



Use of network techniques in project management

Part 4. Guide to resource analysis and cost control

L'utilisation des techniques de réseau dans la gestion de projet
Partie 4. Guide d'analyse de ressources et contrôle budgétaire

Anwendung von Verbindungsnetztechnik in der Projektierung
Teil 4. Leitfaden zur Hilfsquellenanalyse und Kostenlenkung

Contents

	Page
Foreword	Inside front cover
Cooperating organizations	Back cover
Guide	
0. Introduction	1
1. Scope	3
2. References	3
3. Definitions	4
4. General considerations	4
5. Resource analysis	4
6. Cost control of projects	13

Figures

1. Use of a time-based diagram (linked bar chart) for resource aggregation at earliest dates	8
2. Use of a time-based diagram (linked bar chart) for resource aggregation at latest dates	8
3. Examples of resource cumulation	9
4. Use of a time-based diagram (linked bar chart) for resource allocation within resource limit	11
5. Use of a time-based diagram (linked bar chart) for resource allocation within time limit	11
6. Cumulative cost curves	15
7. Use of hammock activity in network	16

Foreword

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 the 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 the 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.

This guide will be 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, 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.

*In course of preparation.

British Standard

Use of network techniques in project management

Part 4. Guide to resource analysis and cost control

0. Introduction

0.1 General. Although this guide concentrates on the use of project network techniques, project managers can, and often do, make use of other techniques covered by operational research, work study, organization and methods, quality control, production control, data processing using electronic equipment, value engineering, etc.

It is the responsibility of project management to make use of these facilities as appropriate but to balance their impact on the project so that this is not jeopardized by over-enthusiasm on any one aspect or by conflict between opposing objectives. For example, equipment should not be over-designed at the expense of failing to meet a delivery date with items that perform quite satisfactorily.

The project network techniques described in this guide enable the overall management (planning, monitoring and control) of projects to be conducted in an efficient and logical manner. To control a project, rather than merely to monitor what is actually occurring, it is necessary for project management to make decisions; for these decisions to be effective they should be based on the best information available and this requires an adequate communication system together with defined objectives and procedures. The methods used should also be dynamic, so that they can be adapted to suit changes in the environment, and also rapidly reflect changing situations anywhere within the project, so that corrective action can be taken.

This guide 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.

As with all management systems it is desirable that the use of a network-based project management system receives full management backing within the company. There should be adequate training of all persons in contact with networks.

The procedures and methods described in the various Parts of this guide are generalized and are not necessarily applicable to all types of project. Methods of handling project network information vary according to the environment in which these techniques are applied. Some typical

areas of application have been identified and current practice within them is indicated. These types are as follows:

- (a) strategic long term-planning, e.g. economic development at national, local government or company level (see 0.2);
- (b) research and development, e.g. space flight, military weapons, large-scale equipment, pharmaceuticals, etc. (see 0.3);
- (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 (see 0.4);
- (d) capital plant for manufacturing industry, e.g. chemical plant complex, oil refinery, etc. (see 0.5);
- (e) major engineering undertaking on dispersed sites, and usually occurring irregularly, e.g. railway line, service distribution scheme, etc. (see 0.6);
- (f) major engineering undertakings on a localized site, and often regularly recurring, e.g. power station, ship construction, etc. (see 0.7);
- (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 (see 0.8);
- (h) one-off building construction, e.g. hospital, office block, library, etc. (see 0.9);
- (i) repetitive building construction, e.g. housing, particularly at the design stage (see 0.10);
- (j) new product introduction, including marketing and distribution (see 0.11);
- (k) major overhauls and planned maintenance, e.g. blast furnace, chemical plant, ship refit, refinery areas, etc. (see 0.12);
- (l) production planning, e.g. fabrication, assembly (see 0.13);
- (m) key operation of short duration, e.g. aircraft turnaround (see 0.14);
- (n) emergency planning, evacuation of building after fire or flood warning, restoration of services after power failure, rescue operations after natural disasters (see 0.15).

0.2 Strategic long-term planning. Project planning in this environment is often developed backwards from an agreed target. Once a network has been developed, however, the techniques of analysis are not unlike those

described for research and development. Probabilities, related both to activity durations and to alternative strategies, will have to be assessed, and various outcomes considered. The use of gross resource and cost analysis are more appropriate to this area than a detailed approach.

At the national and local government level the time scale can run up to 25 years or more, but company time scales rarely exceed 5 years, or 10 years at the most. Activity durations will normally be expressed in months or even longer time units.

0.3 Research and development. The uncertainty in both the sequence and the duration of activities is a common characteristic of research and development. The sequence often depends on results achieved at earlier stages of the work. It is necessary, therefore, to attempt to pre-think all possible alternatives, using network drawing techniques to display them. These networks tend to contain 'decision nodes', where alternative strategies are presented and a choice has to be made, i.e. the network is 'probabilistic'. The simplest approach is based on time analysis only. More advanced versions of the technique embody cost calculations, both in the form of 'cost gates' and 'background costs'. Cost gates highlight the need to invest in special buildings and equipment before a new chain of work can be started. Background costs reflect the day-to-day running cost of doing the work.

Resource calculations, if performed at all under these conditions, are usually aimed at summarizing total resource requirements for the establishment covering all projects. Estimates and calculations, therefore, need to be only approximate, usually based on a monthly or quarterly analysis.

0.4 Administrative or procedural projects. Such projects involve activities, the need for which does not become apparent until the details of logical links between the major activities are worked out in full. A logic-only network, i.e. without activity durations and hence incapable of time analysis, has been found a useful tool for the complete planning of successful projects in this field. For smooth operations, it is then relatively simple to use hierarchies of timed networks. The main resource requiring careful planning tends to be key administrative personnel.

0.5 Capital plant for manufacturing industry. This environment is often a forcing house of experience in the use and development of advanced techniques of planning and control. This arises because the supplier is often his own designer, manufacturer and erector, and because he is continuously passing plant after plant through his factory. He thus builds up a great deal of experience very rapidly, because of the need for regular and frequent updating.

He will apply time analysis for this total project. The timing from the networks will be used to prompt his cost control accountants in regularly recalculating estimated cost to completion, cash flow, etc., for each project.

In parts of the workshops, particularly those concerned with fabrication and assembly, he may use advanced resource allocation techniques. He may also apply the same techniques at the site, during erection work. Resource calculations will be used as a basis for manpower control, since man-hours are much more meaningful than costs to foremen and supervising engineers.

Budget levels and actual expenditures are, therefore, usually expressed in that form.

0.6 Major engineering undertaking on dispersed sites.

In this environment there will normally be a series of subnetworks, with an overall master network linking them all together. Quite often, each subarea of work is the responsibility of a particular contractor, who can be expected to run his own network. At that level he may employ all the available techniques of time analysis, resource allocation, and cost control.

The many subnetworks will be brought together in one of two ways:

- (a) a main contractor (or client) will exert such a strong influence on subcontractors that they all use the same computer program for processing their networks, and subscribe to running all networks together from time to time in true multiproject fashion; or
- (b) reports from subcontractors will be manually summarized and combined to form input to a master network.

Time analysis will normally be common to all levels, but resource analysis will relate locally to each subcontractor. Occasionally, however, when one subcontractor handles several main sections of the work, e.g. stations on a railway line, he may run the networks for these together to enable him to deploy his resources economically from site to site.

Cost analysis will be generalized by the main contractor or client and a common system of reporting enforced on subcontractors to fit in with the client's scheme of financial control.

In this environment, projects of this kind are not regularly recurring. The client, therefore, seldom carries an experienced team to handle the work. He thus tends to employ consultants or rely on a main contractor for planning and control.

0.7 Major engineering undertaking on a localized site (regularly recurring). The localization of the site tends to cause planning and control to be based on one large network, broken down into subnetworks by area of work, which are routinely interfaced, i.e. processed together. Furthermore, projects in this category, e.g. power stations, ships, etc., tend to repeat, so that the client maintains his own team of experts.

The client's control is normally much tighter than in 0.6, and based primarily on time analysis and cost control. The client will not normally concern himself with resource analysis, but at some local parts of the project the contractor may use resource allocation as the key technique, e.g. in manufacturing, assembly and erection.

0.8 Planning and controlling change-overs. Frequently, the overriding requirement for projects in this area is that the existing organization function or services should be interrupted or interfered with as little as possible. There is a tendency therefore that the networks for such operations have to include many apparently extraneous activities. Whilst the detailed logic analysis often reveals unexpected complications, the implications of such logic constraints on timing may be even more profound. The planning and preparation for operations in this field often take more time and resources than the actual operation itself.

0.9 One-off building construction. At the client level, planning and control will be based on time analysis only, but at the contractor level, networks will tend to be used for time control, resource control, and budgeting. Unlike the capital plant type of project (see 0.5), these building projects contain modules of work that repeat again and again in different constructions, e.g. walls, floors, foundations, drains, etc. A benefit of the use of networks can be the availability of lists of information requirements for the design team.

An experienced contractor may have used networks at one time to plan such work, but, after a few projects he finds he can recognize an optimal pattern of work. He may, therefore, reuse segments of plans derived from previous projects. This approach is quite valid provided he can be sure that methods are not changing, or, more likely, that the staff who came to know and understand the earlier work have not moved on.

0.10 Repetitive building construction. The comments about reusing old plans (see 0.9) may also apply here, but the contractor may do special preliminary analyses for each new project. He may analyse, by means of networks, different ways of doing the work, and the impact on costs and timing of the use of such prime equipment as concrete mixing plants, tower cranes, etc.

Having completed these analyses before the work starts, he may then be content to control one or two key resources throughout the job, since he has established from past experience that, by controlling these resources closely, all the rest will fall into line. He may also use other techniques for day-to-day detailed control.

Cost control will normally be exercised in the form of repetitive calculations of rates per unit of construction (e.g. per area of brickwork, per volume of excavation, etc.) and matching these against company standards.

0.11 New product introduction. Network planning in this environment is applied, but is usually minimal in form. The use of logic only networks, i.e. without timing, is seen as a worthwhile way of forcing crisp thinking and decision into what is all too often a very unstructured approach. No time calculations are made, but attempts to draw a network for the project force their own discipline.

Some firms use time analysis as a means of planning and control of publicity, advertising, printing, etc., and rough timing of initial product manufacture and actual launch on to the market. Resource allocation is rarely carried out, and cost control is normally based on orthodox budgeting and accountancy routines.

0.12 Major overhauls and planned maintenance. The network logic stage is very important in this environment as it involves:

- (a) a study of current plant performance as a means of forecasting the work required during the overhaul;
- (b) the embodiment of scheduled maintenance jobs;
- (c) discussions on ways and means of taking the plant off stream and putting it back into service again;
- (d) safety aspects;
- (e) minimizing of shutdown time and interference with production.

Typically, the overhaul of a particular plant is repeated at regular intervals, and so repays detailed development of the logic. Time analysis will be crucial and resource allocation

will normally be applied, but networking cost control methods are rarely used.

After a few overhauls of the same plant, the staff will have become so familiar with the routines that major effort is then often concentrated on manpower control and the developments of technical short cuts.

0.13 Production planning. Project control by means of network techniques is rarely applied in an environment of batch or quantity production, except up to prototype stage. These techniques are used, however, for fabrication and assembly of major plant items or for the cyclic production of small quantities of complex items.

Emphasis should be given to resource analysis rather than time analysis alone and consideration should be given to the constraints of manpower, machines, factory space, special tools, etc. A network will be required for each small batch or item and multiproject computer runs will be used to plan the week-by-week shop floor schedule.

Activity durations need to be derived and outputs will be required by the shop floor and management to enable them to review, in advance, delivery dates and resource availability; these will probably be obtained by work measurement techniques.

0.14 Key operation of short duration. Project network analysis is used to plan in detail (with time scales in minutes if need be), with the resulting network and resource schedule used as the basis for the control procedure rather than directly as the control tool.

0.15 Emergency planning. Projects of this kind often can and should be planned in considerable detail even though the exact nature of the operation cannot be known. The use of networks has been found particularly useful in making evident the need for some of the logical linkages (e.g. communications) that might otherwise be overlooked. The network's main function is as the basis for working out procedures to be activated should an emergency occur, but rarely as a control tool during the actual emergency; also it allows minimum resource needs to be estimated:

- (a) minimum material stock piles;
- (b) supplies during and after the emergency;
- (c) number and training of personnel.

1. Scope

This Part of this British Standard provides guidance on the use of resource analysis and cost control techniques as a means of improving the management of projects. It is not intended to be a teaching text, nor a philosophical dissertation. The use of these two techniques as a natural extension to the use of time analysis in project network techniques is covered. They are treated separately for the purpose of providing more effective management information.

NOTE. It is essential that any intending user should be experienced in the practice of time-based networks analysis before attempting to use either or both of these techniques.

2. References

The titles of the standards publications referred to in this standard are given on the inside back cover.

3. Definitions

For the purposes of this Part of BS 6046 the definitions given in BS 4335 and BS 5191 apply.

4. General considerations

The time analysis of a network produces a statement of a plan for management to develop and to implement. It assumes that any resources required will be available.

Resource analysis is the process of deriving a schedule for work that considers constraints on money, people, plant, equipment, materials, space and time. Strictly speaking, money is only one kind of storable resource but it is also used as a common measure of disparate resources for financial and cost control purposes. Clauses 5 and 6 of the guide therefore treat resource analysis and cost control separately as techniques in their own right. However, costs and their control should be integrated with resources and their control at all levels of project management and at all stages of the project.

Both resource analysis and cost control techniques can be applied manually, but complexity may cause the user to turn to a computer for assistance. In defining their requirements to computer programming staff, users have to be precise if not pedantic in their description of how a system is to perform. It is from these requirements that many of the terms in use have arisen. However, the spread of this special terminology should not be taken to indicate that use of a computer-based system is necessary in all cases. For further guidance on the use of computers see Part 3 of this standard.

5. Resource analysis

5.1 The need for resource analysis

5.1.1 Introduction. The initial drafting of a project network is based upon a list of activities necessary to complete the project and the logical sequencing of those activities. Activity durations are then entered on the diagram to enable time analysis to be undertaken. It should be noted that defining an activity duration involves an implied rate of resource usage. At this stage, little if any account has been taken of the question of whether sufficient resources are available in the right quantities and at the right time to enable the planned activities to be undertaken.

Further, in a multiproject situation, no account will have been taken of projects that are competing for the same resources. It can be seen that such needs can only be met if the supply of resources is effectively infinite, or some method has to be found of resolving the problems of conflicting or constrained resource requirements. Resource analysis is about constraints (e.g. constraints on time, people, plant and equipment, materials, money and space) and these may well interact.

5.1.2 Constraints on time. Time is an inherent constraint for all projects, and methods for estimating durations and their analysis are dealt with in Part 2 of the guide. It is the results of that analysis which form the basis of all resources analysis procedures. It should be noted that, unless the programme derived from the time analysis is acceptable to management, there is no purpose in proceeding further with consideration of resource constraints.

5.1.3 Constraints on people, plant and equipment. These are the most common problems and arise from the fact that most activities need people and plant equipment to complete them. In the case of personnel, if only one trade or discipline is involved, it is a comparatively simple matter to decide on allocations, even in a multiproject situation, provided that reasonable numbers are available. However, this is rarely the case and in the majority of projects, numbers of personnel, in different trades, each severely limited in number, have to be spread across a multiplicity of activities in a project at specified times. This is difficult to handle manually even in the simplest cases, whilst in others it is impracticable. The role of resource analysis expands here to devise or identify computer programs that can produce resource allocations compatible with project requirements. There is a further constraint here in that it is not normally possible to optimize allocation within the computer programs available and it is necessary to have recourse to heuristic methods. In such cases, at best one can hope to obtain a sub-optimal solution to the requirements, but this is still a great advance on ad hoc allocations. Similar problems occur in the allocation of machines and, since the parallels are fairly obvious, detailed arguments have been omitted.

5.1.4 Constraints on money and cash flow. This problem arises in a budgetary situation where cash flow is restricted. If insufficient money is available to complete a project or projects according to network recommendations, it is obvious that more has to be requested, or that completion dates have to be extended for such time as is necessary to acquire sufficient, or that the project has to be modified.

5.1.5 Constraints on materials. Most projects need materials or components which are required in order to carry out the work. Details are required of what these are, how much they cost and at what time they are required, particularly if they have to be obtained from outside the organization. Resource analysis in this sense reveals what is needed and what is available from where and what lead times are involved in obtaining it. The answers may well involve modifications to the project schedule.

5.1.6 Constraints on space. Three people cannot work in a space which is sufficient for only one and it is not advisable to start building a battleship in a dock designed for trawlers. However, project managers should be aware of the space constraints imposed by their particular product or environment. A typical example is an aircraft cockpit where activities which one would expect to be carried out in parallel have to be performed in series due to space limitations. Such limitations are not always obvious unless conscious consideration is given to them.

5.1.7 Evaluation of the results. First results should not be accepted and applied blindly, particularly in the case of computer outputs. Much reappraisal and adjustment may be required in order that management's objectives can be satisfied. Repetitions of the planning and analysis cycles may often be necessary to achieve acceptable results.

5.1.8 Difficulties in application. At the end of a resource allocation exercise, the analyst has the problem of introducing his results into the organization. This problem is reduced if the members of the organization are already educated to an acceptance of project network techniques, since an understanding of these techniques carries with it

an awareness of the various constraints and the desirability of resource analysis. In the absence of such awareness, there are several difficulties to be overcome.

- (a) Management may see the network or schedules as an attempt by project staff to extract resources over and above those that they are prepared to allow.
- (b) Supervisors may not be able to assimilate computer print-outs and resource schedules easily. In order to cover up this breakdown in communication they may attack other aspects of network analysis.
- (c) Personnel may not understand why they are switched from project to project in an apparently irrational way. Further, in a situation where hourly rates are paid, they may look upon resource schedules as an attempt to impose measured rates.
- (d) Resource allocation may be seen as a means of reducing the authority of individuals.

There are further problems that will occur in most attempts to apply resource scheduling.

- (e) The need to set priorities for competing projects will always arise in multiproject situations.
- (f) Non-scheduled jobs which, because of their short duration, are not fed into the resource analysis, will result in lack of progress on scheduled tasks without apparent reason. Due regard has to be paid to the need to allow for unscheduled occurrences such as absenteeism, machine breakdowns and other such factors.
- (g) Estimates of resource usage should be based on 'typical' performance and are subject to wide variations within the limits of human performance. That is to say that human resources may not be capable of performing activities in the allotted time, since within each group of people of a given discipline there is a wide range of capabilities.

5.2 Project environments from the applications viewpoint

5.2.1 General. In clause 0, a number of project types were identified as being sufficiently different from each other for the purposes of project management to be listed and treated separately.

The comments on ten of these types in 5.2.2 to 5.2.11 treat each project type specifically from the resource analysis point of view only.

5.2.2 Strategic long-term planning. Resource analysis is used occasionally in the form of resource aggregation. It then provides a basis for forecasts of quantities of special resources needed over the years, e.g. factories, schools, hospitals, doctors, qualified engineers, etc. Some practitioners use bar charts as the basis of a limited form of resource aggregation.

5.2.3 Research and development. Although probabilistic networks are particularly relevant to this environment, resource calculations are only applied to simple time networks. Aggregation is more generally used than allocation, and the resource usage tables for all projects are summated time unit by time unit to provide an estimate of total establishment needs over the financial year. Aggregation is often based on earliest start for all activities, but a more realistic answer is obtained by applying a delay start constant of, say, 50 %, which puts the start of each activity midway between earliest and latest start dates.

5.2.4 Major engineering undertaking on dispersed sites.

Detailed resource allocation is applied by each subcontractor for each site or multiple of sites, taking into account personnel, construction machinery, cranes, etc. For major plant such as tunnelling rigs, special cranes, specialist operators, etc., the client's consultant or central planning office may apply resource allocation over the whole job.

5.2.5 Major engineering undertaking on a localized site. In this case the contractor applies full resource allocation. The client may become involved if he is supplying most of the design and specification effort, or if the type of contract is such that he requires a check on resource utilization.

5.2.6 Capital plant for manufacturing industry. Detailed resource allocation applied in various forms:

- (a) for *designers and draughtsmen*: often based on bar charts only;
- (b) for *works*: multiproject (often requiring over 100 resources including space);
- (c) for *site erection*: full single-project approach for each site; multiproject approach for key resources and major plant over all sites.

5.2.7 New product introduction. Resource analysis is rarely applied.

5.2.8 One-off building construction. Resource allocation is applied at contractor level. As buildings tend to contain modules of work which repeat again and again throughout a project, and through all projects, there is a tendency to use networks for a few initial jobs, and then reuse standard programmes for later work.

5.2.9 Repetitive building construction. Once repeating modules have been recognized and analysed there is a strong tendency to use standard programmes. From these, only key resources will be controlled, it being found from experience which resources have the greatest effect on job progress and costs. Line-of-balance (see 5.6.5) techniques are also applicable in this environment.

5.2.10 Major overhauls. Full resource allocation is applied, often with considerable sophistication. As overhauls repeat throughout the life of the enterprise, considerable effort is put into developing plans that use resources most efficiently and that hold the shutdown period to a minimum. Networks are drawn for the 'heavy' overhaul, and the same networks will be used for the 'light' overhaul, but durations on many of the activities will be reduced substantially. Logic for most sections of the overhaul remains unchanged year after year, but there will always be a group of miscellaneous jobs which arise uniquely at each overhaul and which are treated as a special subnetwork. Standard programmes are often used without re-processing, particularly if the overhaul team remains unchanged and so comes to 'learn the job by heart'.

5.2.11 Production. The emphasis is on resource analysis, rather than on time analysis alone, taking into account manpower, plant and equipment, materials, factory space, special tools etc. Each item or small batch will be the subject of its own network, and multiproject computer runs every week or at more frequent intervals will be used to plan the shop floor schedule day by day.

Durations should, if possible, be derived from production control records. The times implied by the latter will have