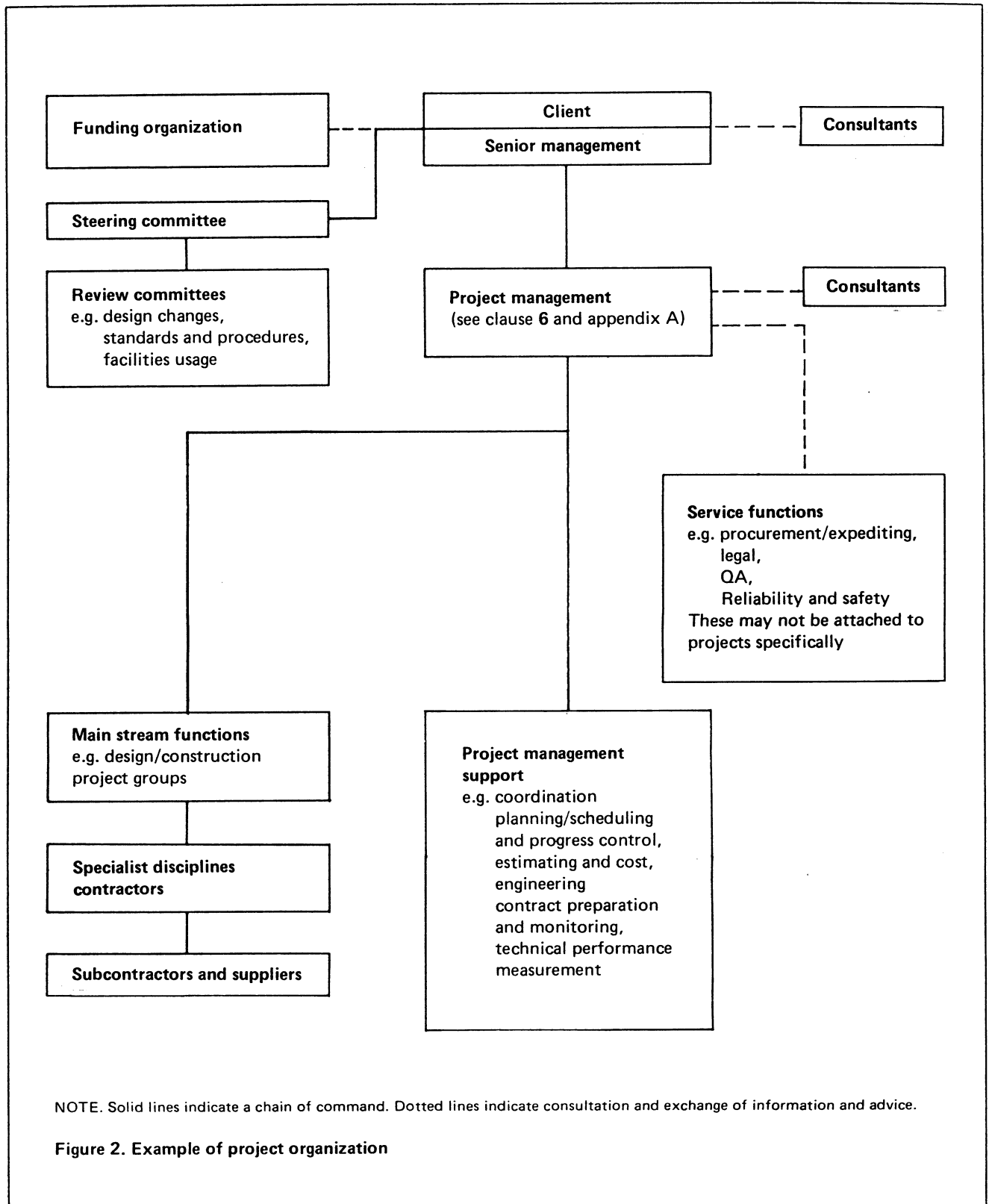
AMD 5111
November 1987

Clause 5.4 Factors to be considered when developing a project organization
In line 2 of item (f) delete 'extent' and substitute 'expedient'.
In line 1 of item (o) delete 'in management' and substitute 'in a management'.

AMD 5111
November 1987

Clause 5.7 Simple organization for project control
In paragraph 3, line 1, delete 'coordinators relating' and substitute 'coordinators for each function relating'.

Figure 2. Example of project organization
Delete the existing figure 2 and substitute the following.



AMD 5111
November 1987

Clause 7. Project objectives

In item (b) delete 'provide basis' and substitute 'provide a basis'.

AMD 5111
November 1987

Figure 6. Stages of project management action for a typical design/construction project

At the top of the figure, delete 'Financial plans give funding' and substitute 'Financial plans including funding'.

AMD 5111
November 1987

Clause 8.3 Basic factors

In line 3 of item (h)(2), delete 'projects' and substitute 'records'.

AMD 5111
November 1987

Clause 8.4 Communications

In paragraph 3, line 3, delete 'containing' and substitute 'containing'.

AMD 5111
November 1987

Clause 9. Contract conditions

In paragraph 1, line 5, delete 'anyway'.

AMD 5111
November 1987

Clause 10. Familiarization and training

Delete the existing paragraph 1 and substitute the following.

'Steps should be taken to familiarize all participants with the project and to discuss with them the choice of the systems and methods for project monitoring, control procedures, documentation and organization. Once all these have been agreed and specified, then all members of the project team should be instructed to work within the agreed system.'

In paragraph 3, line 9, delete 'cover detailed procedures or' and substitute 'cover procedures in detail or'.

In paragraph 5, line 1, delete 'training specific' and substitute 'training which is specific'.

In paragraph 6, line 2 of item (i), delete 'processing, such that' and substitute 'processing, so that'.

AMD 5111
November 1987

Clause 11. General

Delete the existing paragraph 1 and substitute the following.

'Project planning is always necessary, for example in a repetitive building project the planning is usually carried out to define the scope of the project, its overall structure and its needs in terms of resources (including finance). Subsequently, these plans may also set the basis for the measurement of the progress of the project.'

In paragraph 5, lines 1 and 2, delete 'then negotiation and agreement' and substitute 'then by negotiation and agreement'.

In paragraph 11, line 11, delete 'management are' and substitute 'management is'.

In line 1 of item (c) delete 'control on data' and substitute 'control of data'.

In line 2 of item (9) delete 'optimization' and substitute 'improvement'.

AMD 5111
November 1987

Clause 12.1 Assessment of available data and preliminary planning
In paragraph 1, line 4, delete 'often' and substitute 'usually'.
In line 1 of item (i) delete 'questions like' and substitute 'questions such as'.

AMD 5111
November 1987

Clause 12.4 Project organization
Delete the second sentence of paragraph 3 and substitute: 'Decisions should then be made on potential solutions and passed upwards for further consideration.'

AMD 5111
November 1987

Clause 12.5 Structure of networks
In paragraph 2, line 14, delete 'be kept to manageable sizes too.' and substitute 'also be kept to manageable sizes.'
In paragraph 3, line 5, delete 'computer, because this' and substitute 'a computer. This'.

AMD 5111
November 1987

Clause 12.6 Preparation of programmes and budgets
In paragraph 1, line 5, delete 'planning and estimation' and substitute 'plans and estimates'.
Immediately before the penultimate paragraph insert the following:
'NOTE. Modern graphics packages have had a considerable affect on this particular area.'

AMD 5111
November 1987

Clause 12.8 Planning and programming checklists
In line 1 delete 'checklists detail' and substitute 'checklists give the detailed'.

AMD 5111
November 1987

Clause 13.1 General
In paragraph 1, lines 8 and 9, delete 'delays become' and substitute 'delays occur and become'.
In the final line of paragraph 6 delete 'as approach' and substitute 'as the policy'.

AMD 5111
November 1987

Clause 14. General
In note 1, line 9, delete 'so is' and substitute 'so it is'.
In note 2, line 4, delete 'believe and see' and substitute 'see and believe'.
In note 2, line 7, delete 'Also when' and substitute 'When'.
Delete line 1 of paragraph 5 and substitute 'As a general rule, one person should be able in practice to'.

AMD 5111
November 1987

Clause 15. Project review cycle
In paragraph 4, lines 2 and 3, delete 'a published, formal' and substitute 'published as a formal'. In line 9 delete 'improved' and substitute 'assessed'.

AMD 5111
November 1987

Clause 16. Data collection
In paragraph 2, line 4, delete 'Since analysis' and substitute 'Analysis'.

AMD 5111
November 1987

Clause 17. Project monitoring

In paragraph 2, line 3, delete 'as may be' and substitute 'which may be'.

AMD 5111
November 1987

Clause 19. Analyses

In paragraph 5 (beginning 'Cost analysis'), line 6, delete 'been actually reached' and substitute 'actually been achieved'.

In paragraph 7, (beginning 'Whatever analyses'), line 10, delete 'would then' and substitute 'should then'.

AMD 5111
November 1987

Clause 20. Project management decisions, their ratification and implementation

In paragraph 3, line 8, delete 'and implemented where possible'.

In paragraph 4, line 7, delete 'together would' and substitute 'together should'.

In paragraph 6, line 8, delete 'what these are.' and substitute 'these.'.

AMD 5111
November 1987

Clause 21. General

In paragraph 2, line 2, delete 'applied and' and substitute 'applied where applicable and'.

AMD 5111
November 1987

Clause 23.2 Bar charts

In paragraph 5, line 6, delete 'resource levels' and substitute 'resource amounts, though this requires care so that logical errors are not introduced'.

AMD 5111
November 1987

Clause A.1.1 General

In line 5 delete 'On top of this' and substitute 'In addition'.

In lines 7 and 8 delete 'more recently'.

AMD 5111
November 1987

Clause A.2.2.3 Project form

In paragraph 2, line 14, delete 'prioritize' and substitute 'define the priorities for'.

AMD 5111
November 1987

Clause A.2.2.4 Matrix form

In paragraph 1, line 3, delete 'makes pure matrix unique' and substitute 'makes a pure matrix structure unique'. In line 4 delete 'boss' and substitute 'manager'.

In paragraph 2, line 4, delete 'generally'. In line 13 delete 'confusion will likely escalate' and substitute 'confusion are likely to escalate'.

AMD 5111
November 1987

Clause D.4 Float order list

In line 3 delete 'an extremely' and substitute 'an externally'.

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Guide

0. General introduction

0.1 In 1968, BSI published BS 4335 'Glossary of terms and symbols used in project network techniques', which was revised in 1972. For some time, it has been considered that this could usefully be supplemented by a standard guide to the application of these techniques, based on accumulated practical experience. As a result, this standard has been developed. It concentrates on network-based systems, but also discusses related aspects of project organization and management insofar as they influence the application of such methods.

0.2 Projects differ from other enterprises in several ways, in particular by their transient nature, by the speed by which they normally have to be executed and by their relative complexity. Other features which distinguish projects include the following.

- (a) Their duration is usually predetermined (finite) with definite start and termination dates specified.
- (b) What happens during a project often affects the rest of the subsequent life of the end product (hardware or service).
- (c) The project organization is often temporary and may change from one phase to the next.
- (d) Most projects contain some elements of uncertainty and risk.
- (e) Many projects are non-repetitive, and often include some essentially unique features, often beyond the current state of the art.
- (f) Finally, projects are not isolated, they interact with other projects and organizations; their structures and systems are interactive organizationally, technically, economically and socially.

0.3 Two basic elements are present in a project: first the operational activities, e.g. the functions of design, procurement and construction, and, secondly, management systems, which are needed to plan and control the former. This guide deals primarily with the management systems, the details of which will depend on the type of project and the particular industrial sector in which they are applied. These systems also need to be adaptive as changes in project environment and phase occur. However, most projects, by their nature, contain similar stages, phases and procedures, which are diagrammatically summarized in figure 1 and form the basis for the structure of Part 1 of this guide.

BS 6046 as a whole concentrates on the parameters of time, resources and hence costs in general. It deals with the basic requirements of project organization and management with project planning (where the datum conditions for the future conduct of the project are set down) and finally it deals with methods of controlling the subsequent performance of the project and some ways by which control may be maintained when changes occur.

0.4 Project network techniques as used now were developed in the USA, the UK and France more or less simultaneously in the mid 1950's. These developments included both activity-on-arrow and activity-on-node systems. A comparison between these alternative modes and detailed guidance on graphical and estimating techniques is given in BS 6046 : Part 2. With the exception of PERT (programme evaluation and review technique), which contained probabilistic elements appropriate to the research and development (R & D) area for which it was designed, the developments were aimed at improving the ability to plan and control complex engineering projects.

Since then the techniques have been extended to handle resources, uncertainty of outcome as well as duration and many other specific applications.

The benefits of using such techniques can include:

- (a) clearer definition of the scope of the project and the complex interrelationships between tasks;
- (b) better coordination between different organizations within the project, and provision of information about each organization's progress and future plans to the others (communication links);
- (c) ease of preparing schedules of work to be done;
- (d) ready means of reviewing the project and exercising control over time, resources and costs;
- (e) clearer identification of critical and risk areas, plus an excellent model for 'what if' exercises and resultant management decisions.

Networks can be easier than bar charts to develop and maintain, and provide a simple means of assessing the combined effects of activity logic constraints, limited resources, etc., in meeting a required project end date. For most time analysis, and resource analysis especially, computer processing is desirable and for this many computer packages are now available. Means of assessing these computer packages and advice on coding systems is given in BS 6046 : Part 3 and BS 6046 : Part 4 covers the use of resource analysis and project cost control in more detail.

The network techniques described enable the main functions of the management of projects, i.e. planning, coordination, monitoring and control, to be conducted in an efficient and logical manner, in order to control a project, rather than merely monitor what is taking place. If effective decisions are to be made by project management, it is necessary that these decisions be based on the most accurate and up to date information available; this requires an adequate communication system together with defined objectives and procedures. It also implies that management has to look at future plans as well as using past experience, to anticipate problems. Communications have to be such that rapidly changing situations are quickly recognized for corrective action to be effected by management.

0.5 BS 6046 is intended to provide guidance to a number of groups of people:

(a) *general management*: in organizations that operate projects, so that they are aware when setting company policies, of the techniques available *and also their limitations*;

(b) *project managers*: responsible for project performance, so that they may better cope with the many problems they meet (only some of which may be foreseen) and encourage better integration between the different disciplines taking part, aiming for a common goal;

(c) *project support staff*: coordinators, planners, cost engineers, etc., so that they may better appreciate the techniques available and their potential pitfalls;

(d) *educators*: those engaged in the teaching of, or research on, network-based techniques for project management who may need a basic reference on accepted practice.

The guide is designed to draw attention to the problems that project management can resolve in advance, and does this by helping those involved to ask the right questions. Although the use of project network techniques is not a prerequisite for project management and many of the

aspects discussed apply whether or not network techniques are used, the guide is principally concerned with their use.

Although the guide has this emphasis on network-based techniques project managers can, and often do, make use of other techniques, e.g. operational research, work study, organization and methods (O & M), quality control, production control, data processing, computer and information systems and value engineering.

It is the responsibility of project management to select and use these techniques as appropriate and to balance their impact on the project so that this is not jeopardized by over-enthusiasm for any single aspect or by conflict between opposing objectives. For example, equipment should not be over designed or over engineered at the expense of failing to meet a delivery date when equipment which performs quite satisfactorily can be delivered on time.

As with all management techniques, it is desirable that the use of a network-based project management system should receive full management backing within the company or organization and that there should be an adequate training programme for all personnel concerned with network and other techniques for project management,

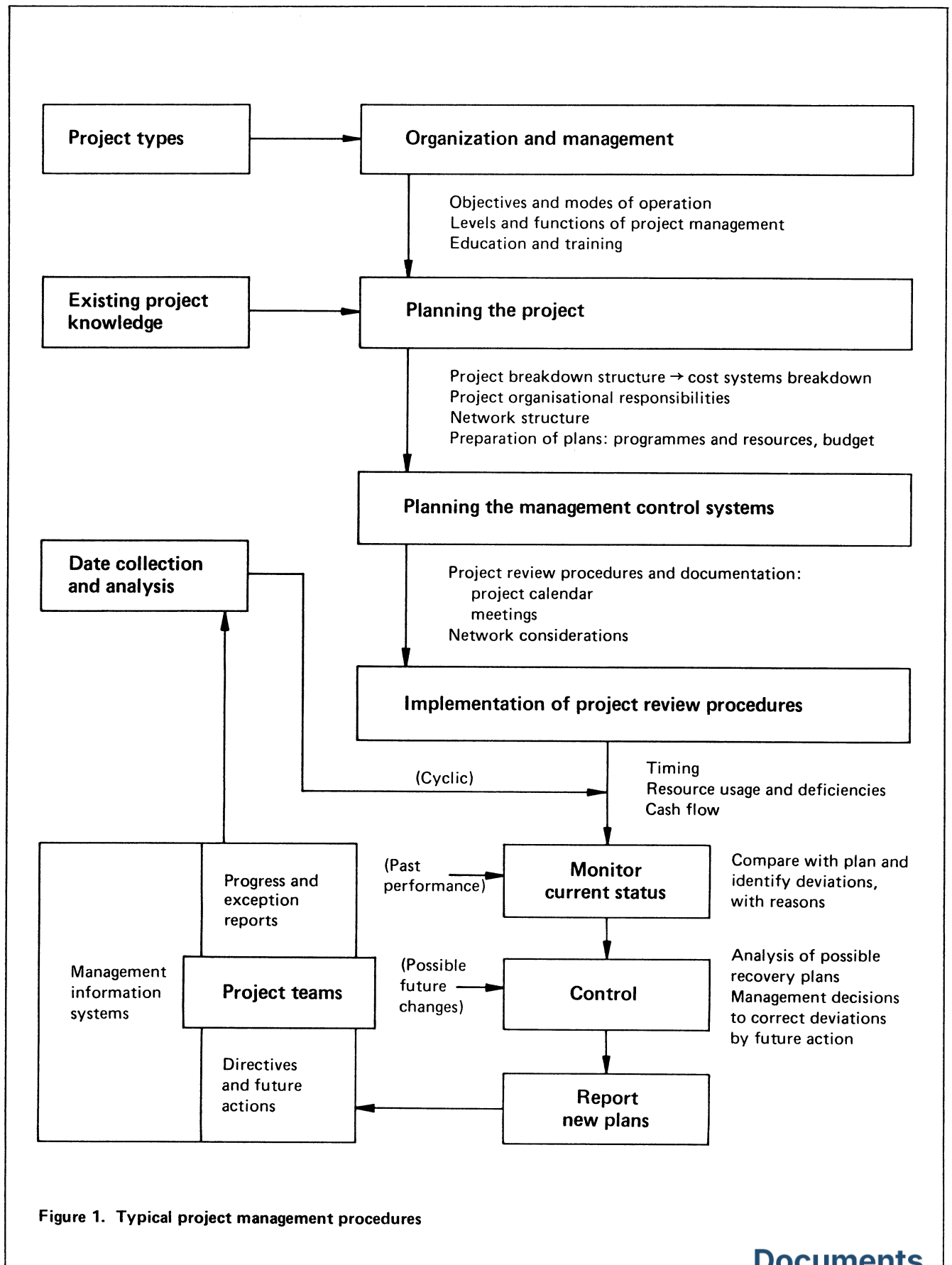


Figure 1. Typical project management procedures

Section one. General

1 Scope

This Part of BS 6046 deals with the basic aspects of project management that are applicable to projects between conception and completion, when using network techniques. It covers project organization and management, planning, review and reporting procedures.

Section one summarizes the content and reviews basic relationships, organizational and cost factors and in particular the importance of pre-contract preparations in the project feasibility and project definition phases.

Section two discusses the features of different project types and organizational considerations to be made in the project environment. It emphasizes the important functions of project management, as opposed to general management, and describes the management stages in setting up a new project. It stresses the need for the objectives of the project and the modes of operation of project management to be defined, and identifies a number of management levels around which the control procedures operate. Factors affecting project organization and contract conditions are considered and the importance of familiarization and training shown.

Section three deals separately with planning of the project itself and planning the project review systems.

Planning the project involves assessment of the available knowledge and, where applicable, definition of work packages from a suitable project breakdown structure. Project organization and network structure should be defined before any *detailed* plans are prepared. Methods of developing these plans are described, leading to a definition of decision points and the potential problem areas. The need for project management involvement in the initial planning or even project selection is emphasized.

Planning the project review systems looks at the factors affecting project networks, i.e. levels, size, activity durations, calendars, policy decisions, analyses and documentation to be produced. Reference is made to types of network construction, selection of symbols and coding, and the decision between manual and computer processing. Planning the review cycle with its associated calendar of meetings and network/cost data updates is discussed and finally the specifications of the documentation and procedures to be used are identified.

Section four is concerned with the actual implementation of the project review procedures themselves. The stages in the review cycle and considerations of its frequency are described, together with methods of data collection. The differences between monitoring and control are defined. Data verification and validation, error correction and programme updating are covered, followed by various analyses to provide information for the project management decisions meetings. Management decisions, their assessment, ratification and implementation are discussed, as is the publication of the analysed data.

Section five deals with reporting procedures, for both management and workforce, identifying types of document and their methods of preparation. It describes data tables

such as listings of event and activity records, charts and presentations such as bar charts, different network applications and graphical displays, e.g. costs or man-hours against time, and written reports.

NOTE. The titles of the publications referred to in this standard are listed on page 65.

2 Basic relationships, organizational and cost factors

2.1 Project initiation and client/contractor relationships

Projects may be conceived, initiated or identified either:

- (a) *internally*, by the top or senior management or a supplier/contractor organization, for purely internal (organizational) purposes or in anticipation of potential market demand; or
- (b) *externally*, by procurement authorities, purchasers', users' or clients' organizations requiring specific facilities, products or services.

This guide concentrates on item (b) since most projects are subsequently defined and/or developed *jointly* by two or more parties via some form of contractual relationship which usually defines the degree of involvement and, specific areas of authority and/or responsibility carried by the participants. However, much of the guidance included can also be applied to item (a) (particularly that given in appendix A).

Further, the involvement of the client has increased appreciably during the last decade, particularly with regard to projects considered as being beyond the state of the art. Subsequently clients may not only arrange project funding but also appoint project (or parallel key) staff, lay down guidelines for contractual requirements (particularly during the pre-contract phase) as well as influence generally methods of operation.

2.2 Pre-contract preparations (project feasibility/definition)

Prior to receiving the go ahead for a new project, once the concept has been identified, it is normal to carry out a feasibility or design study to evaluate its potential; a client or contractor may engage in similar investigations. In addition to a technical assessment of potential designs, risk and discounted cash flow analyses may be carried out together with some outline programming. For some projects, this is followed by a project definition stage during which the potential problem areas are studied in more detail before full financial investment is finally committed.

Pre-contract preparations and early planning on a new project is usually essential even during project definition and should involve not only the project manager but also planning engineers, estimators, senior designers, quality/reliability and safety specialists, commissioning experts and representatives of future maintenance and operations functions as appropriate. Their initial duties would be:

- (a) to define the project objectives;
- (b) to define the broad scope of the work to be carried out and specify the resources required;

- (c) to define in outline a suitable project organization and the responsibilities of key staff;
- (d) to consider the project requirements (through contracts, etc.) and the operation/maintenance requirements of equipment, covering safety/reliability requirements, quality assurance (QA) plans, contracting plans and commissioning requirements, inter alia;
- (e) to set preliminary time scales, budgets and dates for key events;
- (f) to outline procedures (standardized wherever possible);
- (g) to consider potential risks and problem areas and prepare contingency plans.

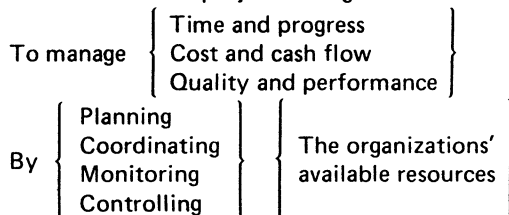
2.3 Project management, planning and control

2.3.1 There is no standard way of managing projects. Choice of organization, role of project management, system of planning/monitoring/control, types of contract let, etc., depend on the complexity, novelty and urgency of the situation, and on the particular industry and personalities involved. However, pointers can be made giving the relative advantages, disadvantages and pitfalls found from experience for guidance in making decisions, since:

- (a) to manage we need to control;
- (b) to control we need to measure;
- (c) to measure we need to define;
- (d) in defining we need to quantify.

NOTE. Although project management is involved in human and industrial relations, health and safety, law, commerce (finance and contracting), etc., these are not considered in detail since they are outside the limited scope of this guide.

The relevant aims of project management are:



2.3.2 The aim of planning and controlling of projects is to anticipate problems *before they arise* so that in-advance remedial action can be initiated. This entails:

- (a) defining the scope of the project;
- (b) setting down the logical sequence of activities and their interactions;
- (c) scheduling time and resources;
- (d) controlling the future conduct of the project using feed-back review methods.

The term 'planning' can be applied to several different functions:

- (1) corporate planning;
- (2) overall project planning, or organization, procedures, etc.;
- (3) programme planning (scheduling and resourcing);
- (4) shop floor planning in a manufacturing organization.

It is primarily category (3) which is covered by this guide and to some extent category (2).

2.3.3 Project management, planning and control system procedures depend on several factors which include:

- (a) project type (technology) and its size/complexity in terms of organization;
- (b) experience available within the organization;
- (c) management structure and its policies;
- (d) particular role of the organization, e.g. client or contractor;
- (e) interrelationships between the companies involved and their organizational structures;
- (f) phase or stage which the project has reached, e.g. design or construction;
- (g) locations of the project teams, i.e. the work sites;
- (h) importance of the project (priorities).

Allowance for (and understanding of) the following should be taken into account:

- (1) company and managerial behaviour patterns;
- (2) conflicts in objectives, e.g. between client and contractor;
- (3) contract conditions and other external constraints;
- (4) political motives (personal as well as national);
- (5) social and economic climates.

The philosophy behind the planning and control systems used should be known, understood and accepted by all project staff to encourage their complete involvement. The aim should be the smooth running of the project, identifying potential problem areas well ahead so that corrective actions can be taken economically. *Remembering that only the future can be altered, the past merely provides experience.*

2.4 Corporate and project management structures

Corporate structures vary appreciably depending on industrial sector, product or service involved. However, they can be generally classified as either:

- (a) centralized functional organizations; or
- (b) decentralized multidivisional organizations.

NOTE 1. All multidivisional organizations are not equally decentralized, nor all functional organizations equally centralized.

On top of this, organizational complexities resulting from increasing size and scale or the need to supply somewhat unique products and services to a definite time scale has recently led to the development of *project management structures* which are usually integrated within the more traditional corporate structures.

NOTE 2. These different forms should not be confused although many similarities exist between them. Further guidance in organization forms is given in section two of this standard and BS 3375 : Part 1.

As an organizational form, project management usually requires a certain amount of freedom of action and flexibility, but top management needs to decide upon both the corporate and project management authority structures required to control, coordinate and integrate the work of the various specialized (functional) groups and project groups involved. See also appendix A for details of the principal factors involved.)

2.5 Project review, reporting and communications

The need for project review is sometimes questioned, but since few projects go exactly according to plan, and then only if control has been adequately maintained, it is usually advisable to adopt some form of review procedures. When considering project/scope variations, it is desirable to separate external, uncontrollable causes, e.g. market and legal changes, trades union effects and changes in rates of exchange, from internal changes under the control of project management.

Reporting is an important part of the review cycle since it not only provides the various managers with information on project status but can also, with suitable presentations, provide basic data against which decisions may be made. However, as reports can also be misleading, they should be backed by objective data wherever possible. *Proliferation of extensive reports should be avoided since these waste the time of both writer and reader.*

Project management systems can provide the means of handling information, i.e. of gathering, of analysing, of using it to make decisions, and of passing on plans and instructions. Communications present one of the biggest problems in any environment; because you have made a decision, it is easy to assume that everyone else is aware of the outcome.

Senior management needs to have up to date information about various areas of the project, in what is a dynamic situation. Understandable directives following management decisions have to be passed down to the project teams, defining project policies and objectives, project organization and responsibilities, and work scope with associated time scales and costs.

Maintenance of adequate records throughout the project, especially successive issues of network-based data, provide a pictorial history of events, ideal for subsequent post-project or post-contract analysis, which can be used to improve the planning of future projects or to assess, or sort out, any claims.

2.6 Project cost factors and improvement potential

It is becoming increasingly desirable to relate cost systems to network data but this should be done with great care and it should not be attempted lightly by inexperienced organizations. The technique appears to be easier than it really is. Programmes need to be flexible, suitable for rapid revision and update as job scope and dates change. Cost

reporting and the control of expenditure should be precise and rapid, even though the accuracy of the figures may not be as high as the traditional accountant would wish.

The measurement of success or failure associated with a project is difficult to assess and really depends on the objectives set and actual achievements realized in terms of time, cost and performance, related to the available resources utilized. Also, where two parties are involved, it is unlikely that any achievements or deficiencies will be equally shared.

Highly visible factors such as labour productivity or lack of control are often cited as the obvious reasons for expensive failures with respect to time and cost schedules. However, recent research on the importance of controllable factors relative to project costs (for the construction of transportation facilities in the USA) has indicated the following orders of significance.

(a) *Improvement potential (within state of the art).*

Controllable factors relative to project costs in descending order of importance are:

- (1) timeliness of decisions;
- (2) pre-contract preparations;
- (3) organizational structure;
- (4) design capability/effectiveness;
- (5) contract documentation/requirements;
- (6) design subcontracts;
- (7) { construction/production methods;
 | planning and control.

(b) *Improvement potential (beyond state of the art).*

Controllable factors relative to project costs in descending order of importance are:

- (1) design capability/effectiveness;
- (2) { organizational structure;
 | pre-contract preparations;
- (3) contract documentation/requirements;
- (4) timeliness of decisions;
- (5) planning and control;
- (6) construction/production methods;
- (7) design subcontracts.

Of particular interest in both the above lists is the high significance of *pre-contract preparations* and *organizational structure*; with *timeliness of decisions* taking precedence, within the state of the art and *design capability/effectiveness* in projects beyond the state of the art.

Section two. Organization and management of projects

3 General

This section of the guide is not intended to be a treatise on project organization and management. Its purpose is to provide a general background and to emphasize those aspects that can specially affect the efficiency and application of network techniques to the planning and control of projects.

It aims to bring out those points which influence such application but which often are not defined adequately or early enough in the life of the project, or are not passed down to the appropriate levels. For instance, objectives, authorities and responsibilities have to be defined since these influence the criteria initially needed when planning a programme, and later when reviewing that programme and making management decisions.

NOTE. Organizational or internal political pressures (within the corporate or project organizations themselves rather than national policies) often place superfluous constraints on people and procedures and can impede their efficiency. This type of interference should be explicitly identified and resisted if not relevant to the project, otherwise project procedures can become unnecessarily complicated.

When setting up control procedures, a knowledge of the peculiarities of the particular industry, the personalities involved and the organizational structures can be as important as a knowledge of the technical features of the project. Where applicable, the conditions of contract between client and contractor are also important, since irrespective of what control systems are potentially desirable and beneficial, the only legal requirements to be met are those agreed by contract. However, for reasons of good relations, additional demands from a client will usually be given serious consideration by a contractor.

This section describes some key features of a number of different but typical project environments; it also discusses project organizations. Finally, the importance of familiarization and training is emphasized, especially covering the methods of planning and control to be applied and which should be defined in the early stages of the project. All too often new techniques are established too late to be of effective benefit to existing projects and are not adequately developed before the next project.

4 Project types and features

4.1 Project pattern

Most projects follow a common pattern during their lives.

- (a) Gradual build-up in the use of resources of personnel, materials and equipment, energy, etc.

NOTE. Alternative plans might be considered during this phase.

- (b) A relatively long-duration plateau, when resources are used at a high rate.

- (c) Run-down, when control may be simplified and resources released.

NOTE. Problems in this period are likely to arise from reduced interest in the project, limited choice of corrective actions, recriminations for things which have gone wrong during the project and also any difficulties of hand-over at the end.

4.2 Project phases

A typical project (involving the development of hardware) will pass through the following phases.

- (a) Feasibility or design study, and project definition (if accepted).

NOTE. It is advisable to assess risks plus best combinations of programme duration, resource allocation and cost control, not just technical feasibility.

- (b) Design, specification and procurement.
- (c) Construction, i.e. manufacture, fabrication, assembly.
- (d) Installation, testing and commissioning, and hand-over to an operator/user.

4.3 Project categories

Projects may be categorized in many different ways, e.g. by time scale, by particular feature, by industry or by value. Examples against different time scales are as follows.

- (a) *Long term* (over 10 years):

- (1) industrial development (of a country);
- (2) electrification programme;
- (3) integration of large units into a central organization, e.g. nationalization programme;
- (4) development/production of aircraft, ships or defence equipment.

- (b) *Medium term* (3 years to 10 years):

- (1) construction of an iron ore/steel mill complex, a large dam or an offshore oil installation;
- (2) development and implementation of an extensive computerized system;
- (3) disintegration of large organization, e.g. privatization;
- (4) part of a long term project.

- (c) *Short term* (0.5 years to 3 years):

- (1) development of an effluent or waste disposal system;
- (2) building a roadway or stretch of railway track;
- (3) decentralization, e.g. moving office and plant locations;
- (4) organizing a conference;
- (5) part of a longer term contract.

- (d) *Special small scale*:

- (1) emergencies: evacuation of a building or restoration of vital services after a disaster;
- (2) complex key operation: changeover, e.g. decimalization or shutdown repair to plant;
- (3) high-cost procedures: stock reordering or data transmission.

4.4 Environments

Some typical examples of environments in which project network techniques are applied are as follows and current practice in these areas is given in more detail in appendix B.

- (a) Strategic long term planning, e.g. economic development at national, local government or company level.
- (b) Research and development, e.g. space flight, military weapons, new large-scale equipments or pharmaceuticals.

(c) Administrative or procedural projects, e.g. setting-up of a new organization, centralization or decentralization of administration, introduction of major administrative or organizational changes, or planning an exhibition. (See also item (g).)

(d) Capital plant manufacture for industry, e.g. chemical plant package or oil refinery equipment, which implies design, construction and erection on site.

(e) Major engineering undertaking on dispersed sites and usually occurring at irregular intervals, e.g. railway line, roads, service distribution scheme, pipelines and highways.

(f) Major engineering undertaking on a localized site and often regularly recurring, e.g. power station or ship construction.

(g) Planning and controlling change-overs, interruption of services or functions, e.g. metrication, traffic diversion during rebuilding operation, factory or office move, computerization of financial operation, intermediate/short term planning, plant/process modification or improvement working within production requirements. (See also item (c).)

(h) One-off building construction, e.g. hospital, office block, library, flats or bridge.

(i) Repetitive building construction, e.g. housing or service stations (particularly at the design stage).

(j) New product introduction, including marketing and distribution.

(k) Major overhauls and planned maintenance, e.g. blast furnace, chemical plant, ship refit or oil refinery areas.

(l) Production planning, e.g. fabrication or assembly.

(m) Key operation of short duration, e.g. aircraft turn-round.

(n) Emergency planning, e.g. evacuation of building after fire or flood warning, restoration of services after power failure, rescue operations after natural disasters such as an earthquake or coal mine incident.

(o) Plant commissioning.

(p) Plant operation.

NOTE. Many projects pass through a number of the above categories during their lives, and so different stages of a single project will require different treatment as the project progresses. For example, stages in the development of an offshore oil platform and its installation may at different times relate to categories (a) to (h) and (k) to (p).

5 Project organizations

5.1 General

Once an enterprise takes on a project, then, even if this is only small, its basic organization will be affected. (See also appendix A.)

There are three main characteristics associated with project organizations as follows.

(a) *Functional specialization*, by the departmental groups, who apply previous experience to a specific stage or aspect of the project, e.g. planning, design, construction,

etc., but whose departmental objectives and responsibilities often produce differing attitudes, in terms of what they may each see as their primary or secondary functions.

(b) *Sequential relationships*, between the primary functions of these groups, in terms of completing a series of project tasks the interfaces of which usually need to be controlled by defined procedures.

(c) *Hierarchy of management and/or project authority structure*, to coordinate and control the work.

The requirements of project organizations include:

- (1) innovation to overcome problems as they arise;
- (2) experience on which to make sound, efficient decisions;
- (3) rapid response to changing situations;
- (4) effective control of expenditure and progress.

These attributes need to be coordinated by such approaches as:

- (i) locating together the project groups and encouraging informal relationships to develop between them (this helps communications);
- (ii) setting up a steering committee of main function departmental managers, encouraging commitment to decisions;
- (iii) forming a project team, with at least one senior person from each department concerned;
- (iv) appointing independent project management, project managers or coordinators with no strong functional ties.

The project organization should relate to the project breakdown structure (see 12.2). It will vary with the size and complexity of the project and with the extent to which the teams are separated. It will also be affected by language and other communication problems, and should take account of any established organizations with which it has to interface.

Where project teams are spread across the country or, more particularly, where they are in different countries, then there needs to be a central project management office with satellite managements where appropriate. It is then necessary to define and agree the roles and limits of responsibility of these two management environments for maximum efficiency. Account has to be taken of the fact that satellite management is on the spot and should therefore react quickly to local fluctuations in situation, whereas central management can perform only the initial planning and make the longer term, across-the-project decisions.

The method by which resources and/or funding are made available to the project can also affect its organization. Methods vary in different countries, where the local environments and governments may change the incentives and motivations.

5.2 Organizational environments in which project teams are built up

With increasing complexity, projects may be organized:

- (a) at a single establishment or location;
- (b) within a single company but at establishments spread nationally and internationally;
- (c) by joint ventures between several national companies; and
- (d) as multinational enterprises.

5.3 Methods by which projects are staffed

A project organization may be manned in a number of different ways as follows.

- (a) From within a single department, as part of the staff's normal function, e.g. to improve a particular facility. The department may be engaged on several projects at one time.
- (b) Staff within a department split their time between a project and their functional duties.
- (c) Individual staff seconded from functional groups to a project for as long as necessary.
- (d) Functional groups providing a specialist service to the project throughout its life, e.g. project planning, coordination and cost engineering, independently of which individuals are working on the project.
- (e) Dedicated project teams with no functional ties, who move from one project to the next.

Category (a) retains the basic *functional* organizational form (with limited *project* management authority).

Categories (b) to (d) lead to *matrix* organizational forms.

Categories (b) to (e) will require either full or part time project management and/or coordination.

Category (e) indicates complete *project* management authority but in practice there is usually some limited *functional* involvement at the senior/top management level.

Categories (c) to (e) may need to be supplemented by outside staff, e.g.:

- (1) consultants;
- (2) temporary staff.

5.4 Factors to be considered when developing a project organization

When defining a project organization, the following factors plus those given in appendix A need to be taken into account.

- (a) Each group within the project should be responsible for a coherent, specified function.
- (b) The groups have to be able to interface and communicate with each other, either:
 - (1) by direct contact with opposite numbers; and/or
 - (2) through a more senior coordinator or the project management.
- (c) Where possible, use should be made of established departments which have their own expertise as working, coordinated teams.

(d) An ideal organization should be defined first so that the weaknesses of the actual (expedient) organization (normally a compromise) can be foreseen.

(e) The project organization will have to be adaptable (in size and structure) to the changes which take place, as the project progresses from phase to phase and requirements alter. Some continuity of staff is essential, however.

(f) The current organization should be assessed and consideration given to the extent of employing consultants and contractors, to delegate risks, cover temporary peaks of labour needed, etc.

(g) The prime functions of each project group should be defined together with their relationships with others both internal and external to the project itself, e.g. between supplier and fabricator in a construction project.

(h) The responsibilities of each group in meeting the overall objectives should be defined: who makes the decisions, who has the technical authority, financial authority, etc.

NOTE. Overlapping responsibilities should be avoided on the project and line and functional responsibilities in matrix organizations differentiated.

(i) Since project organizations often cut across functional organizations, split loyalties exist and so motivation and commitment of the project teams has to be considered seriously.

(j) The interfaces and communication links (for information handling systems) between the groups should be defined.

(k) It should be ensured that the roles of project management and management support groups are separately defined.

(l) Some reasons for employing *more* contractors:

- (1) to use contractors' particular skills, equipment, etc.;
- (2) to place contracts quickly;
- (3) to simplify conditions of contract and terms of payment;
- (4) to start parts of a project before others;
- (5) to enable changes to be made readily during the work;
- (6) to simplify lines of communication;
- (7) to limit the circulation of information.

(m) Some reasons for employing *fewer* contractors:

- (1) to reduce interference between contractors;
- (2) to achieve self-sufficient systems of plant, services, etc.;
- (3) to avoid duplication of resources;
- (4) to reduce inter-union disruptions caused by demarcation disputes, etc.
- (5) to achieve consistent standards in design, construction, management and employment of labour;
- (6) to secure greater contractual liabilities;
- (7) to reduce the effort of coordinating contractors' work.

(n) The organization has to provide people in the right place to make decisions and the scope of their authority should be defined together with when it is necessary to refer upwards or outwards. These points may be included in job specifications.

(o) The more levels there are in management hierarchy the greater the tendency to become bureaucratic and politically minded and less dynamic; the communication of information and instructions becomes interrupted and often modified.

This list provides information from which a project organization can be developed together with the systems and procedures required for project management. The numbers of staff required, together with their individual responsibilities and departmental organizations, should also be considered.

5.5 Example of project organization

A typical project organization (showing mainly management groups) may be structured as shown in figure 2.

The project management support groups cover those duties (but in more detail) that could be carried out by a project manager on smaller projects. If this detail is handled by specialists it allows project management to concentrate on overall coordination and decision-making.

Service functions support the project and contribute indirectly to the main stream of the project. In some projects, procurement is considered important enough to be part of this main stream.

The steering committee would be made up of representatives from the funding organizations, client directors, senior managers of all main functions and possibly directors/senior managers of the major contractors. Its powers would depend on particular circumstances, but such a structure would ensure involvement by the senior people in the organizations concerned. On smaller (or in-house) projects the project management may also be represented, or may in fact be responsible for the operation of a steering committee internally.

5.6 Large project management organization

A large project management (support group) organization, e.g. project coordination, planning and control (see figure 3), might also comprise the following.

(a) Project planning engineers responsible for overall planning, scope definition, preparation and maintenance

of project programmes, analysis of resources and provision of time-related data to the project management and above as required.

(b) Support staff for converting networks and other charts into presentable forms for issue, for inputting network-related computer data and other routine duties.

(c) Support from experienced staff in the development and application of relevant techniques and procedures, and forward planning of potential future projects.

The requirements for the staff of such groups should include the following.

(1) Knowledge of the particular industry and its methods of operation in a project environment.

(2) An understanding of the problems and requirements of project management.

(3) Knowledge of planning technology, i.e. network analysis of time, resources and costs, bar charting and other techniques.

(4) Expertise in specific applications of computing methods for network analysis and data processing.

(5) Ability in the rapid presentation of data to all levels of management, so as to highlight key problems and summarize current status in clear, simple ways.

It is desirable that the organization provide a career structure within groups like this so that the personnel may progress as they gain experience and may later move into project coordination and management.

5.7 Simple organization for project control

Assume there are three projects P_1 , P_2 and P_3 (see figure 4).

Each project team has a coordinator responsible for planning and estimating the work of that team, using bar charts, networks, etc., as necessary.

The coordinators relating to a single project, e.g. P_1 , together form a project management team responsible to the project manager. This team defines all aspects such as milestones in the overall project programme, which have to be agreed and maintained by the functional heads.

Functional heads are responsible for providing and controlling their resources to meet the milestone dates for all projects within their scope.