भारतीय मानक

परियोजना प्रबन्ध के लिए नेटवर्क विश्लेषण का प्रयोग

भाग 1 प्रबन्ध, आयोजना, समीक्षा, रिपोर्टिंग और समाप्ति प्रक्रियाएँ

Indian Standard

USE OF NETWORK ANALYSIS FOR PROJECT MANAGEMENT

PART 1 MANAGEMENT, PLANNING, REVIEW, REPORTING AND TERMINATION PROCEDURES

ICS 03.100.40

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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FOREWORD

This Indian Standard (Part 1) was adopted by the Bureau of Indian Standards, after the draft finalized by the Management and Productivity Sectional Committee had been approved by the Management and Systems Division Council.

This standard deals with the Project management — methodology using the technique of network analysis. It concentrates on network-based systems, and also discusses related aspects of project organization in so far as they influence the application of such methods.

A project is described as a one time activity with an identifiable beginning and an identifiable end unlike other routine activities that are repetitive. A project has a well defined purpose and scope and a definite set of separate but interrelated and interdependent activities which must be completed to achieve the objectives for which the project is instituted. It has a well defined project product, including product performance criteria and a well defined completion criteria. For example, the construction of a steel plant or the development of a computer software system is a project but its subsequent operation is not a project.

Project implementation is preceded by a project formulation and a feasibility phase. The recognition of need for the project may be environment based originating from customers, vendors or government sources. It may also be received or initiated internally by the top or senior management to channelise opportunities of potential market demand, availability of more cost-effective technologies, or more effective utilization of organizational resources. The decision to implement the project is made on the basis of a feasibility study which may involve technical, financial, economic and other operational aspects of the project. The technical assessment of potential project designs is followed by estimation of projected cash flows during the life cycle of the project. The techniques of discounted cash flow and risk analysis may be used to determine the economic viability of the project. In addition to financial costs and benefits, other social and environmental factors may be taken into consideration during the feasibility study.

This standard, however, focuses on the implementation phase of the project using network techniques. It covers project organization, planning, review, reporting and termination procedures. Project network techniques as used now have developed since the mid 1950's. These developments include both activity-on-arrow and activity-on-node systems. The technique as developed aimed at improving the ability to plan and control complex engineering projects and was called the Critical Path Method (CPM). Probabilistic elements appropriate to the research and development (R&D) area were also included in a modified technique called Programme Evaluation and Review Technique (PERT).

Activity-on-arrow networks were quite popular in the manual processing of networks. With the increasing use of computer for processing, activity-on-node or precedence networks have now become more popular. A number of ready-made software packages are available for use on computers which provide support not only for planning but also for updating and monitoring of progress from time to time.

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

Systems based on network analysis provide various advantages over the conventional methods of planning and control based on bar charts. These advantages may include:

a) clearer definition of the scope of the project and the complex interrelationships between its constituent activities;

b) better coordination between different organizations within the project and provision of information about each organization's progress and future plans to the others;

c) ease of preparing schedules of activities and adjusting these schedules to last minute developments;

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Indian Standard

USE OF NETWORK ANALYSIS FOR PROJECT MANAGEMENT

PART 1 MANAGEMENT, PLANNING, REVIEW, REPORTING AND TERMINATION PROCEDURES

1 SCOPE

1.1 This standard (Part 1) deals with the basic aspects of project management that are applicable to the projects between conception and completion/termination, when using network techniques. It covers project organization and management, planning, review procedures, reporting procedures and termination procedures.

1.2 The contents of this part have been divided into following five sections:

Section 1 Organization and management of projects

Section 2 Planning the project

Section 3 Review procedures for project coordination and control

Section 4 Reporting documentation and procedures

Section 5 Project termination/closure

SECTION 1 ORGANIZATION AND MANAGEMENT OF PROJECTS

2 GENERAL

2.1 The purpose of this section is to highlight those important aspects which influence the efficient application of network techniques to the planning and control of projects and need to be defined adequately or early enough in the life cycle of the project. These aspects relate to project organizations, project management, contract management and familiarization and training.

3 PROJECT TYPES AND FEATURES

3.1 In setting up project planning and control procedures, it is necessary to take into account the specific phase of the project cycle and the category to which the project belongs. A typical project cycle, for example, has the following important sequential phases/stages:

a) Formulation/Planning phase,

b) Implementation/Construction phase, and

c) Commissioning and handing over.

3.2 Projects could be categorized in a number of different ways according to requirements such as by,

a) time scale (for example, long term, medium term and short term);

b) cost (small, medium, major and mega);

c) purpose or function (for example, social infrastructure projects such as schools, hospitals; economic infrastructure projects such as roads, railways, ports, telecommunications, power, gas and water etc);

d) direct production of goods (for example, steel, cement, petroleum, fertilisers etc);

e) sectors of the economy (for example, agriculture, industry, mining, transport, education, health care, housing etc);

f) ownership (for example, public, private, joint sectors, cooperatives, etc); and

g) specific purpose (for example, export oriented, research and development, modernization, replacement and renewal, etc).

3.3 The contract system and terms and conditions of contract agreed between the client and the contractor are also important as technical, financial, legal and managerial basis for project planning and control.

4 PROJECT ORGANIZATIONS

4.1 The basic attributes of the project organizations would include:

a) innovative approaches to overcome problems;

b) sound and experience based decisions;

c) expeditious management of changes and changing situations; and

d) effective monitoring and control of progress and performance.

4.1.1 These attributes could be achieved by forming project groups of main departmental heads; ensuring informal relationships; setting up a Steering Committee; encouraging commitment to decisions; constituting a project team involving concerned departments; and appointing independent project management, project managers or coordinators with no strong functional ties. The project organization would depend on the nature of the project, its size and complexity, work content and also on the methods by which resources and funds are made available to the project.

4.2 The project organization structure could be of 3 types:

a) *Functional Organization Structure* — with specialized functional departments undertaking corresponding specialized task of each project. A department may be engaged in a number of

projects at one time. The project is not identifiable with one special person or department.

b) *Matrix Organization Structure* — where staff is drawn from corporate functional departments and assigned to the project as a team. This team may be supported by outside personnel, for example, consultants, temporary staff. A coordinator/manager is identified for each project, who operates through the functional department, and has overall responsibility for the project.

c) *Projectised Organization Structure* — under the projectised structure a new self-contained interactive organizational setup is created headed by a project manager and separated from corporate functional departments. The project manager has complete authority and control. A partial projectised structure could be used in which crucial project functions are assigned to the project manager and support functions are performed within corporate functional departments.

4.3 Factors to be taken into account for developing a project organization:

a) First of all define an ideal organization so that weaknesses of existing organization could be foreseen.

b) The project organization should be adaptable to changes as the project moves from phase to phase.

c) The number/type of personnel and their prime function, authority and responsibility required should be defined.

d) The current organizational capabilities and the need to employ consultants should be assessed.

e) The motivation and commitment of project groups should be ensured.

5 PROJECT MANAGEMENT

5.1 Project management refers to both, project managers and to project management support disciplines. This could be one person in the organization, a management team or a management contractor. The aim of project management is to successfully achieve the objectives of the project by completing it on schedule, within cost and performance criteria with prescribed human, physical resource and other constraints.

5.2 The principles for project management should be as follows:

a) It should be forward looking.

b) Decisions should be made at the lowest feasible level consistent with responsibility and authority. Decisions by managers at senior levels should be based on the principle of management by exception.

c) Project managers and project teams should be carefully selected and trained based on job requirements and the ability to manage.

d) The authority should always match with project responsibilities at all levels.

5.3 The principal role of a project manager should be as follows:

a) To help formulate objectives and policies for the project and operationalise them to ensure that these are adequately met.

b) To ensure availability and effective utilization of project resources.

c) To prepare and ensure approval of all project plans.

d) To approve all operational plans and procedures and inform project staff of their duties and responsibilities.

e) To monitor and control progress, performance quality and expenditure.

f) To ensure safety standards and conformity to legal requirements.

g) To ensure establishment and operation of communication, information and reporting system.

h) To serve as the prime point of contact for the project.

5.4 Project management should perform the following functions:

a) Define the scope and work content of the project.

b) Decide how to get the project activities executed.

c) Adapt the organization as the project progresses.

d) Develop a suitable project organization.

e) Prepare implementation plans and involve all concerned project participants ensuring that all project components and elements are inter-related, integrated and coordinated.

f) Define contracting strategy and policy, prepare the contract plan and specify contractors responsibilities.

g) Develop time schedules, budgets and identify key milestones.

h) Design monitoring and control, information and reporting systems and ensure their proper operation.

j) Define methods and procedures to manage change from its initial stage to its finalization.

k) Specify training requirements and make appropriate provisions.

5.5 The stages in setting up and managing a project starts with a statement of what is required, by whom, when and at what cost, leading to plans — financial, design and engineering, construction, materials, quality assurance and reliability, contract and management plan. The plans are adequately

communicated and agreed. During execution of the project deviations should be detected, reasons for deviations identified corrective measures assessed, decisions for future course of action taken and implemented at all levels. Appropriate management systems and procedures with decision-making being the key factor.

6 CONTRACT MANAGEMENT

6.1 A large and complex project involves a wide range of works and jobs, which require various types of specialisation, experience, technical competence and skills. Majority of these works and jobs are got executed through contracts.

6.2 The contracts are basically of four types:

a) *Item Rate Contract* — It is an agreement requiring the completion of different items of project work according to bills of quantities, specifications of quality and rates for unit quantity of work of each item.

b) *Percentage Rate Contract* — It provides for reimbursement of actual costs of different items of project work plus payment of an agreed percentage of the cost as profit.

c) *Lump Sum Rate Contract* — Under this, the payment is made for the project as a whole either at a fixed price or at a fixed price plus a pre-determined fee for superior work.

d) *Cost Plus Contract* — It provides reimbursement of actual cost plus either a fixed fee proportionate to the project work, or a pre-determined fee as a bonus for superior work.

6.3 Standard procedures should be developed for:

a) pre-tender planning;

b) pre-qualification of agencies and suppliers;

c) invitation and receipt of tenders;

d) opening, evaluation and negotiation of tenders;

e) award of contract;

f) release of work orders, designs and drawings;

g) measurements and payments;

h) modifications and changes in contracts;

j) termination/closing and off-loading contracts; and

k) monitoring, reporting and reviewing progress and performance of contracts.

6.4 Standard form of contract, including general and special clauses and conditions, related documents and methods for each type of contract should be developed.

7 FAMILIARIZATION AND TRAINING

7.1 After the basic project management and control systems have been developed and agreed, all those who have to participate in the project should be appropriately familiarized and trained to operate/use them. This would help in creating team environment, establishing lines of communication, breaking barriers between organizations and reducing confusion and misunderstanding as to who does what, when and why.

7.2 In addition to project specific training, supplementary educational courses may be organized to provide background information in the application of network based techniques.

SECTION 2 PLANNING THE PROJECT

8 GENERAL

8.1 This section deals with the planning for the execution of the project in order to ensure timely completion of the project and optimal utilization of project resources to avoid time and cost over-runs.

8.2 The owners/corporate management should outline the scope of work, defining what is required, the global objectives, the enterprise's policies, boundary conditions, overall timescales to be met and levels of resourcing and funding generally available. It is the responsibility of the project management to decide how the work will be conducted within these constraints.

8.3 Planning is the process by which a manager looks to the future and discovers alternative courses of action. A project plan should give details about product/work (quantity and quality), timescale, resources, cost and organization; also monitoring and control. It will involve:

— conscious and explicit awareness of the ultimate corporate goals;

— establishment of project objectives;

— articulation and evaluation of alternatives;

— selection of most suitable alternative; and

— identification of activities required to achieve the objectives.

9 LEVELS OF PLANNING

9.1 Plans are prepared for use at various levels of the organization. In a typical organization, the different levels in this context can be viewed as:

a) Corporate Management,

b) Project Management, and

c) Operational Management.

9.1.1 To cater to the needs of different project management levels, there may be hierarchy of plans, which may consist of the following:

a) *Project Plan* — Project plan relates specifically to the project and indicates the plans of execution of all the activities in a project. Project's

relationship with the environment is indicated in the form of external dependencies, but activities outside the project are not reflected in the project plan. The project plan is the basic reference document for all the members of the project team though its approval involves the project management as well as the corporate management.

b) *Stage Plan* — A project is usually composed of a set of chronological stages or phases. A set of products at the end of each phase form a 'baseline' on which further development of the project is planned. To that extent, the project plan prepared at the beginning of the project is tentative, except for the first stage, and needs to be revised at the end of each stage. For large projects, a stage plan may preferably be prepared at the beginning of each stage that is accurate on the basis of full information about the stage.

c) *Detailed Plan* — For some activities, it may be useful to record more details than what appears in the Project/Stage Plan. For such an activity, a separate detailed plan may be prepared. The detailed plan would form a sub-set of the stage plan and be prepared along with the respective stage plan. A detailed plan may also be necessary for an activity which spans more than one stage.

d) *Individual Work Plan* — Individual work plan schedules the activities of an individual team member. Where the responsibility of work is assigned to a group, rather than individual members, individual work plan may be prepared for the group. Such plans are useful to allocate precise responsibilities to each member or group of members for the activities of the project.

e) *Equipment Loading Plan* — Equipment loading plan indicates the allocation schedule of an individual equipment to various activities from time to time. When the equipment is not allocated to any activity, it is indicated as unallocated.

10 COMPONENTS OF PROJECT PLANS

10.1 A project plan would provide information about technical, resource, quality and cost aspects of the project. The four components are interrelated and should be in agreement with each other.

a) *Technical/Work Plans* — Technical/Work plans focus on the technical dependencies and the work content of the project, the relationship between the work components and their plan of execution. They:

- define logical relationships amongst activities which may be represented in the form of an activity network.
- identify the resources required for each activity.
- provide a time schedule of activities consistent with resource requirements and the total resources available to the project.
- identify the milestones in projects and stages for major assessment and review.
- identify internal and external dependencies on activities.

They may be prepared separately for each level of planning and plans at each level must be consistent with each other. Consistency must be maintained after every review when the plans are revised.

b) *Resource Plans* — Resource plans specify the resource requirements of the project during different periods and how they are planned to be made available. It would indicate:

- how resources would be obtained and allocated.
- the work schedule for each individual/ group resource.
- methods of disposition of excess resources, if any.

Resource plan should be derived from the technical plan and not *vice versa*. It should be consistent with the technical plan at all levels of planning.

Resources should be indicated in physical quantities for each category as well as in terms of cost.

c) *Quality Plans* — Quality plans focus on the quality characteristics that need to be achieved in the products of the project and the procedures of quality control and quality assurance to ensure the achievement of these characteristics. Quality plan would indicate the required quality criteria for each end product and the relative priorities of those quality criteria related to the work plan. The quality characteristic must be measurable.

Quality planning must cover at least the following topics:

i) Agreement on quality with all concerned;

ii) Prevention, detection and rectification of faults;

iii) Setting appropriate and measurable quality criteria for each product;

iv) Establishment of systems and procedures to assess and demonstrate whether quality goals have been achieved; and

v) Resourcing of quality control activities.

Activities to assure quality will form part of technical plans as well as resource plans. Thus the quality plan cannot be separated from technical and resource plans at the same planning level.

d) *Cost and Cashflow Plans* — Cost and cashflow plans are required to make necessary financial provisions, and to exercise financial and cost control on the project. The cost estimate of each activity should be worked out from the standard unit cost and quantity of each resource category required by the activity. The cashflow plans can be derived by translating the technical plan into financial terms.

Performance budgeting is the technique used to relate the financial aspects of the project with its physical aspects. It requires that for monitoring, physical progress must always be reported with financial progress and the two should be interrelated.

Zero-base budgeting is the technique to ensure cost effectiveness of the project at every stage. It requires that the financial provisions of the project are to be notionally reduced to zero-base at every budget review. The revised estimated benefits are justified against revised provisions for the remaining activities of the projects.

11 STEPS IN PROJECT PLANNING

11.1 Planning of a typical project may follow the following steps:

a) *Identify the project objectives and components* — The first step in the planning of project would be to prepare a list of the objectives and components of the project. The components may be identified in Work Breakdown Structure (WBS) of the project, which shows the work structure in a hierarchic way.

b) *Identify the activities* — The plan must identify all the activities necessary to achieve the objectives of the project. This can be shown in the form of a Work Breakdown Structure. The work breakdown decomposes the project into its various components. Each component will be further broken down into its constituent activities in a hierarchic structure.

c) *Identify dependencies* — Activities may be dependent on other activities (internal dependencies) or on resources outside the project (external dependencies). The internal and external dependencies for each activity may be recorded in the activity breakdown derived from the Work Breakdown Structure.

d) *Produce activity network* — Once the activities and their dependencies have been identified they can be represented in the form of an activity network. Either an activity-on-arrow or a precedence network may be used for the purpose. For large projects, multilevel networks may be produced. At the project level, a 'Master Control Network' will give only an overview of the organization of activity. The activities included in the master control network will be at much higher level of hierarchy than the lowest level in the activity breakdown. The detailed activities would be included in the detailed networks prepared for each stage of the project. The initial network will not show planned start and finish dates for the activities, which would be determined later after the time and resource analysis.

e) *Determine time and resource requirement of activities* — The next step would be to estimate the normal expected duration and the normal resource requirement of each activity. But, before starting to estimate it is necessary to classify the project resources into resource types. The resource type may be classified in such a way that the individual resources within a type are interchangeable and any individual of a resource type could be assigned to an activity requiring that type.

At this stage, the most efficient way of performing the activity should be selected without regard to the availability of resources or the clash of resources with other activities. This is the best starting point as the clash of resources can be resolved later during resource analysis. Estimates may be produced using an algorithm, an estimating tool or simply on the basis of past experience. The estimates at the beginning of the project may not be very accurate and may need to be revised at every review. If the estimates are expected to vary widely as the project progresses, the approach of zero-base budgeting should be used to ensure continuing cost-effectiveness of the project.

f) *Time analyse the network* — Time analysis determines the time related characteristics of the project namely, estimated project duration, earliest and latest start and finish times of activities, activities' floats, etc. All software project management tools perform analysis automatically. Time analysis takes into consideration the internal and external dependency constraints of activities. External dependencies, where specified, will supersede the internal requirements. Results of time analysis are called the "Operational Plan" of the project and form the baseline for resource and cost analysis. The operational plan can be displayed graphically in the form of bar chart.

g) *Resource and cost analysis* — Operational plan is the first step in the process of planning the project. It provides numerous possibilities for scheduling the project activities. The activities with float could be started on the earliest start date, or they could be started on the latest start date or any time in between the two. But every scheduling option may not be feasible from the point of view of resources. The aggregate resources required by the scheduled activities

may exceed the total resources available to the project during some period. Even if a schedule is feasible from the point of view of resources, it may not be the most economical one. May be the duration of a critical activity can be reduced by allocating more resources to it, at additional cost, but reducing the duration of the project with corresponding cost savings. Or staggering the activities with clash of resources may reduce the total resource requirement. These alternatives can be simulated using "Resource constrained project scheduling". The final choice would depend on the evaluation of the alternatives with respect to the time duration and the cost of the project.

12 PROJECT PLANNING TECHNIQUES

12.1 Bar Charts (Gantt Charts)

12.1.1 In this type of chart, the time which an activity should take is represented by a horizontal line, the length of the line being proportional to the time duration of the activity. In order that several activities can be represented on the same chart, a framework or ruling is setup, giving time flowing from left to right, the activities being listed from top to bottom as shown in Fig.1. The Bar charts can be used both for depicting the plans as well as the progress of activities.

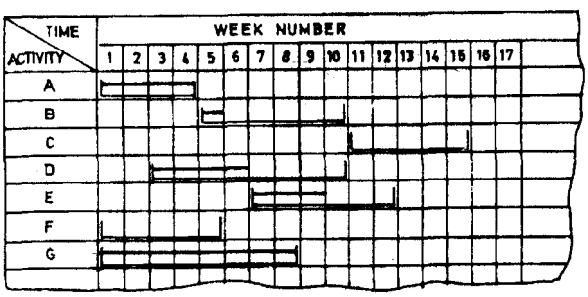

FIG. 1 BAR CHART (GANTT CHART)

12.1.2 However, the Bar charts do not depict the precedence relationship between activities. The plans and progress are only indicated in terms of time; and work content of activities is not clear in the Bar chart.

12.2 Project (Work) Breakdown Structure

A project can be broken down into its elements in a hierarchical structure such that in every step in the structure it is broken down into smaller and smaller elements. These elements could be the components/ products of the project or activities or a combination of the two. The activities can be grouped according to functional or administrative responsibility.

12.2.1 *Component/Product Breakdown Structure*

Component/Product breakdown structure gives the product structure of the project in a hierarchical way, breaking down the project into component/product groups and finally into the individual components/ products at the lowest level of the hierarchy.

12.2.2 *Activity Breakdown*

Components/Products are produced by the performance of activities. The construction of a component/product can also be further broken down into work packages and individual activities. The levels to which activities are broken down into their smaller constituents would depend on the level of detail required in the project plan for a manageable level of control.

One of the guidelines is to break down the activities to a level where they are independent of each other. Though this is usually the level of detail required in network based planning, further breakdown of larger activities is not ruled out.

12.2.3 The Work Breakdown Structure of a project is basically a combination of its product/components breakdown structure and the activity breakdowns of its constituent components/products. For a smaller project, the Work Breakdown Structure may consist of a single level while for a larger project it may consist of multi-level structure.

12.3 Network Techniques

The techniques Critical Path Method (CPM) and Programme Evaluation and Review Technique (PERT), which are more or less identical, are commonly known by the name of Network Technique. The only difference being, that CPM uses deterministic time estimates while PERT uses probable time estimates.

The Network Technique makes use of a network to represent precedence relationships and to analyse various project characteristics. Two types of network diagrams are commonly used. These are activity-on-arrow network (generally used for manual charting) and Precedence Networks (commonly used in the PC-based tools).

12.3.1 *Activity-on-Arrow Network*

12.3.1.1 In activity-on-arrow network, an activity is represented by a directed arrow. The length of the arrow is arbitrary and has no relation to the duration of the activity. The direction of the arrow indicates the flow of time and is usually shown from left to right. The interface between activities, that is, the end of one activity and the beginning of another, are called 'events' and are represented by small circles. Every activity is incident at two events. The 'preceding event' or the 'starting event' indicates the time when the activity can begin and is at the tail of activity arrow. The 'succeeding event' or the 'ending event' at the head of the activity arrow denotes that the activity has been completed. For example, in the project shown in Fig. 2 the activity 'RESEARCH' has preceding or starting event 2 and succeeding or ending event 3.

12.3.1.2 *Precedence rules*

Two fundamental rules that determine the precedence relationships indicated by the network are as follows:

a) An activity can begin only after its preceding event has been achieved.

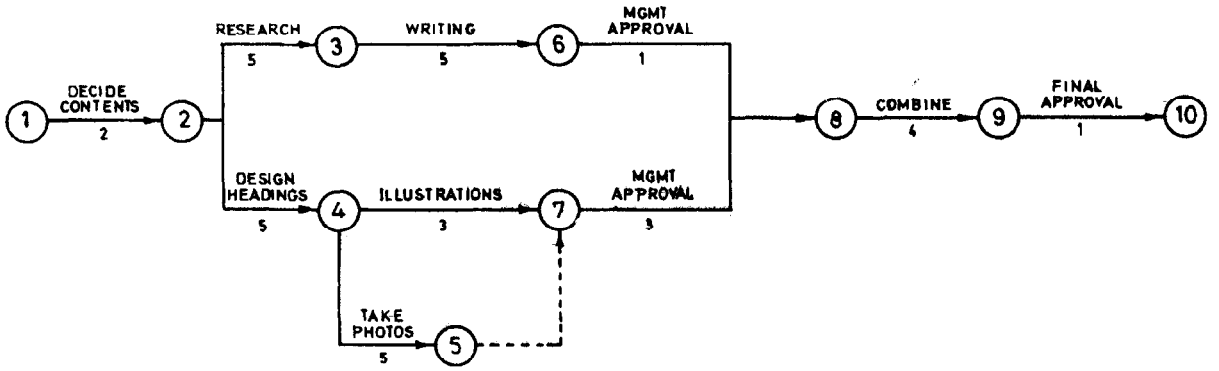

FIG. 2 ACTIVITY-ON-ARROW NETWORK

b) An event is said to have been achieved only after all the activities leading into the event have been completed.

12.3.1.3 *Dummy activities*

Dummy activities in networks are necessary to indicate the correct precedence relationship, though the dummy activities do not exist in the physical process. For example in the network shown in Fig. 2 activity 5-7 is a dummy activity.

12.3.1.4 *Dangling activity*

A dangling activity is an activity in the network which is standing out and has no successor activities. For example activity 5-9 in the network shown in Fig. 3 is a dangling activity. Its relationship to the project completion is not clear.

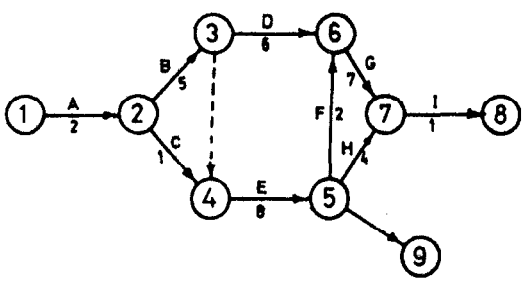

FIG. 3 DANGLING ACTIVITY

12.3.1.5 *Cycle in network*

A cycle in the network represents a physical inconsistency. In a small network of three activities shown in Fig. 4, activity *B* can start only after *A* has been completed and *C* can start only after *B* has been completed and *A* can start only after *C* has been completed. With this logic, none of the three activities can ever be started. In fact, all physical project networks have to be acyclic.

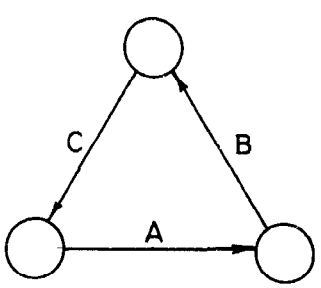

FIG. 4 CYCLE IN NETWORK

12.3.1.6 Dangling activities and cycles in networks can be avoided by following some simple conventions as:

a) All activity arrows are drawn from left to right.

b) Events are numbered in such a way that every activity has a higher succeeding event number than its preceding event number.

c) The project is identified by a unique starting event and a unique ending event of the project. All other events in the project have at least one activity leading into it and at least one activity starting from it.

12.3.2 *Precedence Networks*

Precedence networks are also known as activity-on-node networks. The basic difference between this and the activity-on-arrow representation is that here the activities are represented by the nodes, and the dependencies by arrows. Using this representation, the precedence network for the project 'Design a Sales Leaflet' would be as shown in Fig. 5. Precedence networks do not require dummy activities to maintain logical relationships. One of the main advantages of precedence networks over activity-on-arrow networks is that they can be drawn neatly on the PC monitor.

12.3.3 *Time Estimates*

In order to plan the schedule of activities, it is necessary to estimate the time duration of each activity. The initial time estimate of an activity is called the 'Normal Expected Duration'. The term 'normal' in this context means the normal level of resources and technology which the organization would use had the activity been executed in isolation with no clash of resources with any other activity. This duration is usually indicated as a subscript below the activity arrow in the activity-on-arrow networks. In the precedence networks, the activity duration is usually indicated in the left bottom corner of the activity

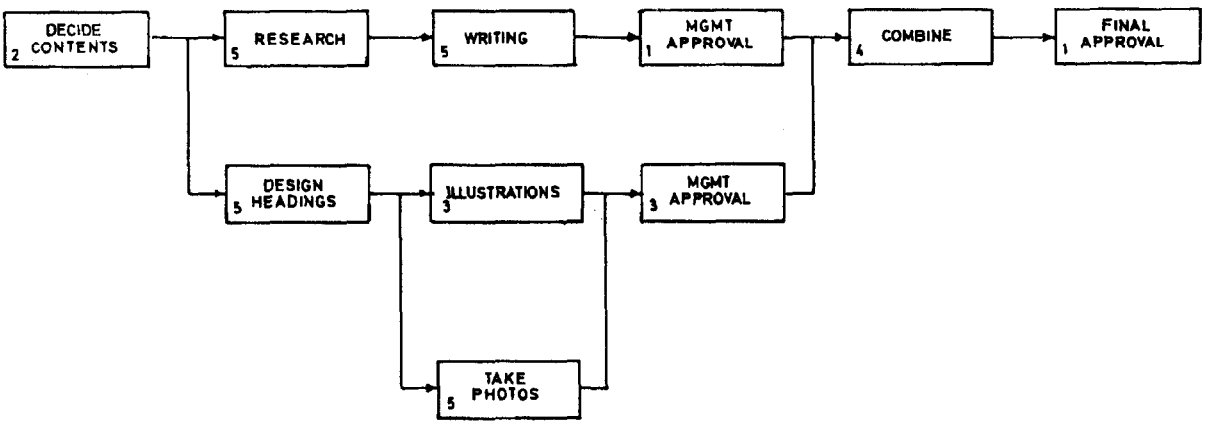

FIG. 5 PRECEDENCE NETWORK FOR THE PROJECT 'DESIGN A SALES LEAFLET'

node. The precedence networks also, sometimes, use the dependency time. This is useful when the dependency between activities is not finish-to-start dependency as usually assumed in the activity-on-arrow networks. In precedence networks, the dependencies may be defined as start-to-start dependencies and the dependency time may indicate the amount of time that must elapse after the start of predecessor activity before the start of the successor activity. This dependency time may be different from the duration of the predecessor activity and is indicated as a subscript to the dependency arrow.

12.3.4 *Milestones in Project*

12.3.4.1 A milestone may be the completion of a phase or a significant stage in the phase of the project. Milestones usually represent the completion of a number of activities leading into a significant event. The event representing the milestone in an activity-on-arrow network is called a 'milestone event'. It may be useful to use a different notation to represent a milestone event in order to distinguish it from other events. A square instead of a circle may be used.

12.3.4.2 In a precedence network, events do not exist as such, but it is possible to represent a milestone by introducing a link activity of zero duration.

12.3.5 *Time Analysis*

12.3.5.1 The time analysis is carried out in two stages, *viz* the forward pass and the backward pass. The following notations are used:

t_{ij} = Normal expected duration of activity 'i-j' (Activity with preceding event 'i' and succeeding event 'j');

$T_{E(n)}$ = Earliest time of event 'n';

$T_{L(n)}$ = Latest allowable time of event 'n';

Sl_n = Slack time of event 'n';

EST_{ij} = Early start time of activity 'i-j';

EFT_{ij} = Early finish time of activity 'i-j';

LST_{ij} = Latest start time of activity 'i-j';

LFT_{ij} = Latest finish time of activity 'i-j';

Fl_{ij} = Total float of activity 'i-j';

FF_{ij} = Free float of activity 'i-j'.

a) *Forward pass* — This involves the forward traversal of the network from the project starting event to the project ending event. During this pass the earliest start and finish times of activities, earliest times of events and the earliest completion time of the project are worked out. The first step is that the starting event of the project is assigned an earliest time of zero from the start of the project. If the event numbers in the project have been topologically ordered, that is every activity has a higher succeeding event number than its preceding event number, then the forward pass proceeds in the ascending order of event numbers. For every next event, the earliest time of the event is determined by the completion of the last activity leading into the event which is largest of the activity duration added to the earliest time of its preceding event. This could be expressed mathematically as:

$$T_{E(n)} = \underset{j=n}{\text{Max}} \left\{ T_{E(i)} + t_{ij} \right\}$$

For example, in the network shown in Fig. 6 there are two activities leading in to event 7. The activity 4-7 has a duration of 3 units and together with the earliest time of its proceding event 4 which is 7 units, the activity can be completed earliest in 10 units of time. The other activity 5-7 is a dummy activity (duration 0) with the earliest time of its preceding event being 12 units. This activity can be completed earliest in 12 units in time. So the earliest time for event 7 is the larger of the two, that is, 12 units of time.

b) *Backward pass* — This involves the backward traversal of the project from the project ending event to the project starting event. During this pass, the latest starting and finish times of activities, the latest allowable time of events, event slacks and activity floats are worked out, and the critical activities are identified. The first step is that the last or the ending event of the project is assigned the latest allowable time from the beginning of the project depending on the target date of completion of the project which may be the same as the earliest time for this event or may be more or less. If the event numbers are in topological order, the backward pass proceeds in the descending order of the event numbers. For every next event, the latest allowable time of the event is worked out by subtracting the activity duration from the latest allowable time of its succeeding event. The smallest of all the latest start time of the activities is the latest allowable time of the event. This can be expressed mathematically as:

$$T_{L(n)} = \min_{i=n} \left\{ T_{L(j)} - t_{ij} \right\}$$

For example, in Fig. 6, for event 2 there are two activities starting from the event. Activity 2-3 has a duration of 5 units and the latest allowable time of its succeeding event is 9 units, so it could start latest at 4 units of time. The other activity 2-4 has a duration of 5 units and the latest allowable time of its succeeding event is 7 units, so it could start latest at 2 units of time. So the latest allowable time of event 2 is the smaller of the two that is, 2 units of time.

12.3.5.2 The time analysis of the precedence network is done in a similar manner. Since the precedence networks are often used on automated tools, the time analysis is carried out automatically by the tool.

12.3.6 *Critical Path, Slack and Float*

Event time characteristics — This difference between the latest allowable time and the earliest time of an event is called the event slack. In the form of mathematical expression:

$$Sl_n = T_{L(n)} - T_{E(n)}$$

Events with slack can be achieved by the latest allowable time without delaying the project. For example, in Fig. 6, events 3 and 6 have slacks. In the example we see only positive slacks, but slack could also be negative if the project target date were earlier than its earliest achievement date.

Activity time characteristics — Earliest start time of an activity is the earliest time its preceding event is achieved. Earliest finish time of an activity is given by adding its duration to its earliest start time. So, the earliest start and finish times of an activity are related to its preceding event:

$$EST_{ij} = T_{E(i)}$$

$$EFT_{ij} = EST_{ij} + t_{ij} = T_{E(i)} + t_{ij}$$

Similarly, the latest finish time of an activity is given by the latest time its succeeding event is achieved. Latest start time of an activity is given by subtracting its duration from the latest finish time. So, the latest times of an activity are related to its succeeding event:

$$LFT_{ij} = T_{L(j)}$$

$$LST_{ij} = LFT_{ij} - t_{ij} = T_{L(j)} - t_{ij}$$

Activity floats — The difference between the earliest and the latest times of an activity is called 'activity float', that is,

$$Fl_{ij} = LST_{ij} - EST_{ij} = LFT_{ij} - EFT_{ij}$$
$$= T_{L(j)} - T_{E(i)} - t_{ij}$$

There is another way in which the activity float is defined, which is the amount of float an activity can consume out of the total float defined above, without effecting the float available to the succeeding activities. This is called the free float. In this case, the activity must be completed by the earliest time of its succeeding event, that is,

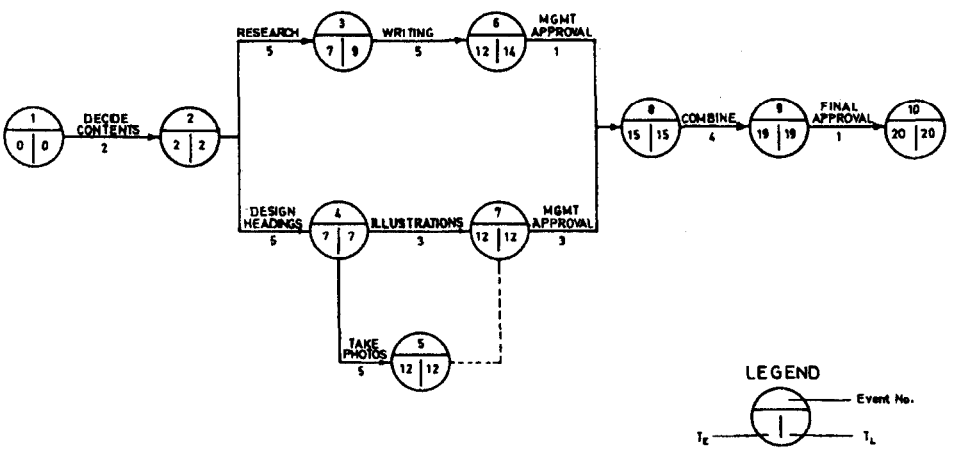

FIG. 6 TIME ANALYSIS OF PROJECT NETWORK

$$FF_i = T_{E(j)} - T_{E(i)} - t_{ij}$$

The activity float can be negative in the same way as the event slack, if the project target date is earlier than its earliest achievement date.

Critical activities, critical path — The activities with zero total float (or in general, with minimum total float if the project target date is different from its earliest achievement date) are called the critical activities. Any delay in the completion of a critical activity means a corresponding delay in the project completion. The path connecting the critical activities, from the starting event of the project to its ending event, is called the critical path. The critical path is also the path of longest duration between the starting and ending event equal to the project duration. A project may have more than one critical path if there are alternative paths of equal duration. In Fig. 6, it is the path connecting activities 1-2, 2-4, 4-5, 5-7, 7-8, 8-9 and 9-10. This could be indicated by double lines on the network. Note that activity 4-7 is not critical although both the events 4 and 7 have zero slack and are both on the critical path. It would be wrong to define the critical path as the one connecting the events with zero slack.

12.3.7 *Network Analysis and Bar Chart*

While the network is a very useful tool for the representation and analysis of precedence relationship, bar chart presents a more useful visual representation of the project schedule. The two advantages can be combined by displaying the results of time analysis on a bar chart. Figure 7 shows a bar chart for the leaflet project. The firm portion of the bar indicates the early schedule of the activity and the extended dotted portion shows the total float available to the activity. The preceding and succeeding event numbers of the activities may be indicated at the two ends of the bar. This is useful for linking the activities and making any on-the-spot modification in the schedule.

12.3.8 *Squared Network*

Squared network is a method of translating an activity-on-arrow network diagram into a bar chart. Any network can be time-scaled by the following

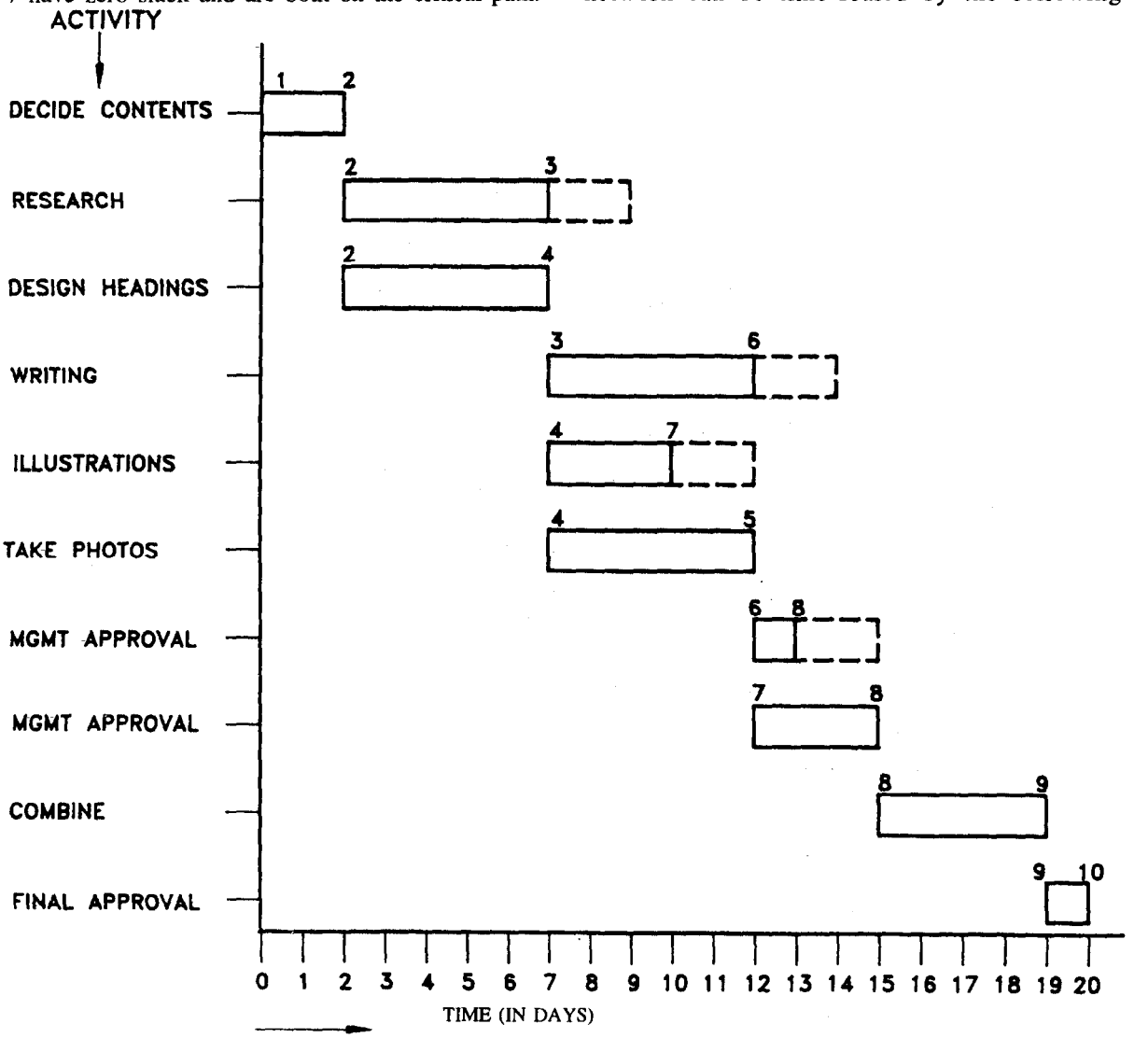

FIG. 7 TIME ANALYSIS ON BAR CHART

procedure:

Start at the initial event and draw to scale all opening activities, identifying them by their event numbers. It is desirable at this stage to space these well out on the page.

Each activity will then either:

a) 'Continue' as a single activity (2-3 continues as 3-6);

b) 'Burst' into two or more activities (1-2 bursts into 2-3 and 2-7);

c) 'Merge' into an event with one or more other activities (6-8 merges into event 8 with 7-8).

The squared network may than be constructed as follows (*see* Fig. 8):

a) In the case of 'continue' activities, extend the activity by the length of the next activity;

b) In the case of 'burst' activities, draw a single vertical line and from this draw to scale the bursting activities;

c) In the case of 'merge' activities, wait until all activities merging into a common event have been drawn, for example, wait until activities 6-8 and 7-8 have been drawn, and then draw a vertical line to form a "barrier" across the end of the activity which extends farthest to the right. Join all the merge activities to that fence by means of dotted lines. These lines represent free float.

Repeat the above until the last event is reached. The squared network may be modified suitably to emphasize special organizational or resource features.

13 CHECKLISTS

Checklists can be used for several purposes and in several ways in computer project planning and control. In the following are described a number of checklists and the ways in which they are used.

13.1 Task Lists

13.1.1 A task list comprises a list of tasks associated with a given activity. The tasks are subdivisions of an activity but of a duration which is at too low a level to warrant formal techniques of planning and control. Standard task lists should be built up over the life of several projects to produce as comprehensive a set of tasks as possible. When planning for a given activity in a particular project, the relevant tasks should be selected from the standard list and other tasks added as found necessary. Task lists should be used as an aid to estimating the resources required to perform a particular activity.

13.1.2 It is quite possible that a task may be added after the start of an activity. Tasks which are not foreseen when the activity was planned are revealed during the life of an activity. Such tasks should be added to the list, but physically separated from the original entries as a measure of the stability of a particular activity in terms of its task content over the life of several projects.

13.1.3 The task list may be used as a follow-up document by entering estimated completion dates against each task and checking, say a week before that date, on the progress of that task. Provision should be made for insertion of that actual completion date if only as a means of ensuring that the particular task has been completed.

13.1.4 Some estimation of partial completion of the activity can be made by examining the task list to determine those tasks which have been completed, compared with those still to be done.

13.2 Document Lists

13.2.1 The list comprises of the necessary documents to be produced to provide information for making project decisions in the proper manner. The documents related to organizational structure, linear responsibility chart, work breakdown structure, activities description,

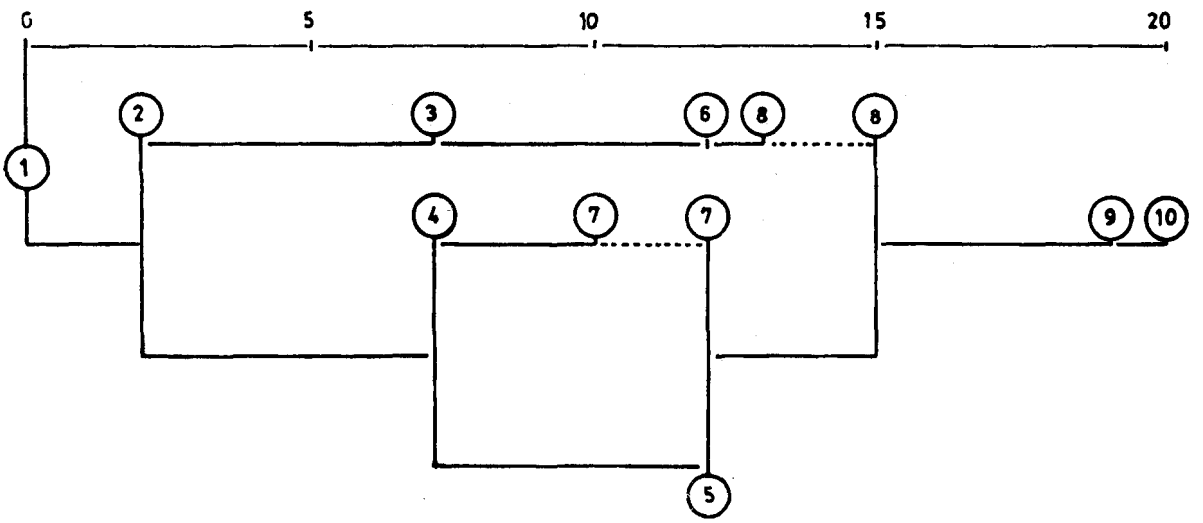

FIG. 8 SQUARED NETWORK

networks (overall and detailed), Bar charts and milestone charts, resource plans and schedules, installation equipment and machiner, construction plant and machinery, cost estimates, specifications, designs and drawings, contract forms and procedures, systems and procedures, operating instructions and manuals.

13.2.2 It is not possible to generate standard list because it would vary with the nature, size and contents of the project.

13.3 Responsibility List

13.3.1 There are parts of projects, especially those concerned with what is usually termed implementation, in which the responsibility for carrying out particular tasks is not always clear. For example, responsibility for ordering new equipment, training staff, preparing test data and transferring files in a software development project can rest with different departments in the organization.

13.3.2 The main purpose of a responsibility list is to assist the project leader by ensuring that responsibility for the completion of tasks has been allocated. The list should be prepared by the project leader comprising those tasks for which responsibility could lie outside his own department. The tasks which appear on the list will probably be the same for different projects within the same organization. So, like the task lists, a standard responsibility list may be developed within an organization.

SECTION 3 REVIEW PROCEDURES FOR PROJECT COORDINATION AND CONTROL

14 GENERAL

14.1 Need and Scope of Project Review

14.1.1 For a complex project which runs from few months to several years, a scientific review procedure is required. The review procedure should provide guidelines for comparing the project performance with the planned targets in terms of performance, time, resource and cost and should set into motion the corrective mechanism. The review procedure should be such that it should avoid any irretrievable damage which may occur due to mis-reporting or delayed reporting.

14.1.2 The project review procedure should have inbuilt mechanism for checking the quality of various systems, sub-systems which may affect the overall performance of the project. While reviewing time, resources and costs, if the conformance to the performance aspect is not done in an integrated way, it may lead to serious consequences in terms of escalation in time and cost and even premature terminations in some cases.

14.1.3 For a smaller project, the review cycle can be set on demand as at the initial planning stage itself, tighter control can be built-in and self-correcting mechanism can be developed which may last throughout the project life.

14.1.4 For a larger project, a comprehensive system of project coordination and project control is to be set up. The review procedure will commence from the conceptual phase of the project, starting from data collection on identification of needs, establishment of goals and objectives, preparing economic feasibility and financial viability, risks to the stakeholders, estimation of resources, identification of alternatives and procedure for getting approval to the next phase.

14.1.5 In the development phase, the review should incorporate appointment of key team members, defining the scope, establishment of master plan, budget, cash flow and work breakdown structure as also the policies and procedures with necessary approval to proceed.

14.1.6 For the implementation phase, review should cover setting up of organizational and communication channels, identification of teams, appointment of team members, establishment of detailed technical requirements for various work packages, execution of various work packages, review of directives, monitoring, various costing and control procedures with respect to scope, quality, time and cost with a mechanism to resolve various problems encountered.

14.1.7 While nearing completion of the project, the procedures relating to the review of the description of the final product, settlement of final accounts, approval of product/services responsibility, documentation of results and release/reallocation of all resources including the re-deployment of project staff.

15 PROJECT REVIEW CYCLE

15.1 Periodic re-assessment of the project becomes necessary to bring back the project to its normal course if any deviation is encountered. The project review cycle should be set keeping in view the requirement from the project owners, statutory and regulatory agencies, project management team and other stakeholders. At the beginning of the project, a typical review cycle for a reasonably large project ranges from two weeks to four weeks. The review cycle also includes engagement of additional resources in critical areas, identification of critical path, changes in methods of execution, re-allocation of resources and operation within the budgeted cost. Project review cycle will also depend upon the product/services. The periodicity of the review cycle should be such as to take care of any deviation which may become necessary for completion of the project.

15.2 Review Procedure

Project review procedure requires involvement of senior management to ratify project management decisions, implementation by project teams and project organization for preparation of plans and establishment of updation mechanism, analysis and monitoring of the project by project organization. The frequency of the project review cycle will depend upon the quantity of the data to be updated, the size of the project management team and the rate at which the project moves. If many organizational levels are involved, the review should be synchronized in such a fashion so that there is no delay in any action which

become necessary at any stage of the project. The project review procedure should take into account all aspects of project life cycle starting from concept/ development/implementation and termination. The review procedures should incorporate various methods to process the data and review project status while updating and analyzing the status depending upon the original plan. The monitoring method should involve the measurement of various deviations from the plan and collection of the data in order to monitor various implementation procedures and methods by the project team. The project management team will consider the changes in the plan and will take appropriate decision.

15.3 Use of Networks for Project Control

Network provides a valuable data for the project in its entirety. At the planning stage of the project, networks are prepared considering the work breakdown structure, work packages and the group of activities and their inter-linking mechanism for completion of various tasks in the project. The network also provides a mechanism for evaluating the performance, a schedule of activities, resource status and various cost aspects concerning various activities individually and for various work packages collectively and the project as a whole.

Based upon this data which have been generated at the initial cycle of the project, that is, upto the planning stage, valuable standards for control are developed. The control mechanism totally depends up on the measurement of various deviations which have been encountered in comparison to the plan. After each update some new critical paths may emerge or some existing ones may cease to be critical or there may be many more things which may require special attention. In a situation like this, the network provides a review mechanism which can be used by changing the methods of working without affecting the performance parameters and/or redeployment of resources with slight or no cost and time overruns. The network will provide an outline for controlling all aspects of project using various methods which have been discussed in Section 2 of this standard, for example, use of master control networks, use of squared network, preparation of histograms for resource deployment and cost control, etc.

16 PROJECT MONITORING, ANALYSIS AND UPDATION

16.1 Project Monitoring

16.1.1 *Sources of Data*

As discussed above, the mechanism for reviews, coordination and control should be well thought out at the planning stage itself. The data originating from the source of activity should be compared with the planned data. The data for project review, coordination and control will be collected from the following:

- General description of the project including the objectives;
- Scope of services required at the various levels of the project;
- Project organization including that of clients, consultants and other participating divisions and the defined inter-relationships amongst them;
- Division of responsibility between the various participants;
- Project control system as described at the planning stage;
- Project completion dates including that of milestones, assemblies, sub-assemblies and various other components;
- Communication channels as defined in the plan, for example, general correspondence, engineering and manufacturing information, correspondence with the vendors and sub-contractors, correspondence with the clients and consultants and other project documentation;
- Approved documents and their distribution among project participants and other ownership documents;
- Project reports comprising of periodical progress report, resource status report, cost status report, etc;
- Change order procedure including deviations;
- Procurement procedure for equipments and material, tax data, customs clearance procedures, management of foreign exchange and associated quality checks and expediting procedures;
- Tendering procedure and documentation, for site activities and coordination procedures;
- Billing and accounting procedures.

16.1.2 *Methods of Data Collection*

The methods of data collection should be such that a clear reference to the plan as specified for the above referred point is provided. The networks will provide a basis for working out details for each and every activity and task to be performed and various inputs including the procedures, drawings, manpower and other materials. Each of these inputs should be assigned a target date from the time analysis of the network being followed. These target dates are drawn from the latest allowable date required for completion of each of these tasks. The network can be divided into its work contents depending upon the work breakdown structure and work packages described at the planning stage. A squared network of major work packages/assemblies, sub-assemblies may be drawn depicting weekly schedule of activities, deployment of resources and associated cost. This will give a datum for comparison with the actual performance of various tasks in the project at the time of each review cycle.

16.1.2.1 *Data on time aspects*

a) A list of activities which have been completed since the last review, together with (if historical

records are to be maintained) the actual start and/or finished dates. (These activities may not necessarily have been scheduled for the current cycle.) Also where historical records are kept, any past activities which were deleted from, or added to the programme.

b) A list of activities started but not finished, together with their start date and/or either an estimated finish date, revised total duration, or time-to-completion from the 'Time Now' date.

c) A list of activities which were at the last review, and still are, in progress, again with an estimated finish date, revised overall duration or time-to-completion.

d) The estimated start date of activities which could start but have not yet done so.

e) The achievement dates for any specified events, particularly key and interface events.

f) Identification of any revised durations for future activities, or changes to any scheduled dates.

g) Details of any revised network logic. If new activities are added to a computer file, they need to be listed with all their relevant information. Activities to be deleted should also be identified.

16.1.2.2 *Data on resource aspects*

Revisions to resource availabilities, giving resource category with the levels and periods of availability. Also any changes in resource requirements against any activity.

16.1.2.3 *Data on cost aspects*

a) Approximate costs of completed work packages; the extent of approximation allowable should be defined. There may be some delay in obtaining these figures after completion of the work, dependent on the organization's cost collection system;

b) Costs-to-date of work packages in progress;

c) Revised estimates of future work packages; and

d) A list of changes to the activity content within any work package, resulting from changes in project scope, corrective procedures or omissions.

NOTE — In certain circumstances, especially where the changes have been significant, for example, basic project requirements, the data collected should be supported by a list of reasons for the changes reported (or allocation of responsibility for such changes).

16.1.3 *Scope, Characteristics and Techniques*

A multi-level system of project monitoring is needed for establishing any meaningful review procedure. For a typical large project with three levels of planning, Level-I will deal with the project in its entirety but the level of control will be such as to be exercised by the top management. The client, consultant and Government agencies are interested in monitoring the project at Level-I stage and activity duration shall be ranging from 4 weeks to 26 weeks. It will determine the status of the project and assess the anticipated completion date which is committed to the client. It will also identify problem areas and assign responsibilities to investigate reasons for slippages and will make agencies responsible for making up for any deviations.

At Level-II, the project is broken down into the levels of participating divisions or the functional level. For this level, the project is divided into either in its systems/components or in the form of various participating divisions and their set-up. At this level, divisional level of performance and problems are reviewed and responsibility assigned.

Level-III is the working level detail. Often comprising list of activities or a work package at supervisor level. The major data collection will take place from here. Care should be taken to link them to Level-I task/ activity through Level-II network. The monitoring of resource deployment and cost incurred will take place at this level. Any corrective action will also flow from top to this level for implementation.

16.2 Project Updation

For any project, updates of the data must be referred to a particular point of time known as 'Time Now'. At this point of time, details of work completed at the time of last review must be collected. The work currently in progress and all work which has over-shot the target dates or latest allowable date affecting the project completion must be monitored. The Level-I network which deals with the corporate activities must be exploded into Level-II covering all participating divisions. These are further exploded into Level-III depicting various tasks being performed. In the multi-level project environment, analysis by the computers becomes essential. If the computer networking facility is not available then with each update run a turn around document must be developed giving the activities falling under the period of review giving their description, performing agencies, earliest possible dates and latest allowable dates of start and completion. In this document, the agency performing that particular activity should fill in the actual status about the start or completion as the case may be. Using this document, the project management planning team must do the analysis using computer and fresh schedules are developed depicting the project status.

16.3 Project Analysis

Once a multi-level system of monitoring and review is established, the most important aspect is the timely review, updation and corrective actions. For this, quick mechanism has to be thought of for time, resources and cost analysis. The data collected should not be very old and preferably on-line updation of all level of networks should be carried out. At the planning stage Level-I is envisaged to the corporate level network, Level-II is divisional level and Level-III is working level document. Level-III can be in the form of network or description of work package

or a component list like drawing schedule, valve schedule or any other material component list. The data collection for updation and review should take place from the source.

The time analysis will show, on each update run the criticality of the project which will require certain modifications with respect to the planned schedules, resource inputs and costs incurred. At the planning stage when the resource analysis is done, the project progress is analyzed keeping in view the available resources and associated cost for project completion as agreed with the client. When the updation takes place at each review cycle and new criticality develops, a relook into the resource and cost analysis is to be done. It may not be essential to do this with every update run because this is a costly exercise. Therefore, a decision must be taken about the cycle of resource and cost analysis. A typical example of time, resource and cost analysis is while doing the time analysis of the project. Some critical areas are identified. These areas, if not attended to, may delay the project. This may require re-deployment of resources during that week/fortnight or month, thus diverting resources from other non-critical areas. This may cause disruption in the weekly resource loading plans. This method of redeployment may affect the project cost structure. Once the cost is collected at the work package level, the cost of work performed should be collected on the following three aspects:

a) Budgeted cost of work performed,

b) Planned cost of work performed, and

c) Actual cost of work performed.

However, the actual cost deviation from the original estimate/contract value should be noted and documented. This will help in investigating the causes of cost deviation and arriving at the projected completion cost of the project.

17 PROJECT MANAGEMENT DECISIONS AND IMPLEMENTATION

Essential part of review procedures, project coordination and control are progress meetings. A quarterly project review meeting can be held at the corporate level involving the Chief Executive and Heads of various participating divisions with the representatives from client and consultant. They will cover the specific areas affecting the project completion adversely, sanction of various resources and decisions regarding the various costs.

A project engineering coordination meeting and divisional review meeting may take place at monthly interval. This will involve divisional managers, project manager and the functional coordinators; also purchase manager, construction manager and technology manager. They will discuss the performance, schedule and cost of various systems, sub-systems including work packages. They will also take decision on performance of various activities within the given schedule.

The project schedule review meeting should take place every week which will assign work to various levels of supervisors. They will prepare a checklist and also collect data on the performance of various activities and also implement decisions taken at the highest level regarding reworking/redeployment or any other changes including the inputs to the projects. The information generated after each cycle of project review may be divided into the following:

a) *For information* — This means for the top management, manufacturing agency, funding agencies and others, having stakes in the project directly or indirectly.

b) *For decision making* — The information is mainly for the Head of the division, the client, inspection agencies, and others who are interested in the project and may affect the project by virtue of their actions.

c) *For action* — The information at this level is most vital. They are the actual doers and each one of them must be told about reflection of their action on the timely completion of the project. Any kind of deviation should be clearly specified in terms of project completion. Thus care should be taken for each and every activity or task which may affect the timely completion of the project. They should also specify the resultant delays on account of non-adherence, effect on resource mobilization and cost overrun.

SECTION 4 REPORTING DOCUMENTATION AND PROCEDURES

18 GENERAL

18.1 Reporting documents are a means to assess the progress in the context of the plan and provides the basis for making revision in the plan. The reports should contain reasons for deviation from plan, corrective actions taken and corrective actions required. The report should be relevant and timely.

18.2 To facilitate selective controls, quick decisions and actions, exception reporting must be followed. For exception reporting, appropriate exception indicators relevant for each decision making level in respect of physical progress, cost, resources, time schedules, etc, should be evolved.

18.3 The reports can be presented in three different ways namely, tables, graphs and charts, narration, and by different medias. The methods of presentation should be selected according to the type and nature of information to be conveyed and the management level. This can be produced manually or by computer.

19 TABULAR PRESENTATION

19.1 The data relating to time, resources and cost details, exceptions, trends and analysis can be meaningfully and effectively presented in a tabular form.

19.1.1 *Tables on Time Schedules and Actuals/ Anticipations*

19.1.1.1 An illustrative list, which can be used to highlight the progress relating to time aspects of the project, is given below:

— Activity list showing schedule and actual/ anticipated time against each activity

— List of critical activities
— List of key/milestone events showing earliest/ latest occurrence, schedule occurrence, actual/ anticipated completion time
— List of events falling on the critical path showing earliest/latest occurrence, schedule occurrence, actual/anticipated completion time
— Exception report to highlight significant variations.

19.1.1.2 *Float order list*

This list enables identification of the critical activities. A float order list depicting activities, in the ascending order of the total float available should be prepared. In cases, where the activities have negative floats, the activities with the highest negative float value should appear first in the list.

19.1.2 *Tables on Resources*

19.1.2.1 An illustrative list, which can be used to highlight resource utilization and their status, is given below:

a) Reports relating to materials, man-power, machines and equipments should reflect the utilization of these resources against the plan.

b) Reports pertaining to resources required and available should also be prepared linking with project schedules.

c) Detailed reports on material requirements can be prepared on the basis of work packages and activities.

d) Separate report for deployment and utilization of equipments on critical activities can also be generated.

19.1.3 *Tables on Cost*

19.1.3.1 The basic unit of costing should be work package. The cost report should contain information on budgeted/actual/projected and cost variances against different work packages. The planned cost, the cost incurred to date and projected cost on completion should be linked to the actual physical progress of the project.

19.1.3.2 Exception reports should be made for variances beyond specified tolerance limits as and when required.

20 GRAPHICAL PRESENTATION

20.1 Graphical presentation should be simple and self contained. The graphical presentation suggested are:

20.1.1 *Squared Network*

Squared network can be prepared to show the earliest start, latest start, earliest finish, latest finish, scheduled start, scheduled finish and float of activities, status of start and finish activities, balance float, projected delays in activities and the project as a whole. It can also be used for the purpose of resource rescheduling and budgeting.

20.1.2 *Commissioning Schedule Network*

The commissioning schedule networks would show the status of completion of milestones or components against plans/schedules and in case of delays or shortfalls, the impact of delays on commissioning of the project.

20.1.3 *Bar Chart*

20.1.3.1 Bar chart constitutes a widely used method of presenting both planned and progress data on time scale. It can also depict data by responsibility area, WBS components and work packages.

20.1.3.2 The time scale is indicated along the horizontal axis and the activities along the vertical axis. The critical activities are indicated by cross-hatches (*see* Fig. 9).

20.1.3.3 Bar charts should show the scheduled start and scheduled finish, the status and projected completion. For manual resource loading of manpower/equipments, the bar charts should show activity floats.

20.1.4 *Milestone Bar Chart*

The milestone bar chart should contain schedules of selected key/critical events derived from the network,

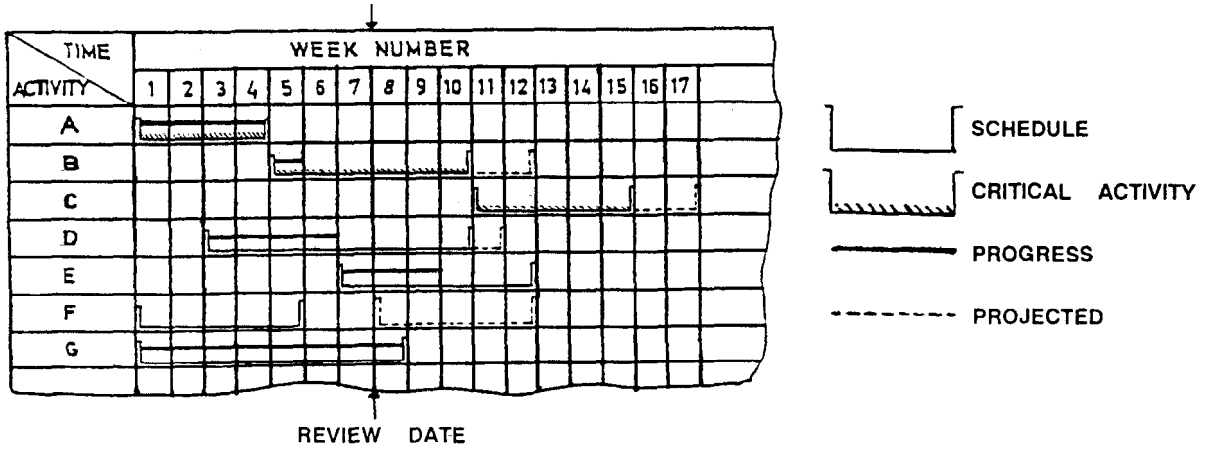

FIG. 9 BAR CHART

their status of start or finish and the projected delay in the occurrences of milestones by a dotted line (*see* Fig. 10).

20.1.5 *S-Curves and Histograms*

20.1.5.1 Typical S-curves depict the cumulative planned and actuals of inputs such as, materials, manpower, expenditure, etc; forecast of these to project completion; time, resources and cost overruns.

20.1.5.2 The diagram (*see* Fig. 11) is an illustration of S-Curve for project manhours interrelated with other facts such as, planned and actual work and cost of activities.

20.1.5.3 Special diagrams like histogram can also be prepared for materials, manpower and critical equipment for resource levelling/loading (*see also* Fig. 11).

20.1.6 Manual loading and status charts of various resources can also be prepared.

21 NARRATIVE PRESENTATION

The narrative portion of the report, expressed in words, should be used to highlight:

a) Special problems,

b) Exceptional situations,

c) New developments and changes,

d) Corrective actions taken and required, and

e) Suggestions for future.

These reports should be simple and concise.

SECTION 5 PROJECT TERMINATION/ CLOSURE

22 PROJECT TERMINATION/CLOSURE

22.1 Project termination/close-out arises when the project objectives have been realised or due to unforeseen circumstances the project is terminated prematurely.

22.2 Project close-out plan and schedule will be based upon:

a) Frozen project objectives, means for achieving them and authorization for commencement of work.

b) Changes in the project plan.

c) Project performance *vis-a-vis* the project objectives.

d) Updated results and modified plans.

23 TYPES OF PROJECT TERMINATION/ CLOSURE

23.1 Project Close-out or Normal Project Termination

It is a process that provides for acceptance of the project by the project authorities, completion of project records, final revision and issue of documentation to reflect the 'as-built' condition and the retention of essential project documentation.

The project authorities authorise dissolution of the project management setup and all concerned are notified. A skeleton staff is identified and retained to tackle only the left out issues and their terms of reference is documented in consultation with project authorities and the project manager prior to his relinquishing the charge of the project.

23.2 Premature Project Termination

It is a condition when the project is terminated before it reaches the stage of full realisation of project objectives.

23.2.1 Premature project termination may become necessary due to changes in environment, both external and internal, changes in the organisation's policies, funding of the project, shift in priorities, economic difficulties, inability of the executing agency to complete the project etc.

The project termination proposal shall be initiated by the project manager on the basis of a written authorisation from the project authorities. The project authority will decide finally whether to continue or terminate the project. All the decisions regarding the project termination shall be documented and signed by all involved.

The project termination proposal shall contain the causes and consequences of the premature termination with reference to the project plan, description of the activities with reference to project plan network and resources required for termination.

24 RESPONSIBILITY OF PROJECT MANAGER

24.1 Making all necessary decisions for suggesting alternative plans for continuation or for termination of the project by keeping records of all the descriptions regarding time, cost performance/technology with respect to project plan and further modifications thereof.

24.2 Preparation of project close-out plan and schedule in consultation with the project authorities within the agreed framework of project scope and contractual obligations.

24.3 Acting as focal point for communication between project authorities and the project/sub-project groups in working out details regarding project closure/ termination.

24.4 Taking stock and recording the accomplishment of all work packages as given in the project plan and subsequent modifications thereof. Any deviation in the project closure/termination network plan emanating due to deviations in accomplishment of work packages in terms of time, cost and performance/ technology should be incorporated in project closure/ termination network.

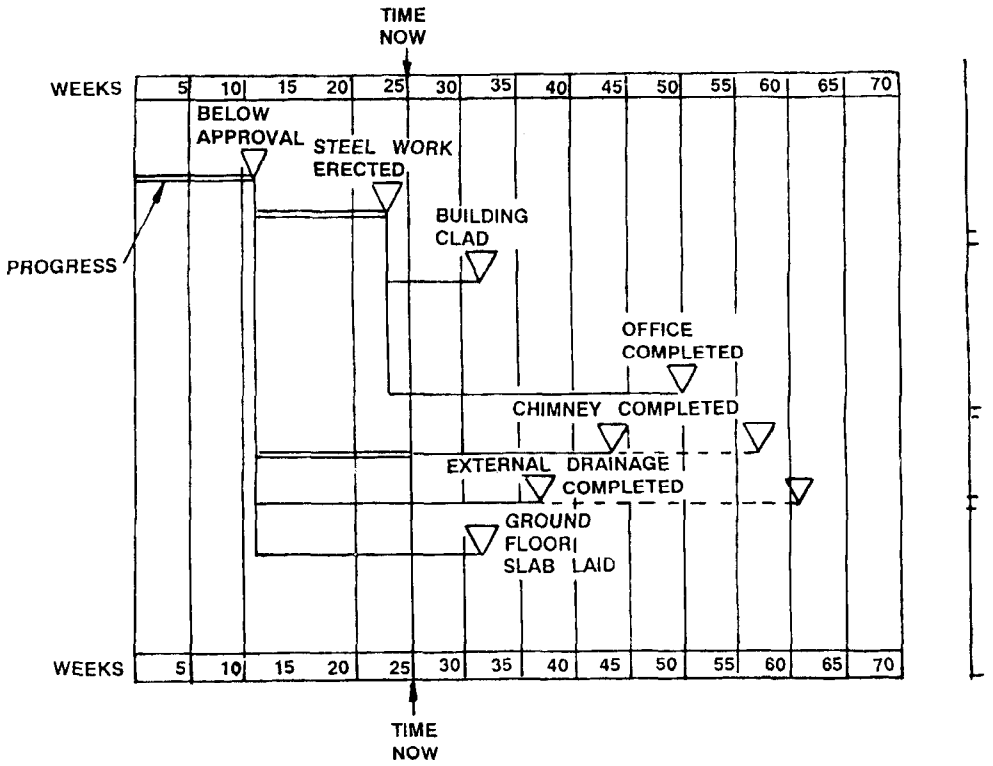

FIG. 10 MILESTONE CHART

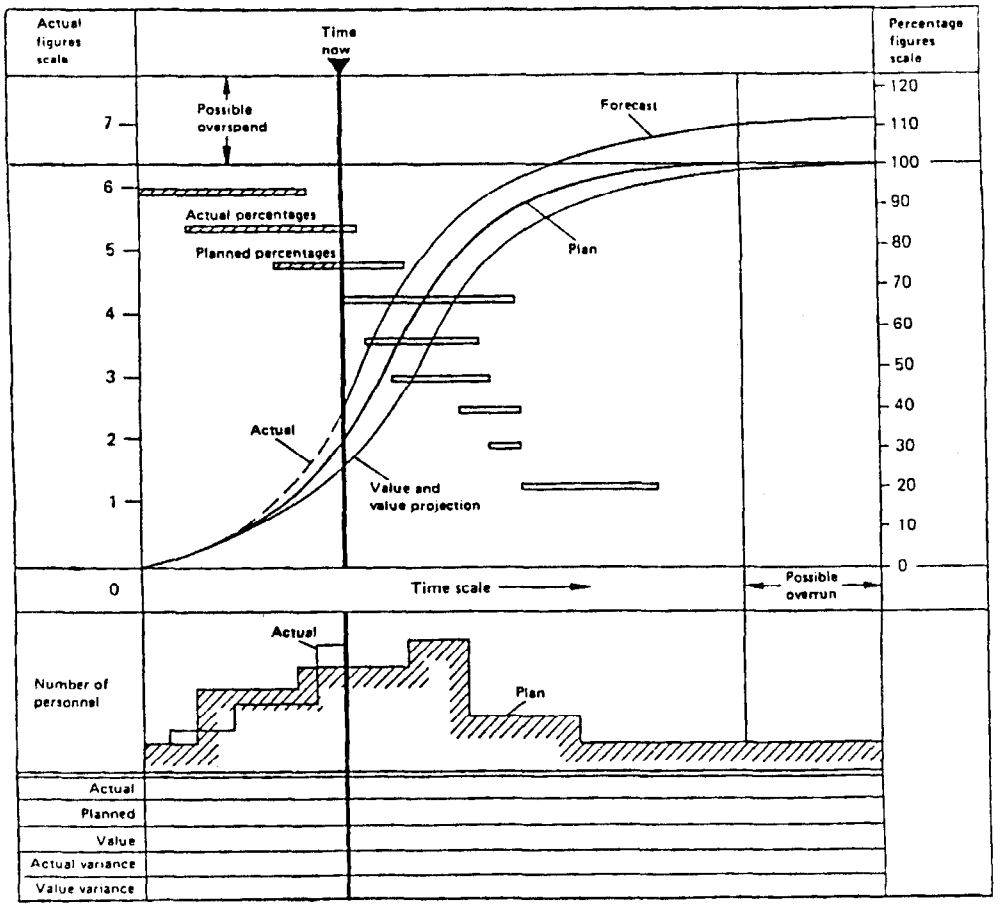

FIG. 11 TYPICAL S-CURVES AND RELATED HISTOGRAM SHOWING CURRENT STATUS AND PLAN

24.5 Documenting results in terms of achievement of project objectives and project closure/termination procedures.

24.6 Handing over 'Operation and Maintenance Procedures Manuals', as-built-drawings, records of deviations,etc.

24.7 Organizing for the completion and closure of the project management activities with the release of resources, redeployment of staff, transfer of responsibility, system checkout and start-up, passing on of historic records, arranging for the financial closing and final handing of the project, to the project authorities.

25 STEPS FOR PROJECT CLOSURE/ TERMINATION

25.1 Project Close-out Plan and Schedule

25.1.1 Project close-out plan and schedule will include:

a) preparation of a complete record of any changes made in the project objectives due to changes in scope, project plan schedules and costs.

b) preparation of record of technical performance *vis-a-vis* original plan, causes for deviations, if any, and remedial measures taken.

c) Establishing procedures for start-up operations, check-out details of all systems/equipments and procedures for total operations.

d) preparation of record of implementation of various systems during the total project life cycle, the success and failure of various systems and their positive and negative impacts in achievement of overall project objectives.

e) preparation of record of formulation and maintenance of quality standards for work/ systems.

f) preparation of record of special actions taken to cope with environmental changes, changes in organizational setup and policies, government regulations, changes in priorities, calamities and unique circumstances which have affected the project objectives, plans, schedules, resources and cost.

g) preparation of record of special tools and tackles used, methods and procedure adopted.

h) preparation of guidelines for future course of action based upon the success and failures of various systems/ procedures/ methods/ processes adopted.

j) in case of premature termination, preparation and execution of all terminal agreements with internal and external sources as authorized by the project authorities.

25.1.2 After the project objectives are frozen and project scope along with the contractual obligation is agreed with the project authorities, Project manager prepares the plan with WBS, establishes the control mechanism and defines procedures for updation.

Network for project close out/termination activities are prepared, which will provide schedule of all the activities of project termination/closure forming part of contract document and is agreed to by project authorities.

25.2 Reassignment of Project Staff

The reassignment of project staff should be done in the following order.

25.2.1 *Reassignment of Project Staff to Other Similar Projects*

This is the best possible way of redeployment to use fruitfully the experience and capabilities acquired as it is also very difficult to find suitable people for project work and even more difficult to train afresh.

25.2.2 *Reassignment of Project Staff to Other Allied Area Projects*

With some additional knowledge related to product/ process, systems pertaining to new projects, the project staff can be redeployed with minimum of training as they are already adapt in project management skills.

25.2.3 *Reassignment of Project Staff for Operations and Maintenance*

The staff engaged in execution, commissioning, quality and performance testing of components, sub-assemblies, assemblies and systems can be trained and retrained for operations and maintenance depending upon the individual preferences. Preparation of position descriptions and organization chart, recruitment of personnel, placement and training of staff required for operation and maintenance. If the project authorities are different from the executing agencies, commercial modalities may be settled between project authorities, executing agency's top management and the project manager for such redeployment.

25.2.4 *Reassignment of Projects Staff as Consultant/ Trainer*

Project management expertise is very scarce, it may not be fair to lose this expertise through redeployment of project staff in a totally new area. The persons who have good communication skills and have shown expertise in planning, control, development of various systems and documentation may be redeployed as consultants and trainers in project management areas.

26 DIVEST PROJECT RESOURCES

26.1 The divesting of project resources should be done in the following manner:

a) Resources drawn from the common pool must be released for use in other projects once the

need of the current project is met as detailed in the project plan, that is, tools and plants, standards, manuals, testing equipment, etc, under the appropriate procedures drawn up for such release.

b) The resources unique to the project and non-consumable in nature as also left over consumables like fuel, oil, lubricants, commissioning spares, attachments etc may be transferred to the project authorities for use during the operations and maintenance with commercial modalities settled between project manager and the project authorities, or can be auctioned by the project manager under the special procedure drawn up for this purpose.

c) Other resources provided by project authorities may either be absorbed as project property or released as per contract stipulations.

d) Finalization of terms of reference for smooth operations of the skeletal staff set up specially for winding up of the project.

27 RECOMMENDATIONS FOR ACTIONS, IF ANY, REQUIRED FOR FUTURE

27.1 The project manager based on his experience would make recommendations in areas such as:

a) project objectives;

b) project plan;

c) project control;

d) project updation and review mechanism;

e) project organization;

f) project staff selection, recruitment, placement and training;

g) efficiency, efficacy and proper use of various resources;

h) systems developed and implemented from start to finish of the project;

j) project process, method and procedures followed;

k) unique features of the project and learnings;

m) temporary arrangements made and future plan of action;

n) difficulties encountered and precautions taken;

p) quality/performance/technology planned versus achieved;

q) safety requirements and early warning signals;

r) interfaces managed with internal and external environment/organisations;

s) recommendations for change of procedures etc; and

t) O & M procedures, instructions for all systems/ sub-systems with precautions needed.

The above information will be useful for developing proposals for future projects and will not only help in improving existing methods, systems, procedures, quality standards, and performance but also in proper planning, scheduling, monitoring and optimum utilization of resources.

28 PREPARE A TERMINATION/CLOSURE REPORT

28.1 Normally this report will contain the following:

a) Historic records containing project documentation that can establish deviations from the project objectives/scope duly authorised by project authorities/participating agencies for proper project closure.

b) A formal analysis in the form of project report containing project data like costs, schedules, technical performance, *vis-a-vis* original plan.

c) A report on financial closing stating how the funds have been raised and spent with total commercial implications at the time of project closure (handing over/termination).

d) Documentation regarding:

— As-built-drawings

— Operating procedures

— Operation and maintenance manuals

— Guidelines for training of operation and maintenance staff

— Position description, placement, and recruitment guidelines for O & M

— Transfer of responsibility

— Release of resources

— Project acceptance and operations report with systems check-out and start-up results (individual and collective)

— Quality/performance/technology documents

— Deviations and remedial action report

— Special features

ANNEX A
(Foreword)

COMMITTEE COMPOSITION

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3148, Sector D, Pocket 3, Vasant Kunj, New Delhi

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(*Continued on page* 22)

(*Continued from page* 21)

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DR B. L. RAWAT	In personal capacity (*175 A, DDA MIG Flats, Rajouri Garden, New Delhi 110 027*)
SHRI A. K. VOHRA	National Productivity Council, Patna

(Continued from second cover)

d) ready means of reviewing the project and exercising control over time, resources and costs;

e) clear identification of critical and risk areas, plus an excellent model for generating 'what-if' scenarios for making management decisions.

Section 1 highlights the important aspects relating to project organizations, project management, contract management and familiarization and training.

Section 2 highlights the various aspects involved in planning at various levels incorporating the various plan components namely, time scales, resources, quality and cost.

Section 3 deals with the review procedures for coordination and control of the project.

Reporting procedures are a means to assess the progress of the project and make revisions in the plan, if needed. There is a need for providing the relevant information in any reporting document. Section 4 highlights the method of presentation of these reports in different ways namely, tabular, graphical and narrative forms.

Section 5 gives details about the project termination/closure activity which arises when either the project objectives have been realized or due to unforeseen circumstances, the project is terminated prematurely.

Other parts planned to be brought out on the subject are:

Part 2 Use of graphical and estimating techniques

Part 3 Use of computers

Part 4 Resource analysis and cost control

While preparing this standard considerable assistance has been taken from:

BS 6046 : Part 1 : 1984 Use of network techniques in project management — Part 1 : Guide to the use of management, planning, review and reporting procedures.

The composition of the committee responsible for the formulation of this standard is given in Annex A.

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