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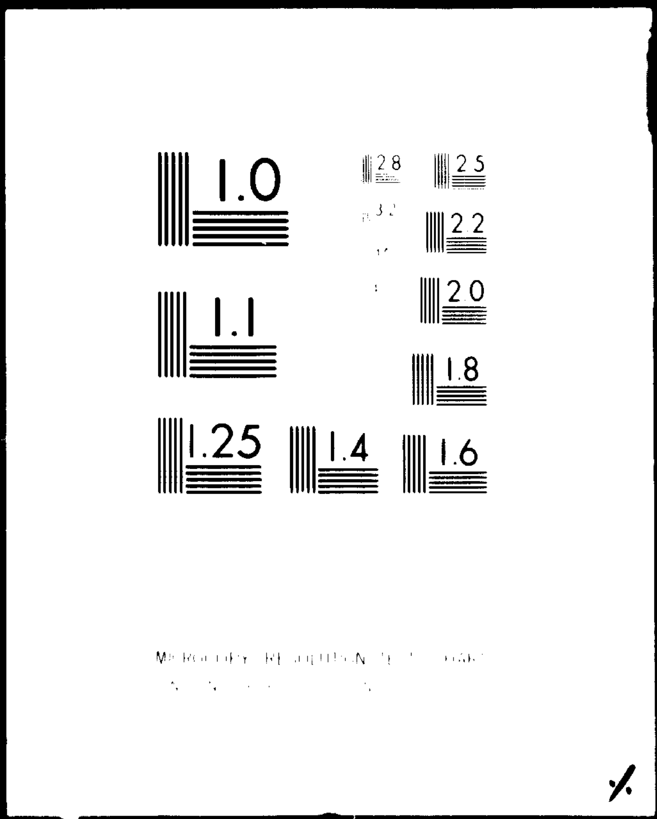

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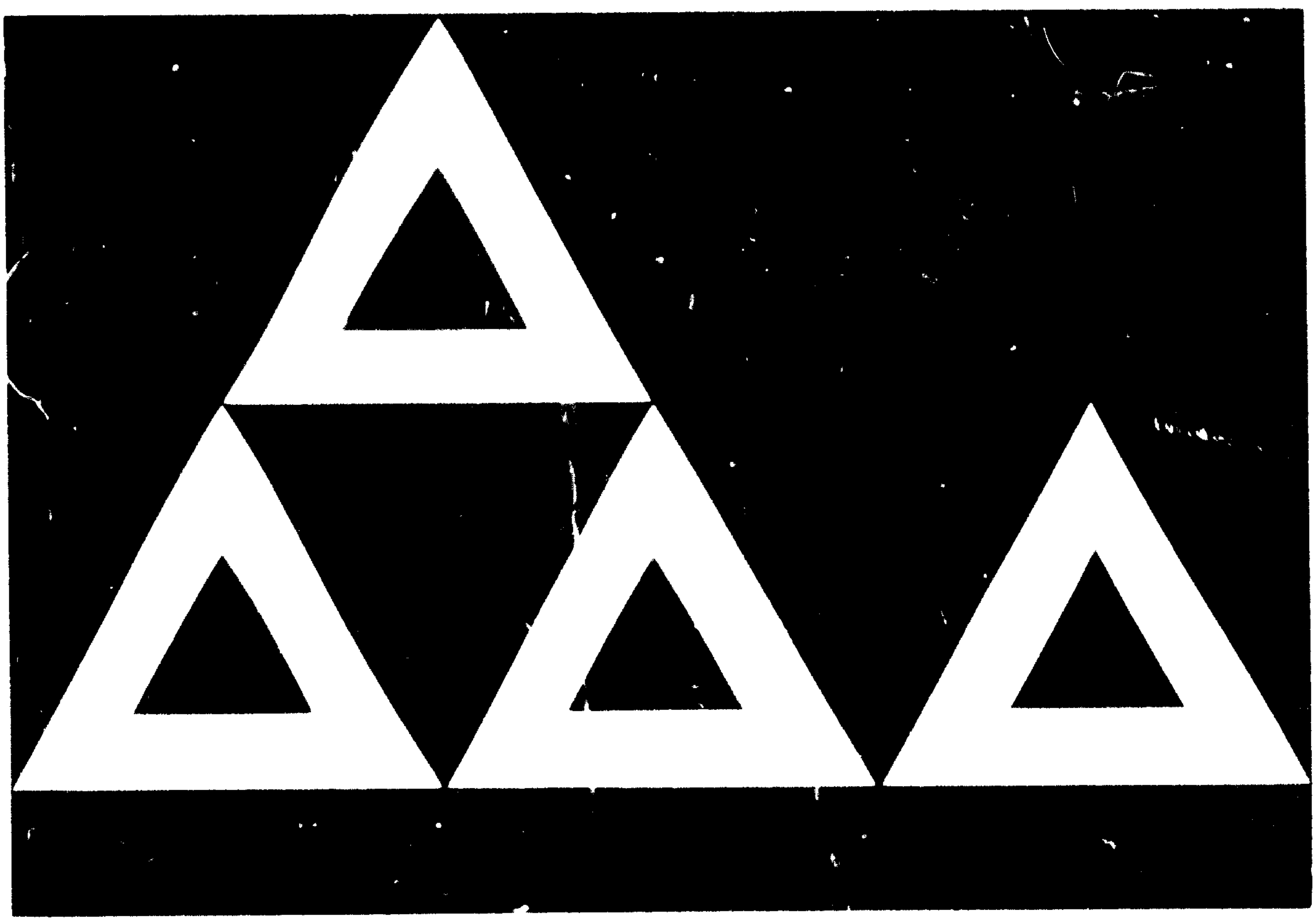
THE INITIATION AND IMPLEMENTATION OF INDUSTRIAL PROJECTS IN DEVELOPING COUNTRIES

A SYSTEMATIC APPROACH



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Corrigendum

Page 13, line 7 from bottom

For risks *read* tasks

Page 39, paragraph 2, line 4

For planning network *read* network planning

Page 40, milestone No. 4

Inner triangle *should be* solid

Page 41, milestone: Funding application completed

First symbol *should be* open

Page 64, first equation

For 5 months *read* 5 million

Page 65, paragraph 3, line 3

For since task 2 *read* since task 3

THE INITIATION AND IMPLEMENTATION OF INDUSTRIAL PROJECTS IN DEVELOPING COUNTRIES

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CONTENTS

Preface

This publication is based on the findings of the Expert Group Meeting on Project Planning and Implementation Information Systems and Related Machinery, which was organized by the United Nations Industrial Development Organization (UNIDO) and held at Vienna from 13 to 18 November 1972. The Expert Group was composed of 10 experts from both developing and developed countries. The discussion centred on the major problems the developing countries are encountering in programming and control of project initiation and implementation and on the development and application of certain management tools, in particular, project management information systems, as a means of overcoming them. The list of participants is contained in annex I.

Mostafa H. A. Hamdy of UNIDO served as Officer-in-Charge of the Meeting.

Chapter I analyses the need for improving existing methods of managing industrial development projects. Chapter II describes some of the project management methods that have been applied in developed countries to overcome problems that impede the completion of projects on schedule. Some of these methods can be used in developing countries, for the fundamental principles of systematic project management can be adapted to the environment of a developing country. These principles can best be understood by observing a specific project. Chapters III and IV present a case project to illustrate how these principles may be applied. The crux of systematic project management is project control. Chapter V describes methods of controlling project implementation in some detail. To obtain the improvements described in the report, a carefully planned series of steps is necessary. Chapter VI presents a recommended plan for accomplishing these steps.

This publication can be of use to many persons at various organizational levels who are concerned with managing project development, and with implementation in particular. For project managers, project team members, functional staff of organizations dealing with project work, contractors, subcontractors and suppliers of machinery and equipment, the publication as a whole provides an operating model for improving project initiation and implementation. Some techniques used in programming and controlling the implementation of projects are included in annexes II-IV.

For those who have no direct responsibility at the project level for initiation and implementation of specific projects, such as executives in government planning organizations or similar bodies, secretaries and under-secretaries for industry, heads of development agencies or banks and members of the boards of companies dealing with project initiation and implementation, chapters I, II and VI are of particular value; some of the important issues are discussed in these chapters.

Moreover, this publication is designed to assist those responsible for project initiation and implementation in developing countries in identifying their needs for the technical assistance that UNIDO can provide in this field.

I. THE NEED FOR SYSTEMATIC MANAGEMENT (SYSTEMATIC INITIATION AND IMPLEMENTATION) OF INDUSTRIAL DEVELOPMENT PROJECTS

Developing countries are faced with the immense challenge of organizing their resources and making decisions affecting industrial development in order to meet the expanding requirements of their societies. Much effort has, in the past, been concentrated on operations, the focal point of which is usually the effective performance of similar or repetitive tasks, functions and processes. The eventual purpose of the invested efforts or manufactured items is of secondary importance and frequently even unknown to the persons involved.

To gain increased security, convenience and wealth, and as a result of the evolution of science and technology, one-time industrial ventures that often go beyond the scope of regular operations in a given institution are being undertaken more and more frequently. Typical examples of such ventures are the construction of a dam, the building of a new factory, or the installation of an electric power plant and power distribution system. These ventures, which are unique and end with the achievement of a specific major objective in the form of a product or operational system, are called projects. In comparison with operations, projects have different management characteristics.

In projects, the focal point is the efficient accomplishment of an objective. For example, in an industrial project this objective usually is to establish, within the time and budget specified, a factory whose performance meets previously established standards. For the achievement of such an objective, where time and money are important and various groups that are organizationally or physically dispersed have to work together, the traditional management methods and philosophies used in operations are inadequate. For projects, a different management philosophy is required. The persons who contribute to and participate in the project must be motivated so that they become primarily goal- or product-oriented.

The basic functions of project management are to plan, organize, co-ordinate, monitor and control activities and resources and to make appropriate decisions in such a way that they are directed towards the accomplishment of a clearly defined major objective, usually a substantial product, facility or system. If project management is to be effective, complete technical, financial and schedule responsibility must be vested in the project leadership, and management must constantly keep in mind how the project's objective can be achieved efficiently. The project management system, therefore, is the tool or mechanism used to develop a product, facility or system from its conception to its realization. It consists of the organizations, policies, procedures, information, methods, systems and practices used to initiate and implement projects.

Frequently, government authorities decide to initiate and implement a complex industrial development project and later become discouraged when the implementation does not achieve the established objective. The fundamental causes of difficulties arising during implementation, which delay and increase the cost of development projects, can be classified as political, environmental, economic and technical.

Political causes. Political decisions are made without sufficient consideration of technical and planning information or on the basis of inadequate information; government officials may be carried away by political optimism and overcommit their resources.

Environmental causes. Existing administrative structures and management decision-making and planning procedures may be inefficient and complicated; greater emphasis may be placed on science and technology than on management, which may result in a lack of appreciation of systematic project planning and implementation; it may be difficult to achieve the agreement and co-operation of the many diverse public and private organizations needed for project implementation.

Economic causes. The strategic objectives may be incompatible with socio-economic, economic, technical and other non-political objectives; development plans and programmes may not be backed by well-studied and well-conceived projects; the systems approach may not be applied when development programmes are established, which may mean lack of co-ordination and co-operation between various government bodies (e.g. failure of the Department of Energy to consider industrial development projects of the Department of Trade and Industry when initiating an electric power plant project in a certain area).

Technical causes. The technologist and the project planning group may fail to adapt their planning approach to the political/environmental/strategic situation; a common language between scientists, technologists, economists and politicians is lacking, and the technologist fails to present his information in an understandable form; the organization of the project is poor; too much concentration is focused on individual planning techniques instead of integrating all relevant techniques and methods into a comprehensive project planning concept; the planning system is characterized by inertia, whereas projects are dynamic; project management methods and techniques are lagging far behind science and technology.

This publication outlines the methodology required for using a project management system to alleviate many of the problems that arise during implementation from the causes stated above. It is believed that improved teamwork and co-ordination of politicians, economists and technicians will be achieved through the consistent use of a project management system. Such teamwork will, in fact, be one of the great benefits derived from the use of such a system.

The methodology is based on awareness of the need for identifying specific management responsibilities and the subsequent development of a project management system that assists executives in fulfilling their assigned responsibilities. Also recognized is the need for a project management information system to provide each executive with the appropriate information regarding schedule, technical progress and cost for the elements of work under his control.

The proposed methodology also recognizes the need for incorporating the individual project management techniques into a comprehensive system that is compatible with the prevailing limitations and the capability of individual developing countries. In particular, it is determined that it is absolutely essential that project management concepts be interjected into the governmental decision-making and planning process at the earliest possible time.

II. CHARACTERISTICS OF INDUSTRIAL DEVELOPMENT PROJECTS

PHASES AND STAGES OF AN INDUSTRIAL DEVELOPMENT PROJECT

When the responsibilities for project initiation and implementation are organized, it is important to have a clear picture of the various phases and stages of a project, the objectives of each, the tasks to be completed during each and the type of decision-making bodies involved and the desirable extent of their responsibility. In the context of this study, the project encompasses all tasks from the analysis of the problem to and including the acceptance of an operational product, facility or system.

A project starts with the decision to pursue an objective, and it ends with the accomplishment of that objective or with the decision to abandon it. A project must be considered this way because the planning and preparation of project management information must start at the very beginning. One of the first and most important tasks the responsible individual (project manager, project planner, project co-ordinator, study manager) must carry out is to divide the project into a series of suitable phases, each of which will be further subdivided into stages.

Each stage has its own particular characteristics and thus requires information and control procedures suited to it. On the basis of the maximum available knowledge about the entire project in a given project stage, the remaining stages must be planned and replanned so that at the end of each stage an acceptable, realistic final plan to control the succeeding stage is available, plus a revised version of the preliminary plans for all future project stages. As the project passes through the various stages, the planning for the last and often most critical stage (construction/pre-operations) becomes more and more comprehensive and precise, and eventually permits improved control of the pertinent project activities. A clear identification of the project stages and pertinent objectives permits the responsible project initiator or other body to assign responsibilities systematically.

Table 1 indicates the project phases and stages, together with their objectives, that are typical of most industrial projects. The planning structure may have to be adapted to the needs of the various projects, for sometimes the stages overlap. As many tasks as possible should be systematically organized throughout the initiation and implementation of the project.

As a project evolves from the identification (preliminary analysis) stage and passes through the succeeding stages, the prime responsibility for decision making and management changes from one level to the other in the project initiator's and participants' hierarchy. The decision-making bodies in the project hierarchy are indicated below:

Higher authorities (development strategy and policy, target approval)
State planning board
Project execution agency
Project manager/project co-ordinator/study manager
Assistant project managers
Contractors, general contractor
Subcontractors
Suppliers

Table 2, which gives a matrix of responsibilities, is only a guideline and may have to be adapted to the different types of projects and to the initiator's hierarchy. It is essential that only one body be given prime responsibility as far as possible within the same project stage and that all other supporting and/or assisting bodies co-operate closely as a team.

The project stages can be classified into two major phases: project preparation or initiation and project implementation (construction). Since project implementation is primarily based on project preparation, deficiencies in preparation will affect

TABLE 1. PHASES, STAGES AND OBJECTIVES OF INDUSTRIAL PROJECTS

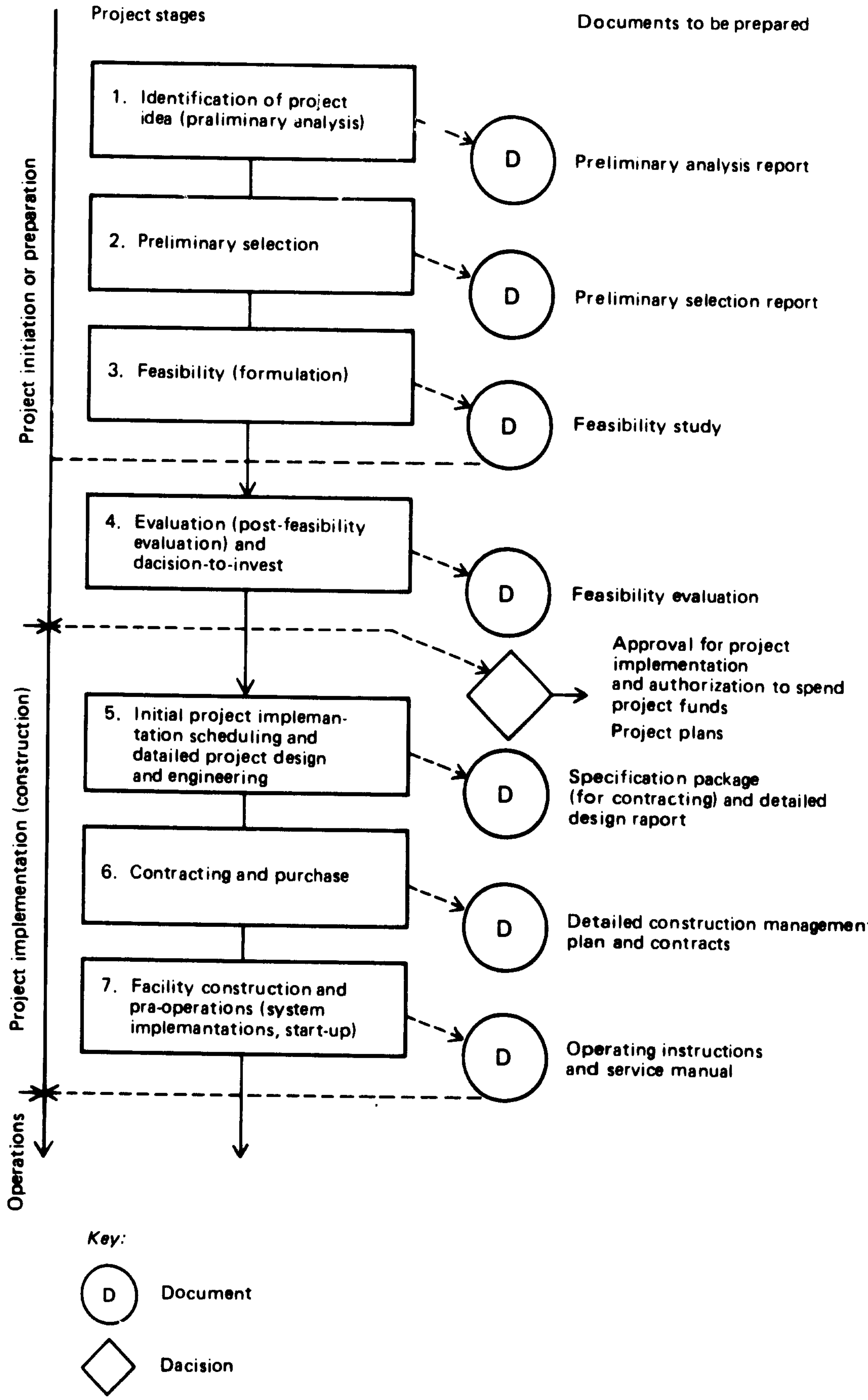
Phase	*Stage*	*Objective*
Preparation or initiation	1. Identification of project idea (preliminary analysis)	Project(s) and programme goals identified and analysed Project objectives and preliminary global schedule and cost estimate determined
	2. Preliminary selection	Ideas for possible solutions developed into alternative concepts; desirable technical solutions identified and classified
	3. Feasibility (formulation)	Feasibility of the envisaged concepts or solutions and relevant alternatives assessed, evaluated and classified
	4. Evaluation (post-feasibility evaluation) and decision-to-invest	Decision on adoption of the most promising alternative solution; funding provided
Implementation (construction)	5. Initial project implementation, scheduling and detailed project design and engineering	All detailed drawings, specifications, bills of materials, schedules, plans, cost estimates and other relevant documentation checked and approved
	6. Contracting and purchase	Appropriate manpower, machinery, manufacturing and construction facilities, utilities, materials, documentation and all other relevant infrastructure components mobilized and available
	7. Facility construction and pre-operations (system implementation, start-up)	Completed, tested, "debugged" and accepted product, facility or system (optimum performance, time and cost)
Operation	8. Operations (not a project phase but listed for interface purposes and programme continuity)	Product, facility or system operational at all times and at optimum cost

TABLE 2. TYPES OF DECISION-MAKING BODIES INVOLVED WITH PROJECT MANAGEMENT

Stage of industrial development project	*Decision-making body*							
	Higher authorities, council for planning	*State planning board*	*Project implementation agency*	*Project manager or prime contractor*	*Assistant project manager*	*Contractor or project co-ordinator*	*Subcontractors*	*Suppliers*
1. Identification of project idea (preliminary analysis)	a	b	c					
2. Preliminary selection	b	a	b	c				
3. Feasibility (formulation)	c	b/c	a	b				
4. Evaluation (post-feasibility evaluation) and decision-to-invest	a	a	b	b				
5. Initial project implementation, scheduling and detailed project design and engineering		c	a	b	b	b/c	c	c
6. Contracting and purchase			a/b	a	b	b	b	c
7. Facility construction and pre-operations (system implementation, start-up)			b	a	b	b	b	b

Note: Involvement: a—Ultimate responsibility; b—Assigned to project; c—Peripheral activities.

Figure 1. Documents to be ready by the end of each project stage



implementation. The event that forms the interface between these major project phases is approval of the project for implementation and authorization to spend major funds. This classification of stages, together with the essential documents to be produced by the end of each stage, is indicated in the flow diagram of figure 1. If the classification of this flow chart is followed, conflicts or gaps in responsibility can be kept to the very minimum and communications between the various project participants considerably improved.

SYSTEMATIC MANAGEMENT OF PROJECTS

A modern project management system consists of a series of compatible procedures concerned with organization of responsibility, tools and facilities. that enable all project matters throughout all phases and stages to be handled efficiently. The system is somewhat comparable to a business enterprise.

The following items are considered essential elements of a project management system:

Procedures, standards and specifications
Work breakdown structure (WBS)
Task descriptions
Project organization structure
Project staff
Communications
Information processing (manual and/or automatic)
Documentation

THE PROJECT MANAGEMENT INFORMATION SYSTEM

Since the project management information system (PMIS) is an essential component of a project management system, this study will concentrate on its design and application. Although the PMIS in the framework of a comprehensive project management system is considered a "subsystem", for the sake of simplicity it will here be called a "system".

The PMIS will be considered a self-contained operational entity that provides all relevant project participants and decision-making bodies at higher levels with essential information for programming, scheduling and controlling the project. A PMIS can give the full benefit and be a real success only if it is treated as an integral part of the project management system.

Functions

The essential functions of a PMIS are to generate, transmit, process, transform, store, retrieve and display information concerning a project; in particular:

(a) To develop plans, schedules and standards against which project execution can be measured later;

(b) To provide all contributors to the project with information on what action is to be taken and when;

(c) To generate and extract from the field all essential information on progress and to transmit it to the project management office;

(d) To verify, analyse, compare and synthesize this information to obtain summaries, lists, graphs, tables and other suitable displays, on the basis of which conclusions can be drawn and sound decisions taken;

(e) To convey the processed and reduced management information to the concerned management bodies and project staff, and to ensure that the information shall be understood and used by the recipients;

(f) To revise or redevelop, depending upon appropriate management decisions, the project plans and standards;

(g) To convey the revised information to all project contributors;

(h) To simulate and analyse alternative project management decisions under consideration.

Constituents of a PMIS

The aforementioned functions lead to the major constituents of a PMIS:

(a) Individuals, who implement, operate and use the results;

(b) Policies, which enable a PMIS to be established and which enforce the discipline required to maintain and operate it;

(c) Procedures, which include: planning; preparation, collection and preparation of data; data processing, both manual and computer-based; data display; project evaluation; contract management; and simulation and analysis;

(d) Facilities, which include an office, facilities for data processing and a project control room.

DESIGN AND IMPLEMENTATION OF A PMIS

The development, design and implementation of a PMIS have presented many problems. The size, complexity and decentralization of today's industrial projects demand a systematic approach to the handling of management information and data. The individual methods of phased project planning, network analysis, and work package cost control must be integrated into a comprehensive system—the PMIS. The difficulties connected with the PMIS do not so much lie in the technical design and development as in the implementation. Good and thorough human engineering is the crucial factor that makes or breaks a PMIS. The human factor must be adequately considered, in the design as well as in the implementation. The most sophisticated information-processing facilities and software are worthless if people cannot or do not want to use them effectively.

In the following chapters a typical industrial development project is used to illustrate these concepts. As demonstrated by this example, a PMIS can be completely manual and does not require a computer. Each organization implementing a PMIS should progress from the initial manual procedures to more advanced systems as their understanding and capabilities increase and their projects become more complex.

III. PREPARATION AND USE OF INFORMATION IN PROJECT INITIATION

In this and the following chapters the project chosen to illustrate how a PMIS is applied during the initiation and evaluation stages of project implementation concerns an electric motor factory. The details of the application of a PMIS at each stage will have to be determined according to the specific needs of the project in question.

INITIAL STATEMENT OF THE ELECTRIC MOTOR FACTORY CASE PROJECT

"The Government of a certain country is considering the idea that it should in the future mass produce small electric motors. To prepare for the timely mobilization and organization of the country's resources, it is necessary to consider all relevant political, environmental, economic and technical factors. An electric motor manufacturing facility known as the Motoric Manufacturing Company already exists."

PROJECT INITIATION STAGES AS APPLIED TO THE ELECTRIC MOTOR FACTORY CASE

Identification of project idea (preliminary analysis) stage

The higher authorities in the Government who have developed the idea that an electric motor factory should be built confirm the initial need for the project, analyse this need and state the requirements of the project. Requirements to be considered include:

Marketing requirements and plans
Specification of production plans (types of products, number of units, production rate, price, manufacturing cost)
Formulation of the manufacturing processes (flow diagrams, charts)
Finance (funds required, sources, terms)
Technical and economic requirements
Resources (manpower, materials)
Schedules

Preliminary selection stage

The State Planning Board considers the results of the preliminary analysis on the basis of which it develops alternatives. The advantages and disadvantages of each alternative may be presented as follows:

Alternative A

The main plant of the Motoric Manufacturing Company will be expanded at a cost of $1.5 million, expansion to be completed within 18 months from final decision to implement.

Advantages:

Effective use of existing organization and facilities
Larger labour supply to draw on and use of present local personnel to train new manufacturing operators
Easy transportation of raw materials, components and finished products from and to market
No energy problem

Disadvantages:

Over-concentration of industry in an already well-developed city
Further aggravation of local traffic and housing problems
Building, anti-pollution and other restrictions

The company concerned would prefer this solution because of the advantages listed.

Alternative B

A new plant in a small, less-developed town, 300 kilometres from the home plant will be constructed at a cost of $2 million and within 20 months from final decision to proceed.

Advantages:

Promotion of regional development
Les population, less traffic, fewer housing problems
New jobs for a growing population
Easy introduction of new manufacturing techniques, methods, processes etc. and labour practices

Disadvantages:

Separation from home plant; communication and transportation problems; increased overhead cost
Possible rivalry between the two plants
Higher investment cost and shortage of experienced labour
Slightly longer period required to complete the project

The State Planning Board prefers this solution because it would expand the industrial development base geographically at relatively low cost.

Feasibility (formulation) stage

In the feasibility stage, the alternatives are analysed in sufficient detail to permit a sound selection of one alternative during the next stage. Elements of the analysis include the following items:

Establishment of evaluation criteria and weighting factors (e.g. environmental, technical, economic and social)
Performing cost-benefit analyses
Operations research studies if necessary (simulation, linear programming)
Development of rough, preliminary breakdown of the project elements
Development of bar chart schedules into rough, preliminary network plans using established network procedures such as the Programme Evaluation and Review Technique (PERT), Critical Path Method (CPM) covering all future stages including production start-up
Development of preliminary cost plans
Verification of sources of financing, terms and conditions for each alternative
Clarification of the availability of project resources
Evaluation and assessment of the alternatives based on the established criteria

Evaluation (post-feasibility evaluation) and decision-to-invest stage

In the evaluation and decision-to-invest stage, the higher government authorities consider the findings of the feasibility study, and in joint consultation with all relevant decision-making bodies they select the most suitable alternative. Items to be undertaken in this stage include:

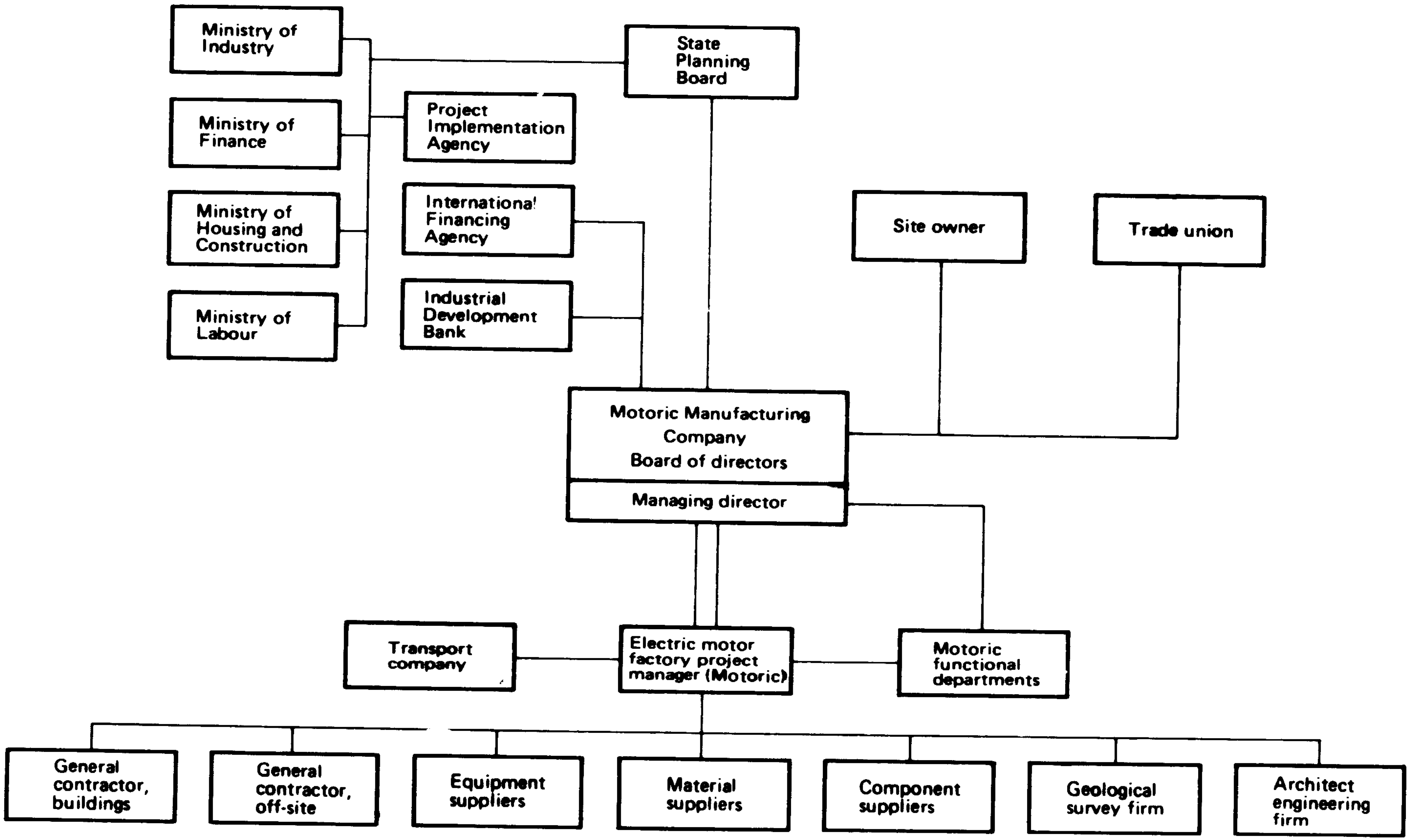
Distribution of the feasibility study with decision guidelines to all concerned
Consideration of the feasibility study in detail
Meetings with relevant decision-making bodies for final selection and adoption
Final selection of the alternative and obtaining the necessary approvals to proceed with the project's implementation

In the case project, the State Planning Board and the Motoric board of directors decided to proceed with alternative B.

DIFFERENCES BETWEEN PROJECT INITIATION STAGES AND IMPLEMENTATION STAGES

While the project initiation stages in this example could be organized systematically in sequence, it is not necessarily feasible for all the stages of project implementation. In table 1, the stages of project implementation have been depicted in sequence because it is convenient to think in this context about the risks to be carried out. In practice, the stages sometimes overlap or are not continuous; therefore, it is not always possible to apply the staged implementation approach strictly. In reading the following chapters concerning the application of systematic project management concepts during the implementation phase of the electric motor factory case project, the reader should note the difference between practice and theory relative to the use of the time-phased concepts previously presented.

Figure 2. Organizational environment of the electric motor factory case project (responsible, performing and other related organizations involved in the project)



RELATIONSHIP OF THE PROJECT ORGANIZATION TO THE PROJECT ENVIRONMENT

When the decision is made to proceed with implementation, a project organization must be established under the direction of a project manager (or leader). This organization must be related to all appropriate agencies of the Government. These relationships define the project's organizational environment, which is shown in figure 2 for the case project.

IV. PREPARATION AND USE OF INFORMATION IN PROJECT IMPLEMENTATION

The implementation of industrial development projects requires many types of information. This information must be prepared and used systematically to ensure that the project shall achieve its technical objectives within the budget and as close as possible to the original schedule.

START-UP OF PROJECT IMPLEMENTATION

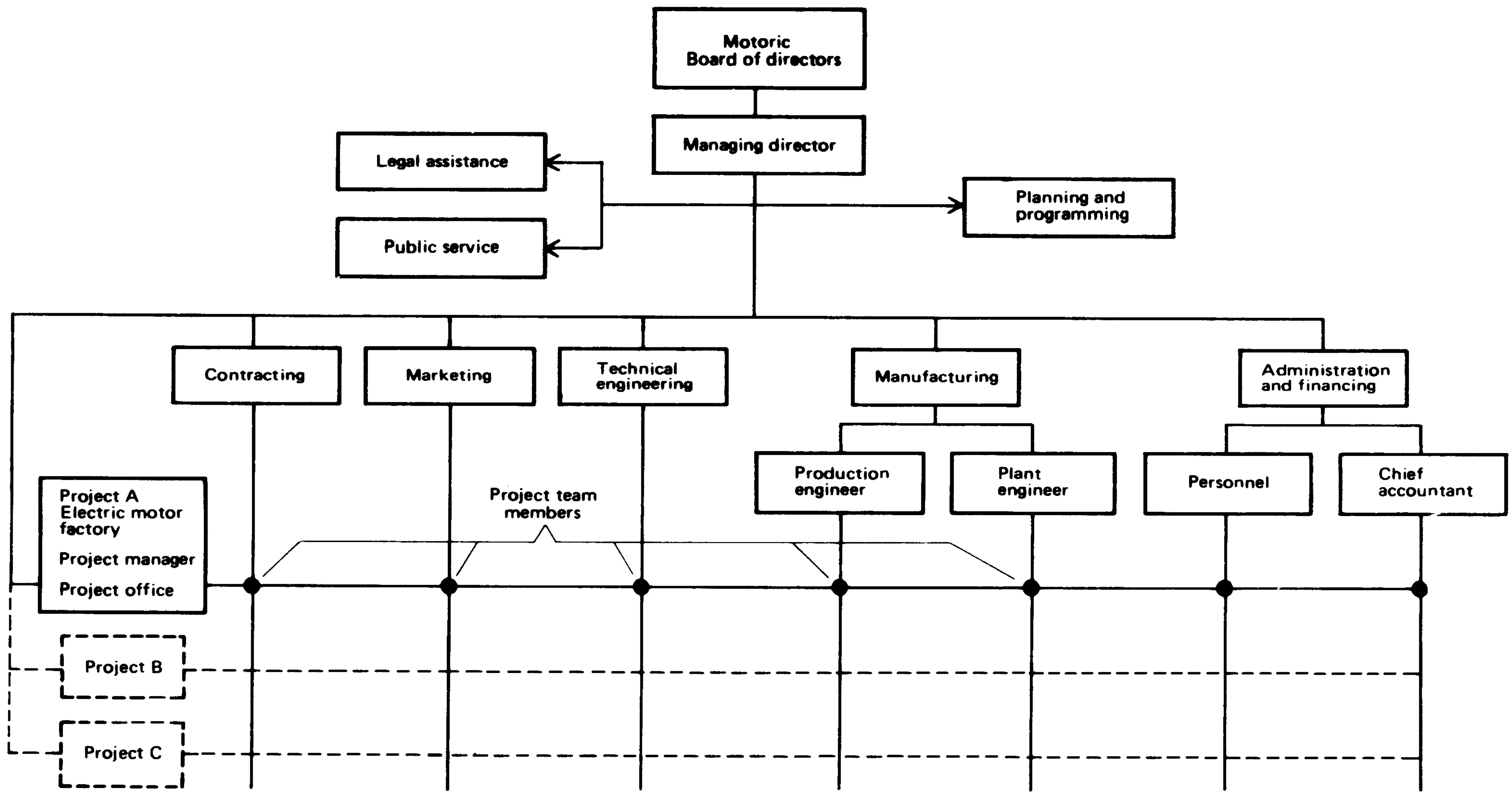
The board of directors of the Motoric Manufacturing Company has decided to proceed with implementation of the electric motor factory project following receipt of all necessary governmental and other approvals. Special action and approval of the Ministry of Labour and possibly of the State Planning Board may be necessary in view of the shortage of qualified labour in the small city where the new plant will be located.

An international monetary conference is scheduled to be held eight months from the day of the board meeting. The rates of exchange are expected to shift drastically after this conference. Therefore, it is extremely important that all contracts be signed and approved, and production equipment ordered, before this conference takes place. If more detailed planning of implementation indicates that this cannot be achieved, the board of directors has resolved that the project will be deferred until after the conference and re-evaluated at that time.

Figure 3 shows the organization of the Motoric Manufacturing Company. On the day of the decision to proceed with implementation, the managing director of Motoric appointed Mr. Laurence Clay as the full-time manager of the new electric motor factory project. In a meeting with the new project manager and all Motoric department directors and managers, the managing director stated:

> "This Electric Motor Factory Project is very important to both the Motoric Manufacturing Company and our national economy. We have received approval of our financing because the electric motors we will produce will be exported, under agreements made by the Government, and this will be an important factor in our national industrial development programme. This will increase the annual sales of Motoric by 50 per cent.
>
> "In carrying out his responsibilities as project manager, Mr. Clay will have my authority with regard to project matters. If there is any conflict with other assignments within the functional departments which Mr. Clay cannot resolve, I will meet with him and the concerned department director to determine what action is necessary.

Figure 3. Structure of Motoric Manufacturing Company



"There will be many outside influences on the project which neither Mr. Clay nor I can control. But we have decided that, because of these uncertainties, we must plan and control the implementation of this project systematically."

Mr. Clay set up his project office within the next few days, and two project specialists were assigned to assist him with the project planning, scheduling and control work.

CATEGORIES OF INFORMATION NEEDED FOR PROJECT IMPLEMENTATION

Seven major types of information are needed for project implementation:

(1) *Project financing information*

(a) Financial plan;

(b) Financial progress reporting and document control.

(2) *Information defining project structure and scope*

(a) Project structure and scope;

(b) Responsible and performing organizations.

(3) *Project action planning and control information*

(a) Master plan and schedule;

(b) Task work statements and action plans;

(c) Task schedules;

(d) Progress reporting.

(4) *Resource planning and budgeting information*

(a) Manpower and cost estimates;

(b) Manpower and cost budgets.

(5) *Contracting, work authorization and resource control information*

(a) Work orders and contracts;

(b) Expenditure records;

(c) Work and resource (funds, manpower) control information.

(6) *Product*[1] *information*

(a) Descriptions, drawings and specifications;

(b) Product control information.

(7) *Environmental information*

It is of interest to note that each of these seven categories of information may be considered to be a module of a project management information system.

[1] The word "product" is used here in a very broad sense. It refers to all products or results to be produced through execution of the project. Such products usually include documents, facilities, buildings, equipment, materials, services, training, software, organizations and consumable items.

(1) *Project financing information*

(a) Financial plan

The financial plan for the project, developed during the project initiation phase, is revised as required to cover all costs throughout project implementation. It identifies and co-ordinates the various sources of funds and indicates how each category of funds is to be used and the means of repayment.

(b) Financial progress reporting and document control

All documents needed to obtain release of funds and to control their movement and disbursement are prepared and maintained. Examples of these documents are not presented here for the case project because of their complexities.

(2) *Information defining project structure and scope*

(a) Project structure and scope

At this point a systematic, understandable and useful definition of the project is needed. This information is prepared in the form of a project breakdown structure (PBS), often called work breakdown structure (WBS), which includes all elements of the project regardless of responsibility. Figure 4 shows the results of this planning step for the electric motor factory project. In this case, there are 5 components at level two, 16 elements at level three and 34 subelements or major tasks at level four. Further definition of the project could be carried out, resulting in the identification of additional elements or tasks (especially at level four).

It should be noted that this is not an organization chart, but rather a logical breakdown of the natural parts of the project to the point where manageable tasks have been defined. It is important to include all aspects of the project, regardless of which organization will have responsibility for the work. In practice, more detailed descriptions of each element are usually prepared.

(b) Responsible and performing organizations

In addition to the departments identified in figure 3 (Structure of Motoric Manufacturing Company), many outside organizations, identified in figure 2, will be involved in the implementation of the project. A systematic way of showing how all these organizations are related to the various elements of the project is very useful. This is accomplished by relating the organizations to the project breakdown structure shown in figure 4. The result, partially illustrated, is presented in figure 5.

Each individual charged with carrying out a task or group of tasks is considered to be a project team member regardless of the organization to which he belongs. The project manager acts as the "team captain" to plan and co-ordinate the work of all team members so that the project will be successful.

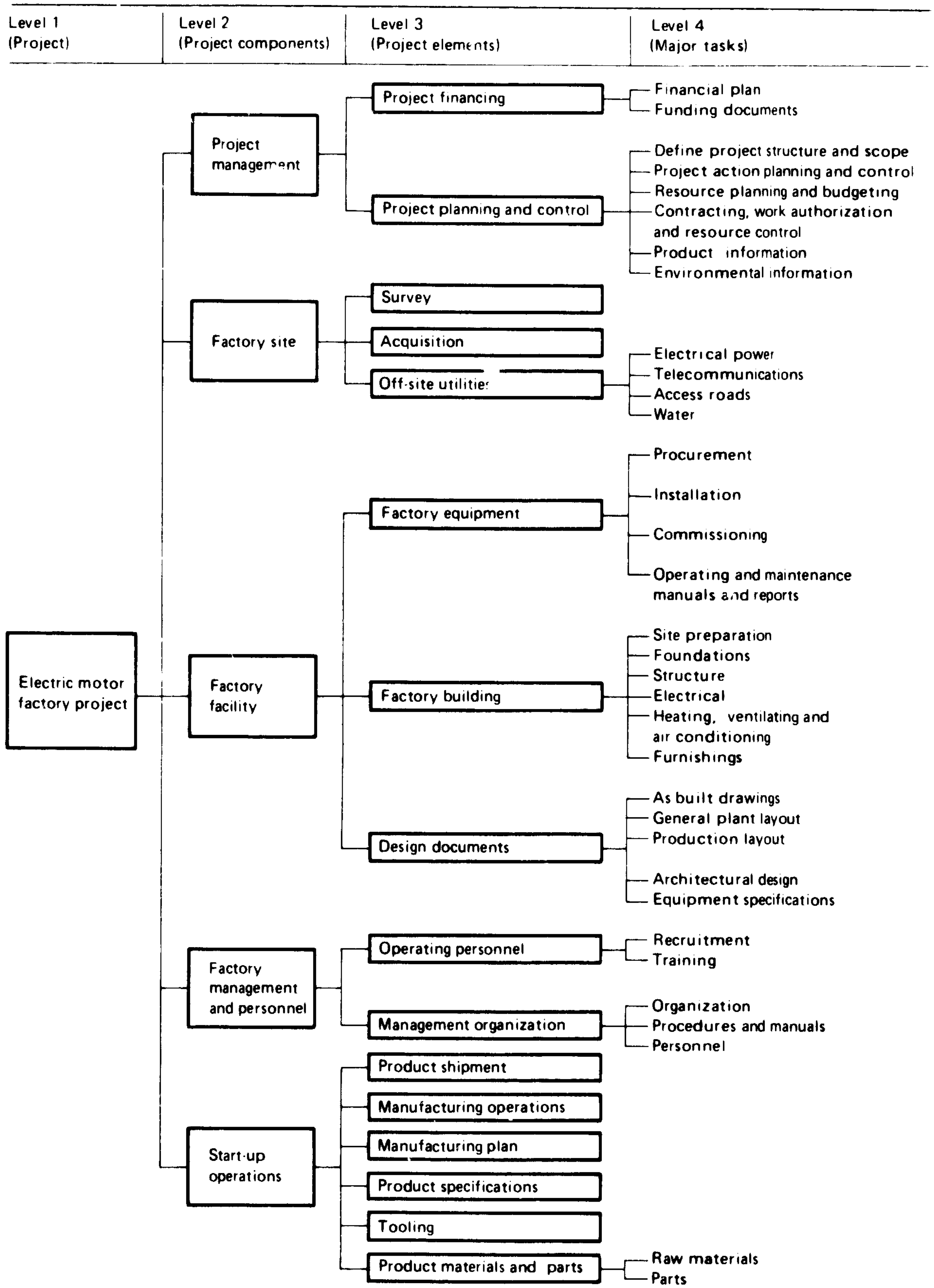
In practice, specific names of every organization and project team member are entered on the project breakdown structure chart. This chart is reviewed during its preparation by all these persons. A mahor benefit of this procedure is that every project team member gains a full understanding of the scope of the project and his specific responsibility in relation to the other team members.

(3) *Project action planning and control information*

(a) Master plan and schedule

On the basis of the project breakdown structure and the information contained in the project feasibility study, the project master plan and schedule is prepared.

Figure 4. Project (or work) breakdown structure (definition of electric motor factory project)



(Not all level-4 tasks are defined in this example.)

Figure 5. Identification of responsible and performing organizations and project team members

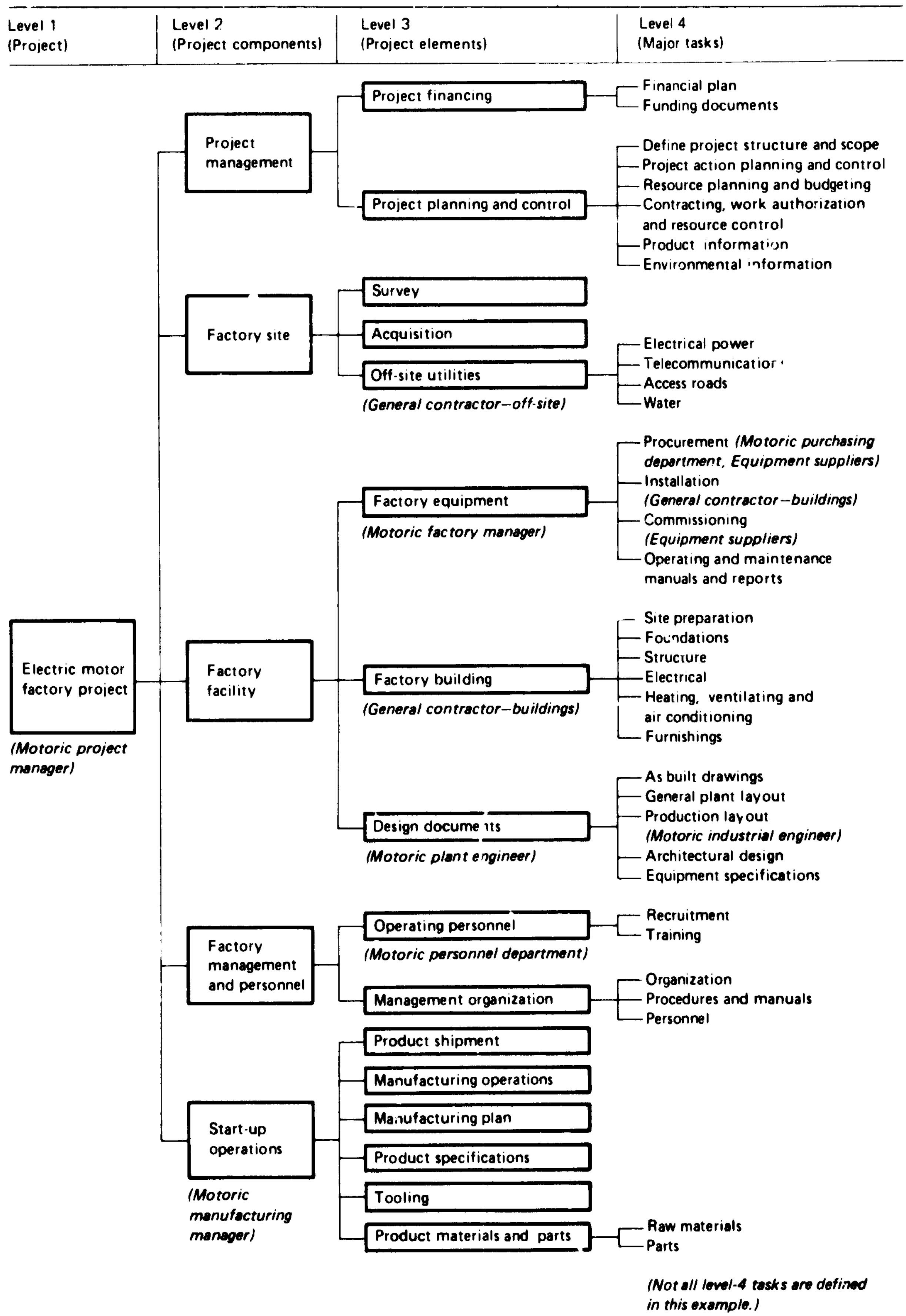


Figure 6 illustrates the result of this step. The project breakdown structure is on the left side of the chart, including level-three elements, and the level-four tasks are shown by the bars, indicating the scheduled duration of each. The project manager must actively direct this planning effort in order to balance out the conflicting time requirements to carry out each major project element.

Events of particular importance to the project are called milestones. Some may be of greater significance than others. Nine executive-level milestones and 24 project-level milestones are identified in figure 6. One of the executive-level milestones, "International monetary conference", is completely outside the project, but it is important to include this event in the project master plan as previously explained. In the more detailed task plans (discussed later), additional task-level milestones will be identified and defined. The special importance and uses of milestones are more fully discussed in chapter V.

The project master plan and schedule must portray all elements and tasks in the project, their key interrelationships and all events concerning important decisions, approvals and authorizations. The initial master plan and schedule is a target that will be confirmed as detailed task plans and schedules are established and major contracts approved by both parties. When detailed planning has been completed and approved, the project master plan and schedule becomes a fixed target that can be changed only by decision of the project manager or higher authority.

(b) Task work statements and actions plans

For each task defined at the lowest level of the project breakdown structure for planning and control purposes, a task work statement is prepared. This is a brief but complete statement of what is to be accomplished by the task and identifying:

Its higher-level "parent" element of the project breakdown structure
Responsible and performing organizations and individuals
Work statement
Prerequisites for starting the work
Specific results to be produced
Target scheduled start and completion milestone event dates, if known

Figure 7 presents a work statement for one task within the case project.

An action plan for each task is prepared, reflecting the information contined in the project master plan and schedule and the task work statement. These action plans may take the form of bar charts or network diagrams, depending on the complexity of the task and the over-all project. If network plans are used, the task may appear as a group of activities in the project network plan. Or, for large or complex tasks, such as the construction of the buildings in the case project, a separate subnetwork may be prepared.

Figure 8 shows the portion of the detailed project network plan related to the task described in figure 7. The over-all project network plan incorporates all milestones shown on the project master plan and schedule, plus additional task-level milestones, and shows the chronological sequences of more detailed activities and events for all tasks, including interrelationships and time constraints between tasks.

(c) Task schedules

Analysis of the over-all project network plan (if needed owing to the complexity of the project) will show predicted start and completion times (dates) for all activities of each task. In most cases, replanning is required to ensure that the predicted times shall agree with the desired schedule. In some cases, rescheduling of the tasks or even the project is required. After analysis and consideration of all

Figure 6. Project master plan and schedule for electric motor manufacturing project

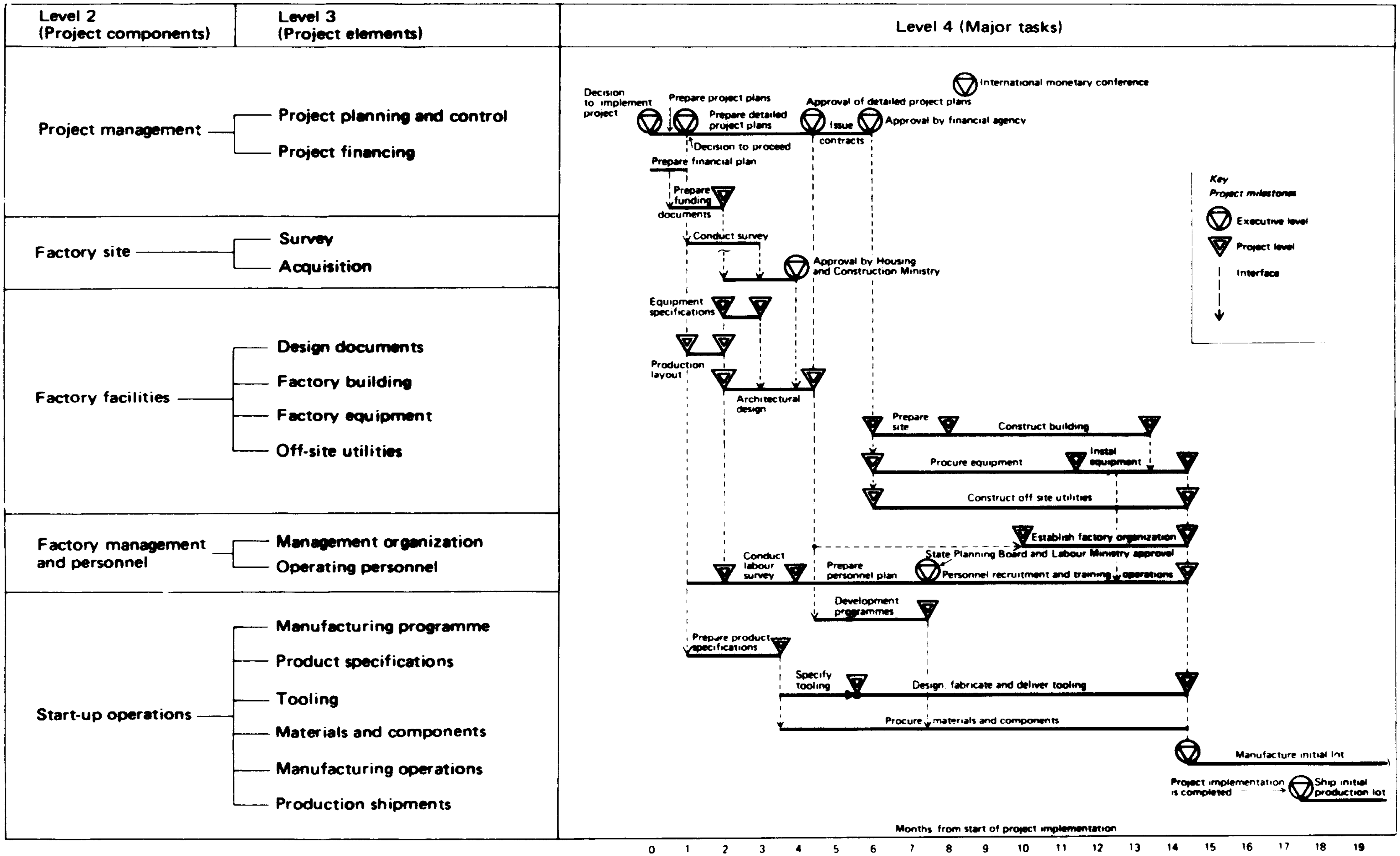


Figure 7. Example of a task work statement

TASK WORK STATEMENT

Project:	Electric motor factory
Parent project elements:	Design documents (level 3) Factory facilities (level 2)
Task:	**Prepare factory production layout plan**
Responsible:	Motoric Plant Engineering Department, Mr. A., Department Manager
Performing:	Motoric Plant Engineering Department, Mr. B., Industrial Engineer

Work statement:

Prepare a detailed, 1-50 scale layout of the production machinery, storage, and all work areas for the factory, to produce the type and quantity of electric motors specified in the project feasibility study.

Information inputs required to start work:

1. Preliminary factory layout
2. Type and quantity of electric motors to be produced
3. Preliminary equipment specifications

(Items 1–3: From project feasibility study)

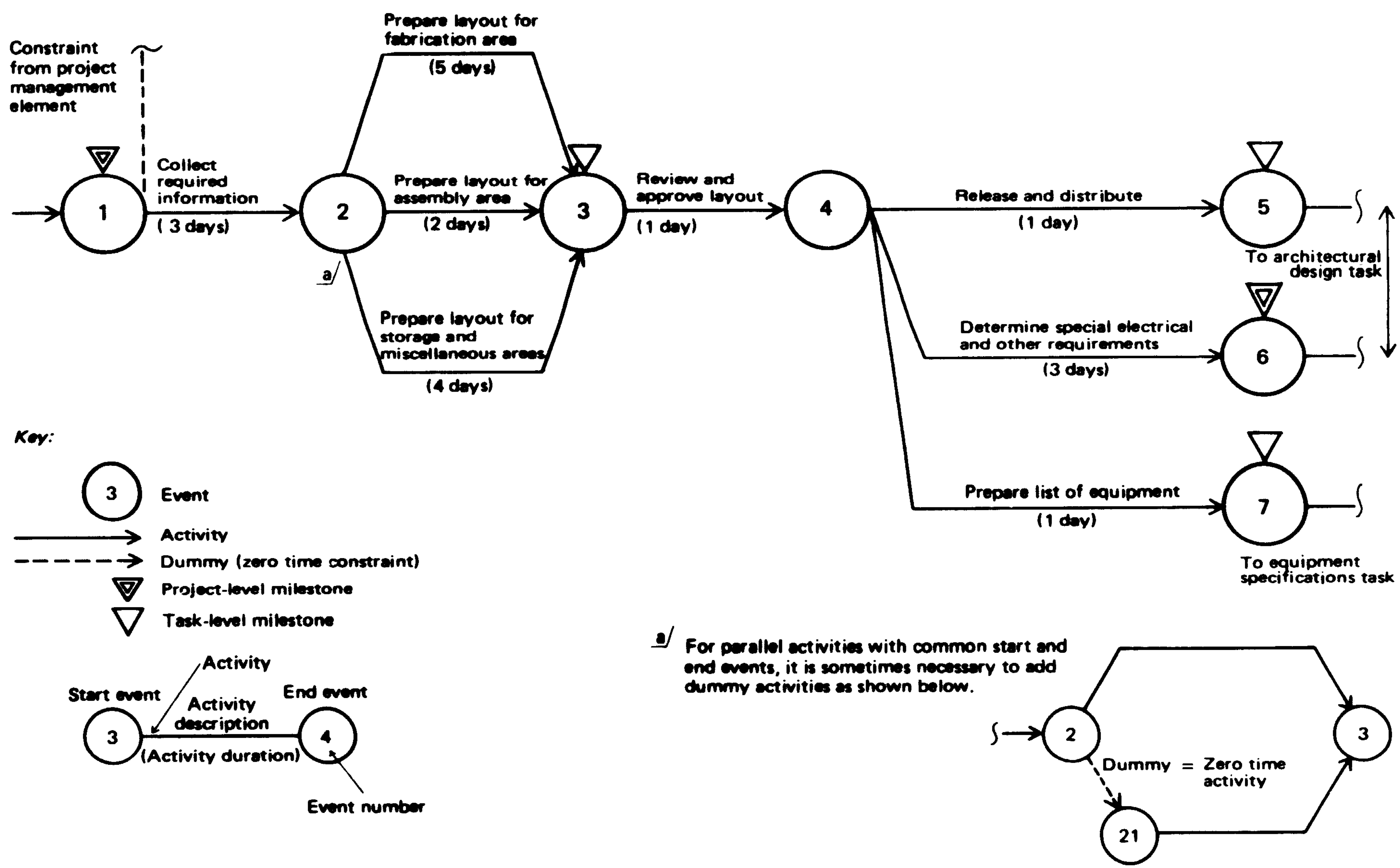
Results to be produced:

1. Detailed production layout, 1-50 scale
2. List of production equipment items required
3. Special requirements for electric power etc.

Scheduled dates:

Start: 2 January 1974
Complete: 16 January 1974

Figure 8. Task action plan (segment of project network plan for factory production layout)



factors, a firm task schedule (top half of figure 9) is established, with dates for every task milestone and the start and finish dates of each activity. This is then communicated to the persons performing the work.

(d) Progress reporting

At regular intervals, usually weekly in the early stages of project implementation and fortnightly or monthly in the later stages, each responsible person reports his actual progress for comparison with the plan and schedule. This is done by reporting:

Work accomplished–activities completed (with date of completion)
Work in progress–time required to complete in-progress activities
Future work–any changes in duration, definition or sequence of future activities, reflecting additional knowledge acquired during the work to date

In the first step, the responsible person decides which, if any, of the activities (as shown on the task plan, for example, "Collect required information" in figure 8) has been completed on or before the status date, which is the effective date of the revision of the plan and collection of all required information.

In the second step, the status is reported of all activities that have been started but have not yet been completed. The most vital information is not the "percentage complete", which is frequently emphasized, but rather the length of time required to complete each activity in progress. In estimating this time to complete, the project team member must be realistic and base his estimate on the rate of progress made to date and with available resources in the current conditions. If he uses a higher rate of progress, he must have some justification for doing so, such as having additional persons assigned to the activity.

The third step in progress reporting is to look ahead in the plan, to the extent feasible, and to decide whether any changes should be made because of new information or improved understanding of the project. If major changes are required that may affect other tasks or the over-all project, they must be integrated and analysed by the project manager prior to approval and rescheduling of tasks to determine their effect.

(4) *Resource planning and budgeting information*

(a) Manpower and cost estimate

Using the task work statement (figure 7) and the task schedule, the responsible project team member plans and estimates the resources (funds, skilled manpower) needed to carry out the task.

(b) Manpower and cost budget

Upon review and approval by the project manager, a firm task budget is set for the task. Figure 9 shows this information for the factory production layout task.

(5) *Contracting, work authorization and resource control information*

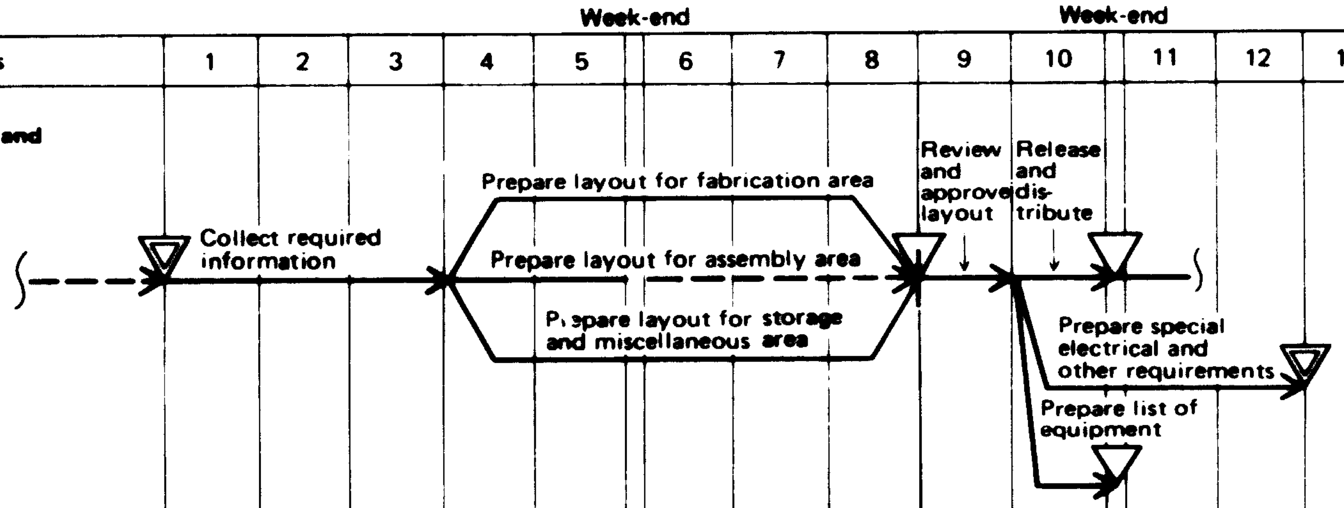
(a) Work orders and contracts

In this step, the information previously developed is contained in work orders and contracts. A work order is an internal company document authorizing the expenditure of funds, labour, materials and other resources required to accomplish a specific task. It usually contains:

Task work statement (information as shown in figure 7)
Task milestone event schedule (from the task schedule)
Summary of the task budget (from figure 9)

Figure 9. Resource plan and budget (task budget)

Task plan and schedule



Work days	1	2	3	4	5	6	7	8	9	10	11	12	13	
Manpower plan														**Total**
Senior industrial engineer	1	1	1	1	1	1	1	1	1	1	1	1		12
Industrial engineer		1	1	1	1	1	1	1	1	1				9
Draftsman				1	1	1	1	1	1	1				7
	1	2	2	3	3	3	3	3	3	3	1	1		28

Manpower and cost budget

Labour:	Professional	21 man-days @ $20 =	$420
	Support (non-professional)	7 man-days @ $10 =	70
		Total	490
Travel etc. (none required)			–
Other direct costs: long-distance telephone calls			100
Other:			100
		Total	200
		Grand total	**690**

Approving, authorizing and accepting signatures:

Project team member (responsible person)
Functional department manager
Project manager

For the electric motor factory project, work orders were issued for the following tasks:

Development of project financing information
Development of project planning and control information
Preparation of general plant layout
Preparation of factory production layout
Preparation of equipment specifications
Preparation of product specifications
Issuance of contracts
Preparation of personnel plan
Recruitment and training of personnel
Establishment of factory organization
Development of manufacturing plan
Specification or design of tooling
Procurement of materials and parts
Manufacture of initial production lot
Shipment of initial production lot

Contracts are required for formally authorizing organizations outside the company to execute major tasks. For the case project, contracts were prepared, reviewed, approved and issued, based on the task work statement and budgets established for:

Survey of site
Acquisition of site (land purchase)
Architectural design
Construction of buildings
Procurement of production equipment
Procurement of tooling
Installation of production equipment
Construction of off-site utilities
Procurement of production materials and parts

(b) Expenditure records

Each week, for internal tasks in progress and for tasks under contract, the actual expenditures of funds and critical resources are reported and recorded. For the factory production layout task, this information may appear as follows:

Work day	1	2	3	4	5	
Budgeted manpower	1	2	2	3	3	(from figure 9)
Actual manpower expended	1	1	1	2	3	(reported by responsible project team member)
Difference		−1	−1	−1		3 man-days below budget

Similar information can be prepared for the related cost of labour and other resources as well.

(c) Control information

Task control

The above comparison of actual expenditure with the budget generates valuable control information. In the example used, the expenditure is three man-days below the budget. This immediately raises the question whether the task is falling behind schedule as a result. The physical progress report, described earlier, will indicate which of the activities in the task plan and schedule have been completed, when they were completed and what the remaining duration is for the activities in progress. Using the network from figure 9, the effect of actual progress on the future plan becomes evident, as shown in figure 10. In this case, the entire task will be delayed by one work day, apparently as a result of the loss of the three man-days budgeted.

Project control

Figure 11 illustrates how each task budget is associated with the task schedule. Cost at completion of each task is forecast by adding the expenditures to date to the revised (updated) estimate to complete.

Summaries of this information can be made for each higher level "parent" element in the project breakdown structure (a level-two component is the summary of its related level-three elements). For example, all tasks within the "design documents" element at level three are summarized for that element. Subsequently, all level-three elements for "factory facility" can be summarized. Finally, all level-two elements are summarized to produce the over-all project total, as represented in figure 11. Reporting of task information to the project manager and higher levels is discussed in chapter V, which describes control methods for use by the project manager.

Figure 11 illustrates that a 3 per cent cost overrun is predicted for the project and a delay of several weeks, based on the status as of the twelfth month of the project. The task of the project manager, in exerting effective control of his project, is to find ways to reduce selected budgets for future tasks and shorten the time required to recover the predicted cost overrun and schedule delay. A technique to assist the project manager in evaluating overrun (or underrun) situations is discussed under "Value-of-work analysis" in chapter V.

(6) *Product information*

(a) Descriptions, drawings and specifications

The case project will produce the following primary end results:

An operating factory, including site, building, equipment, materials, tools and operating manuals

Access roads, water, electrical and telecommunication facilities

A management organization, including personnel and procedures

Trained operating personnel

One lot of finished electric motors (the first production lot)

Information regarding these general products includes:

All drawings, site plans, specifications, contracts etc. related to the physical facilities

Management charts, records, policies and procedures related to the operation and management of the factory

Personnel records

Specifications, drawings, inspection records etc. for the finished electric motors and the materials and components used in their manufacture

Figure 10. Progress related to the plan and schedule

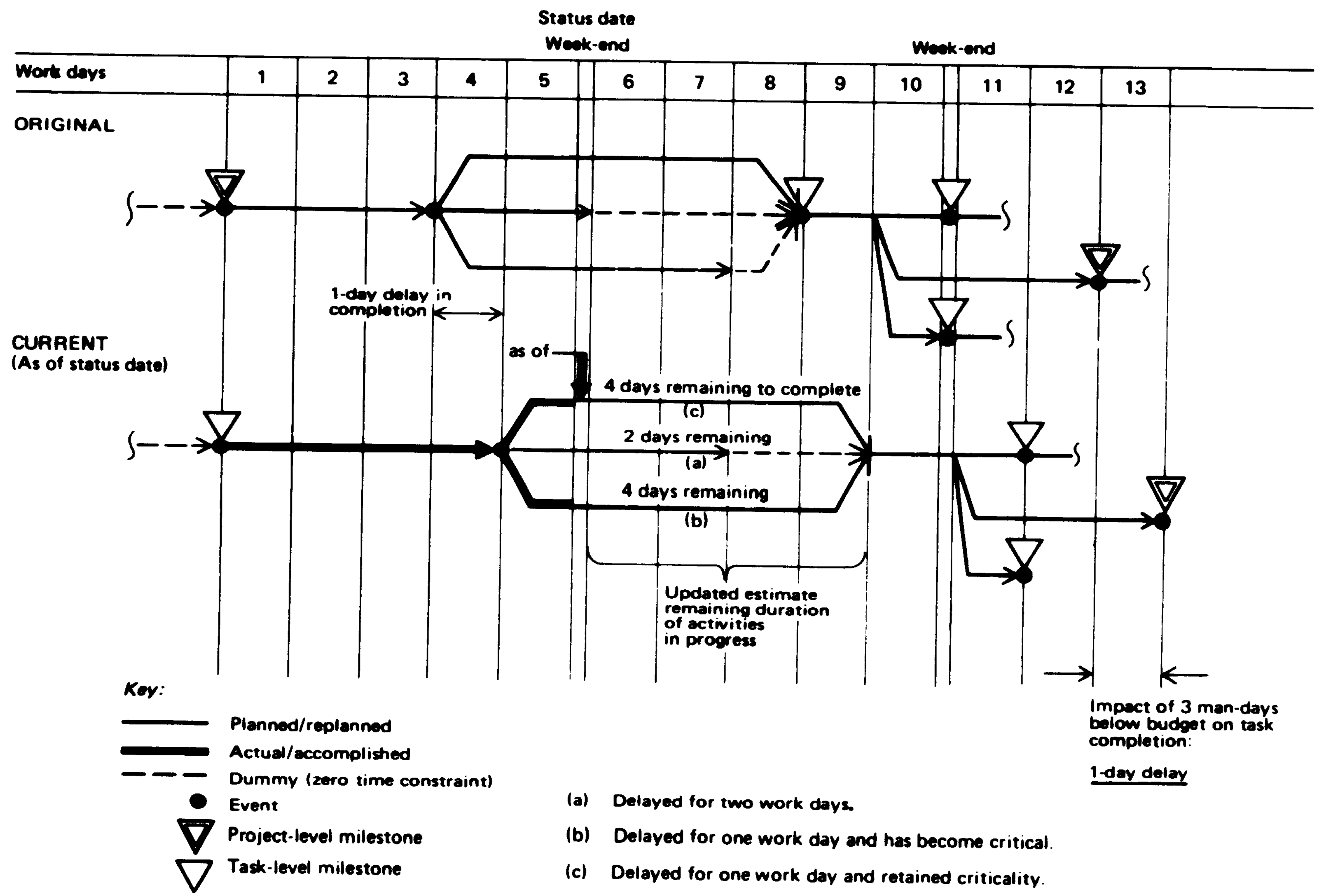
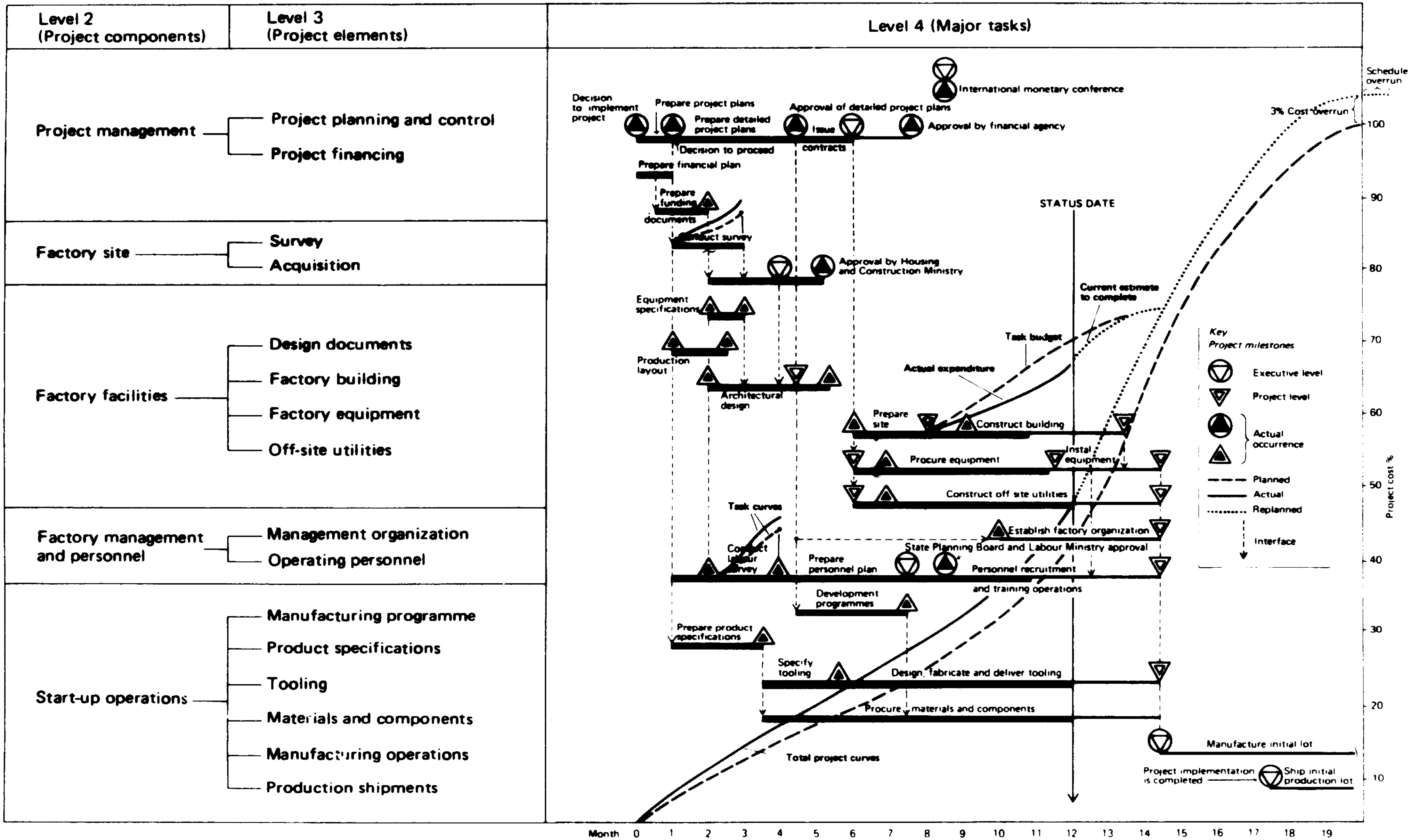


Figure 11. Updated project master plan and schedule of electric motor factory



In addition to these end items the project will yield several intermediate products. These include:

Management plans and schedules
Financial plans
Funding documents
Preliminary factory and equipment specifications and drawings
Temporary facilities
Model and prototype electric motors

Information regarding these intermediate results should be collected and maintained.

(b) Product control information

For each of the items identified above, changes in specifications, contract terms and conditions, budgets plans and schedules must be carefully controlled. Each proposed change must be reviewed and approved before its incorporation. An accurate record of each authorized change is required. This is especially important with regard to changes affecting tasks under contract, since such changes invariably increase contract costs significantly.

For example, in the case project, if the company decides to change the factory production layout after the construction contract is awarded, this would require:

Revision of the architectural plans, at additional cost

Revision of the construction contractor's cost estimate, plans and schedules, at additional cost

Revision of the construction contract

Delay in project completion owing to:

Legitimate effect of the design change

Absorption of the contractor's own delays under the guise of the design change delay, which makes it impossible for the project manager to force the contractor to accelerate his work to recover such delays

Complete records of changes and delays caused by outside forces (strikes, natural disasters, fires) must also be maintained. All this information is vital to prevent disputes or to prepare for legal proceedings if they should arise.

For the factory building itself, in the case project, an important element of information of this type is a set of "as-built" drawings, showing all changes, whether design revision or field changes to overcome design deficiencies, in order to have an accurate record of how the building was actually constructed. Failure to prepare such "as-built" drawings often causes great difficulties in future maintenance or plant expansion.

(7) *Environmental information*

For the case project, environmental information would include all available information from and about the ministries, contractors, suppliers concerned and general information on the labour situation at the factory location, the market for electric motors, current financial markets for funds and similar items.

THE FLOWS OF INFORMATION DURING PROJECT IMPLEMENTATION

The previous section dealt with categories of information needed during project implementation. It is now necessary to consider the information flows to identify the type of information with the appropriate level of management and the specific time during implementation at which the flows occur.

Figure 12 shows the project management information flows during implementation. Information from the field (project work performed) is passed for storage in information files and then analysed. If the volume of information is large, this process may be computerized with advantage. Directives, corrective action or other modifications are fed to the task leaders for implementation in the field. At the task level some external bodies can also be equated with task leaders, e.g. contractors and suppliers. However, for these bodies, information may flow in both directions at the lower levels, the task level and directly at the project management level. In the first two cases, the data may be processed as described above, but this is not necessarily so. Conventionally, the functions of information preparation, collection and retrieval, analysis, the project-level decision-making body (project management team or project manager) and the field data source are collectively known as the project management information system (PMIS). The functions of project work performed, operational control decisions (task leaders) and the project management decisions form the project management control system (PMCS).

Identification with management levels

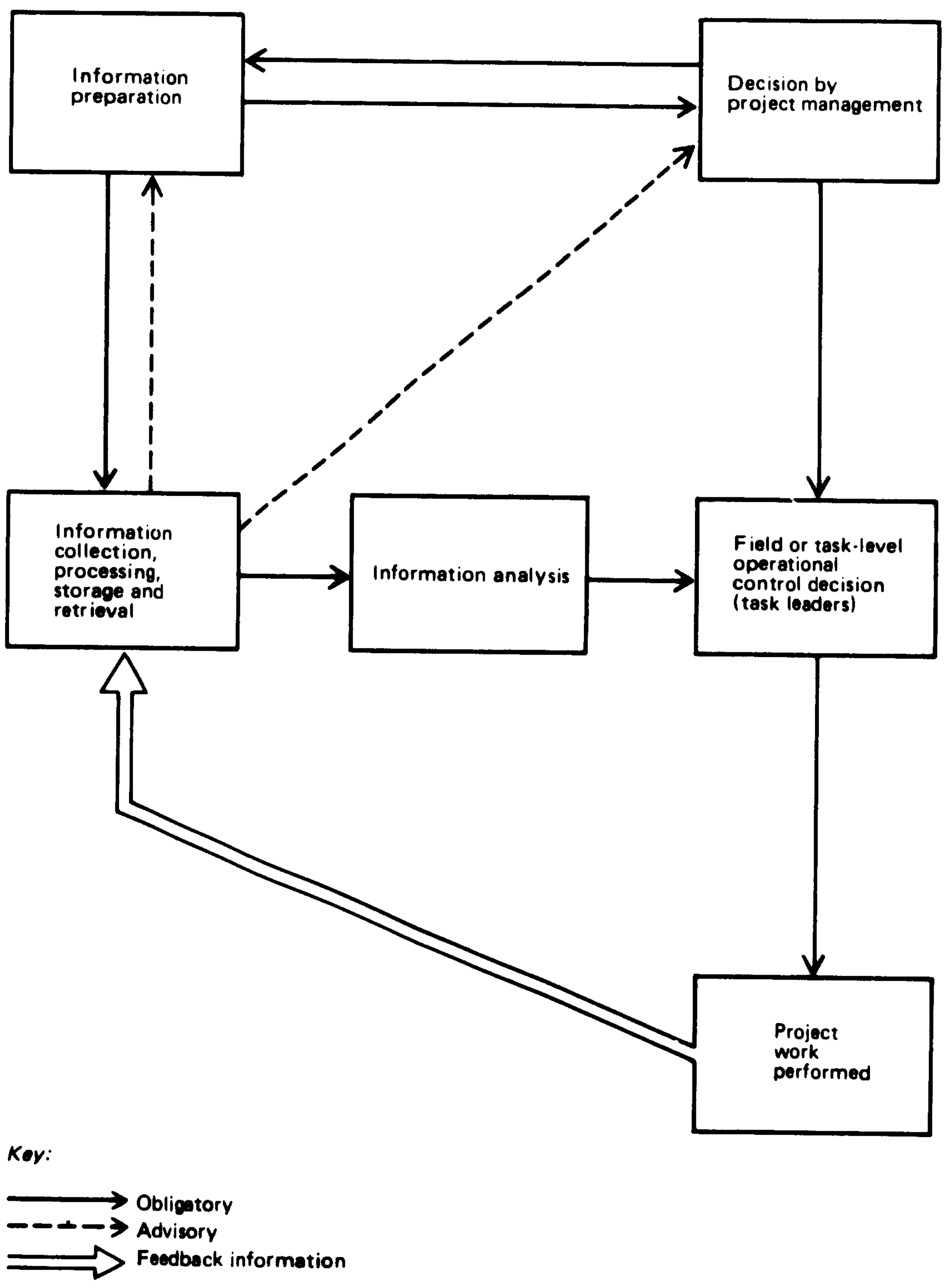
The recipient of information at any hierarchical level should be provided only with the information he needs. The degree of detail of information transmitted should therefore depend on the level of the recipient of information in the organizational hierarchy. For example, figure 6 shows the milestone events of the project master plan and schedule. Information at the project-level milestones will be acted on by the project manager, and only if serious overrun of cost, time or resources is involved will decisions be taken at the executive level.

Specific times when information flows occur

Superimposed on the milestone control concept is the routine project updating procedure at certain intervals, which need not be fixed. Indeed, it is probable that at critical stages during project implementation frequent updating (e.g. weekly) will be called for, whereas at other stages less frequent (e.g. monthly) updating will be adequate. At routine or regular updating times, the project manager will receive reports from the field via the information filing and analysis functions of the PMIS. Exceptional reports to the executive level will be made only if an overrun is serious and problems are imminent or likely to occur. Contractors and other related organizations are to be contacted at routine updating times.

The above information flows are predictable and predefined at the planning stage either as milestones or as part of the updating schedule. However, superimposed

Figure 12. Information flows for the management of project implementation



on this scheme is the random input of information from interrelated organizations. At the executive level, this could result in considerable revision of project plans. In the case study, one such event is given as an international monetary conference. Figure 5 lists the important external organizations in the case of the electric motor factory project. Some of these organizations will be in direct contact with the project manager or a member of his team, and implications of minor deviations from the project master plan will be dealt with at his level. The Motoric Manufacturing Company's board of directors will be referred to when a major change of plan is involved.

Other inputs for higher-level consideration will be conducted by a specifically assigned director from the Motoric Manufacturing Company; and, possibly after a full board meeting, the instructions for a major revision in the project plan (in an extreme case possibly the abandonment of the entire project) will be passed to the project manager for execution.

To relate information requirements to management levels, a brief description of the latter together with their main functions seems appropriate.

Management at the executive level deals mainly with policy making and strategic planning, which involves setting objectives and determining resources to be allocated to the project. The decisions on such questions are taken at random, and the inputs required are usually internal reports on achievements, staff studies and external factors. The information systems here are of the inquiry nature and simulation is frequently used.

Management at the project level is management control and involves allocating project resources to tasks, measuring performance and executing control. The necessary decisions are made periodically, i.e. quarterly, monthly, fortnightly or weekly, and the inputs are usually summaries of operating data with internal perspective. The output of the information system is either decisions or a set of procedures.

Management at the task level is field or operating control and involves using the resources to carry out tasks in conformity with rules. It is concerned with internal events and transactions. The information system suitable here is fixed procedures, concrete and formal. The output of this information system is action.

Various levels of management and numerous interrelationships among firms and agencies necessitate various network plans:

(a) Detailed network plans at the operating level when all details are required within the project or a fragment of a project (project analyst);

(b) Integrated network plan, which combines into one comprehensive network all events in the entire project (middle management and project manager).;

(c) Condensed or summary network plan (necessary because detailed networks contain too much operating data), which eliminates much of the detail yet retains the milestones of essential importance to top management.

Table 3 illustrates these relationships.

TABLE 3. RELATIONSHIP BETWEEN INFORMATION REQUIREMENTS AND MANAGEMENT LEVELS

Level	*Main responsibility*	*Functions related to planning, scheduling and executing*	*Project management information*					
			Characteristics	*Frequency*	*Input*	*Processing*	*Output*	*Control*
Executive	Strategic planning	Set objectives Establish policies Develop master schedule	External Unpredictable *Ad hoc*	Irregular	Staff studies External information	One-time reports Inquiries	Policies Constraints	Condensed network plan or mainly bar chart summary Limited number of milestones
Project	Management control	Develop detailed schedules Allocate resources to tasks Make rules and instructions Measure performance Detect unfavourable trends and implement corrective action	Line-oriented Requiring a judgement Primarily internal Regular	Periodic Quarterly, monthly, fortnightly, weekly, daily	Summaries Exceptions	Regular reports Data banks	Decisions Procedures	Integrated network plan Medium number of milestones
Task performance	Field or operational control	Execute tasks according to schedules Use resources to accomplish tasks within set rules and instructions	Predictable Prescribed Stable Internal	Regular	Transactions Internal information	Reports Fixed procedures	Action	Detailed network plan Large number of milestones

V. METHODS OF CONTROLLING PROJECT IMPLEMENTATION

Methods that can be used to control project implementation include periodic reporting. Sets of formal reports summarizing and integrating task-level information are prepared and presented to project and higher-level management. The objective of this periodic reporting is *(a)* to provide the project manager with summary-level information to assist him in his primary responsibility of seeing that the project is accomplished on time and within cost constraints; and *(b)* to provide condensed project status information to the executive levels above the project manager.

Through use of the methods described here, the project manager can exercise control over the project work being performed at lower levels as shown in figure 2. The methods described here are not intended, however, to provide the project manager with detailed control techniques to be used in day-to-day management of the contractor's activity or to assist the task leader in operational control decisions. For example, allocation of manpower to specific tasks and jobs on a daily basis is seen as the responsibility of the contractor. (Techniques are available to assist the lower-level task leader in fulfilling this kind of responsibility but are not presented in this report.) The methods described here are based on summarizing the detailed information from the task level to give the project manager *(a)* an assessment of the status of the project and its significant elements (as opposed to each detailed activity); and *(b)* an indication of potential problem areas (again in relation to significant elements, for example, project milestones, as opposed to detailed activities).

To illustrate, in the case of the Motoric Manufacturing Company, the project manager will receive in his periodic reports information on the status of project milestones, "building construction completed" being one example. He will be informed of progress made on building construction, how many weeks construction is ahead or behind schedule, and when it is expected to be completed. He will also receive a brief discussion of significant problems. This summary information is taken from more detailed information from the task level which the project manager does not need, but which the contractor at the task level needs and uses in day-to-day management. The task leader has several intermediate, task-level milestones to measure progress on construction, such as:

Foundation completed
Structure erected
External walls erected
Roof completed
Plumbing installed
Heating and electrical systems installed
Internal walls built
Doors and windows installed

Floors installed
Electrical outlets and fixtures installed
Finishing work completed

These task-level milestones will be useful to the task leader, but information on the status of building construction will be reported as related to the project-level milestone, "building construction completed". If problems are reported, the project manager can discuss building construction with the contractor and secure more detailed information on the task-level milestones if desired.

Operation of the control methods will be described here in terms of three management levels: executive, project and task. The control methods can be adjusted to accommodate more than three levels.

The structure and content of the reports presented here are suggested as possibilities. These can and should be modified to suit the implementation of a particular project. The report for the project manager prepared on a periodic basis might contain the items described below.

SCHEDULE ANALYSIS

Milestone events provide the core for schedule reporting. As already mentioned, the number of milestones varies with the management level. For example, two project-level milestones were identified for the task "production layout" shown in figure 6. In addition, task-level milestones will be identified, such as "fabrication area layout completed", "assembly area layout completed" and "storage and miscellaneous areas layout completed". When task-level milestones have been identified for each of the tasks in the project, the number of task-level milestones for the electric motor factory project could be about 200. The total number of project-level milestones, or major activities, would be about 24, as shown in figure 6. Of these 24, 9 would be of interest for reporting to executive levels.

To facilitate the reporting mechanism, a code is established for identifying the various reporting levels of milestones as follows:

Symbol	*Associated management level*	*Number of milestones in case project*
	Executive	9
	Project	24
	Task	200

The approval authority is specified and related to the various levels of milestones. To illustrate, accomplishment of the task, "production layout" is the responsibility of the respective task leader. He has, therefore, the authority to change the schedule for any of the task-level milestones within his sphere of responsibility. However, a change in the schedule for either of the two project-level milestones associated with his task requires the approval of the project manager. (Note that the significance of such a procedure is enhanced with larger tasks than shown in the example. None the less, the formal recording of schedule decisions provided for here is useful for all projects, regardless of size.)

Figure 13 suggests a standard set of symbols to be used in the reporting system. The reports provided to the project manager to assist him in schedule analysis are described below.

Milestone status chart

The milestone status chart (figure 14) lists all the project-level and executive-level milestones and their status. Status is indicated according to the symbols specified in figure 13. Status information for this report comes from the detailed schedule system (planning network, for example).

The purpose of this chart is to provide the project manager with a concise view of the status of the project as represented by its more significant milestones. The chart shows that the milestone "building constructed" was late by more than two months, as indicated by the dashed lines. Approximately one-and-a-half months of work have been accomplished on the task, as represented by the darkened portion. The task remains two months behind schedule, as indicated by the open bar between the darkened portion and the "status date" line. The project schedule has not changed but remains at 13.5 months, as represented by the open triangle. The task leader is recommending a change of the schedule to 15.5 months, as shown by the triangle with an "x" inside. The "E" gives the best estimate of milestone accomplishment as indicated from the task-level detailed scheduling system (planning network, for example).

Schedule trend chart

The purpose of the schedule trend chart (figure 15) is to give a quick view of the history and outlook for a few selected milestones of particular interest at the time of the report to the project manager. On the chart, the milestones being considered are shown at the top. The person most closely associated with accomplishing the particular milestone is listed. The vertical scale is the project month, the number of months from project initiation. The horizontal scale represents the year in which the milestone is scheduled for accomplishment (shown in months). The dark dashed trend line represents the scheduled accomplishment date of the milestone. As shown, the milestone "personnel recruited and trained" was rescheduled at "month 3" of the year. The solid trend line represents the best estimate of accomplishment calculated from a detailed schedule system (network planning, for example). As shown, the best estimate of accomplishment as determined from detailed schedules has continually moved farther away from the original schedule.

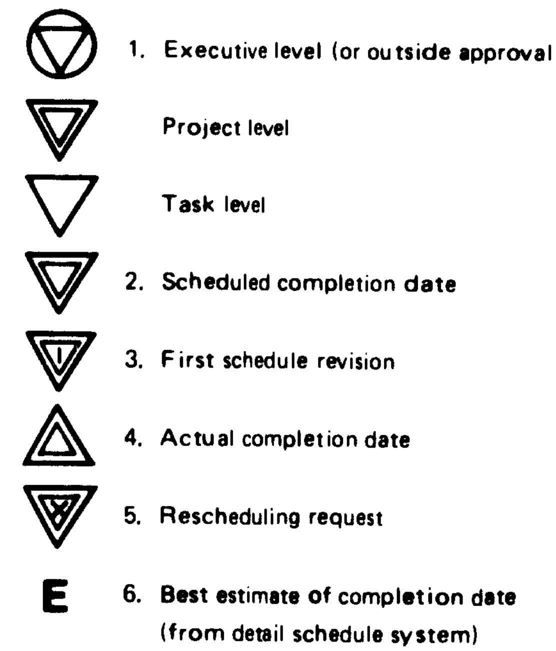
Narrative report

The narrative report (figure 16) gives a brief summary of project status, potential problems etc., with a short analysis of tasks controlling completion of the project. It includes a summary outlook describing in a few words significant progress, status or problems (related to milestones). For example, the building construction is behind schedule. This is mentioned as well as the apparent impossibility of speeding up the work to complete the building on time. A four-week slippage of the schedule is therefore recommended. The critical area is also discussed. For example, although the building is behind schedule, the recruitment of personnel is more critical, since

Figure 13. Schedule symbols

Milestones

All symbols in the following figures apply to all three levels but will be shown for the project level only.



Note:
Open symbol indicates scheduled completion.
Solid, inverted symbol indicates actual completion.

Activity bars

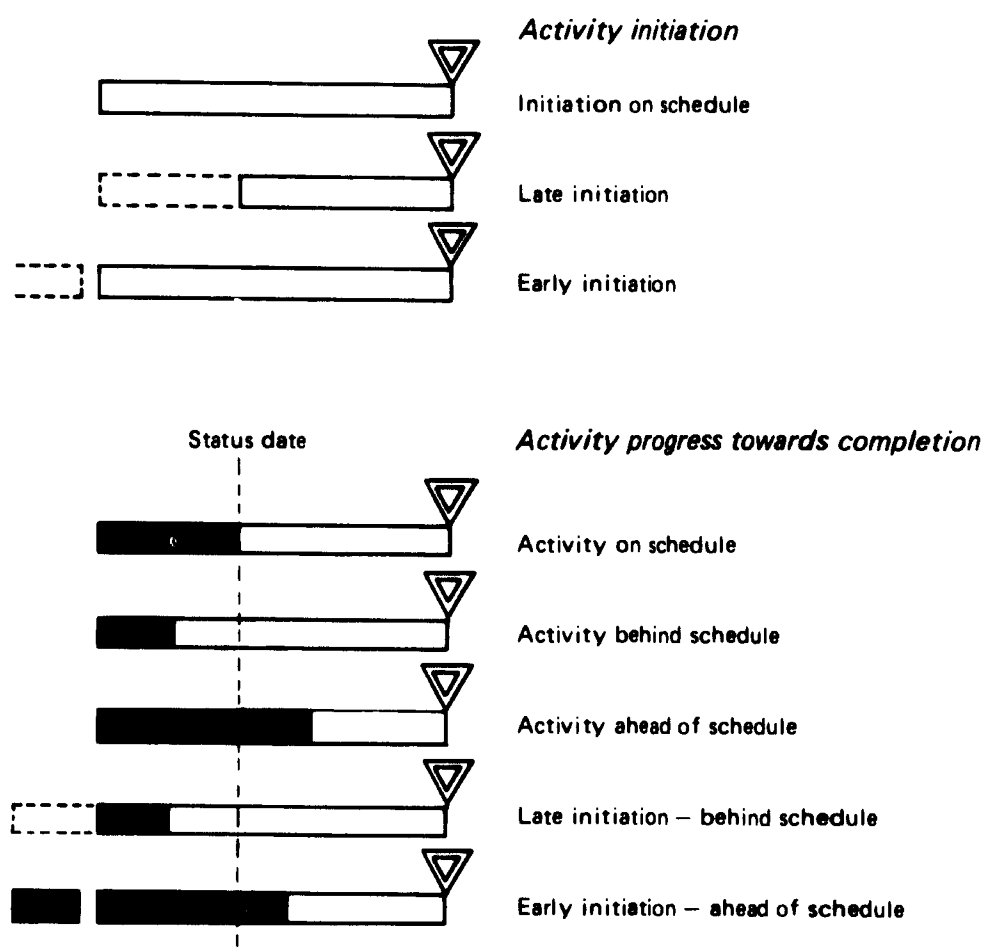


Figure 14. Milestone status chart

(Continue to include all project and executive milestones.)

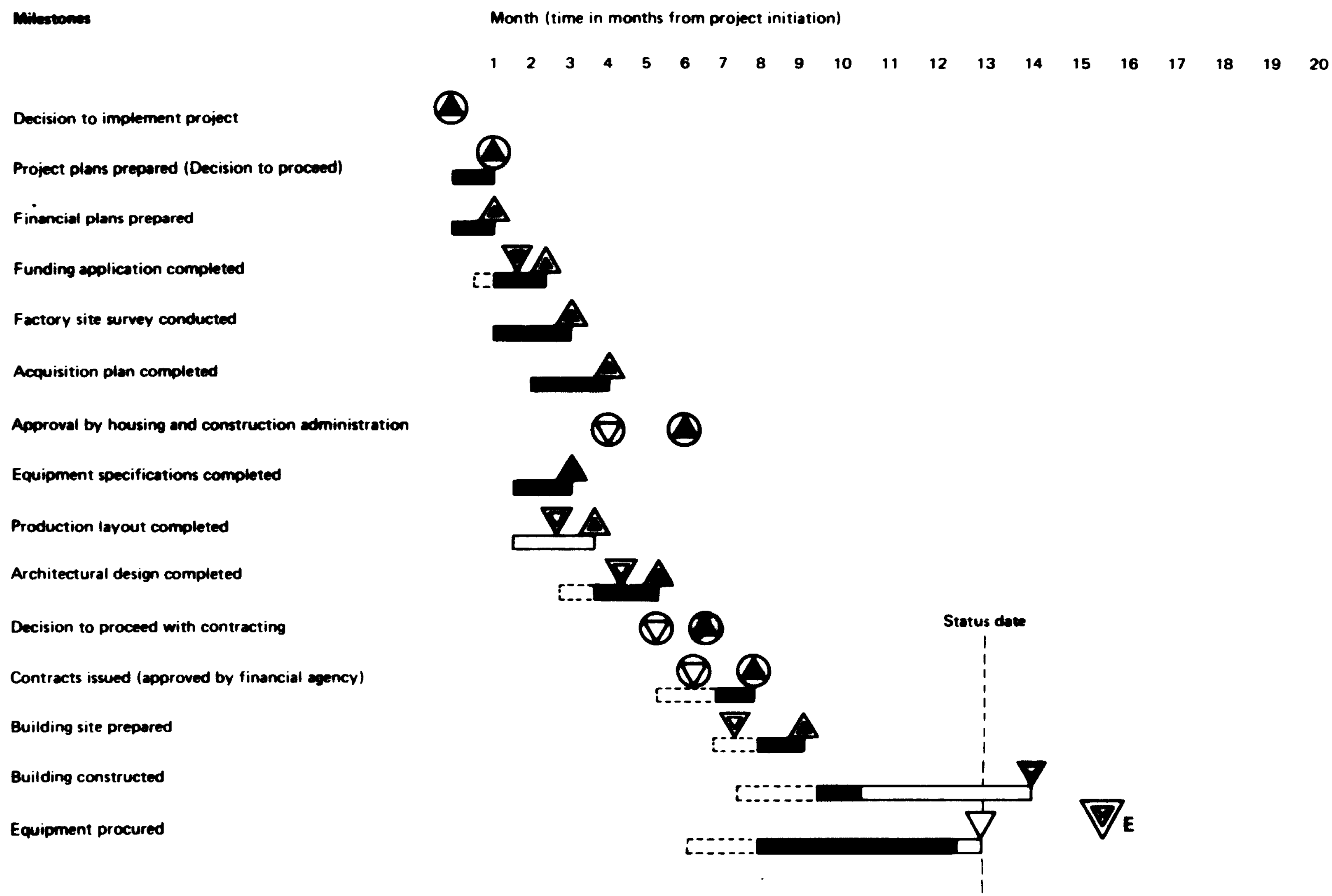
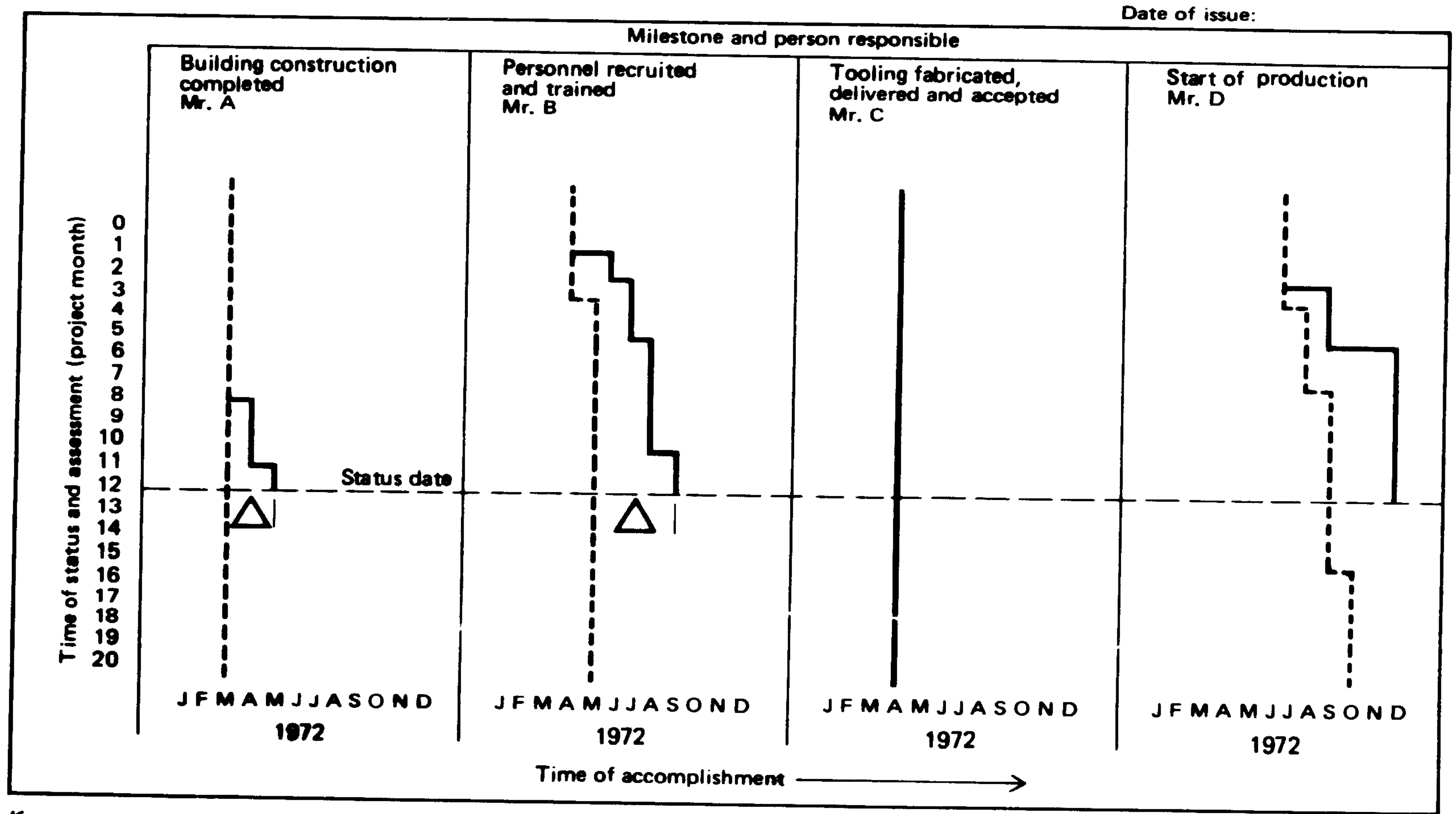


Figure 15. Milestone schedule trend chart



Key:

- - - - Scheduled accomplishment as per latest schedule or contract

——— Expected accomplishment as per latest schedule network analysis

△ Expected deviation from established schedule

Figure 16. Narrative report

Responsible: J. Foster

Status as of: 24 June 1973
(Date)

Summary outlook

Tooling design is in progress and continues on schedule with no problems foreseen in meeting schedule.

Foundation structure for the building has been completed within two weeks as scheduled. However, delays in preceding events caused late initiation of building construction. No possibilities have been identified for reducing the total construction time. Therefore, a four-week slippage of the building completion date is recommended.

Many problems have been encountered in recruiting personnel for production work. This has, in turn, delayed the original schedule for training. The expected date for completion of personnel recruitment and training is now 2.5 months later than present schedule.

Critical area

Recruitment of personnel is the limiting factor at present. This will affect directly the date at which factory production can be started (day-to-day slippage).

Recommendations

Over-all project schedule should be slipped four weeks, since there is no apparent way to speed up building construction. Increased pressure should be placed on Personnel Department to take necessary steps to recruit required personnel. Personnel recruitment and training schedule should be adjusted to be complete by the time building construction is complete.

this task directly affects the date at which factory production should begin. Recommendations are described and solutions to problems are suggested. The above three reports must be considered together to make an over-all analysis of the project schedule.

COST ANALYSIS

The reports provided to the project manager to assist in cost analysis are described below.

Master financial plan

The master financial plan (figure 17) is a graphic presentation of project costs to date, costs planned for the remainder of the project, funding received to date and funding requirements through the remainder of the project (all identified on chart).

The purpose of this chart is to provide an overview of the history and outlook for the project's costs and funding plan, which corresponds to the over-all budget plan for the project as shown in figure 11. However, if the project manager wishes, the same plan can be developed for the individual tasks as indicated also in figure 11.

Cost-trend analysis

Cost-trend analysis (figure 18) is a simple history and outlook of the projected total cost of completing the project. The vertical scale is the projected cost of the total project in millions of dollars. The horizontal scale is the number of months from project initiation. The solid trend line represents the projected cost of the total project as calculated from more detailed analysis including the "value-of-work analysis" to be discussed next. The purpose of this chart is to show graphically in one display the trend of projected cost of the project for comparison with the approved budget.

MANPOWER ANALYSIS

The purpose of manpower analysis is to assist in analysing manpower utilization. Figure 19 shows a graphic representation of the direct manpower used on the project and a monthly projection of planned requirements. The solid vertical bars represent actual, direct man-hours charged to the project each month. The dashed curve represents the planned manpower level during the project. This report makes it possible to compare actual manpower with the manpower plan. The project manager can discuss any significant deviations with task members.

VALUE-OF-WORK ANALYSIS

An analysis of the value of work assists the project manager in correlating schedule and cost information and then in evaluating project performance. A value-of-work index must therefore be calculated. The general concept of work

Figure 17. Master financial plan

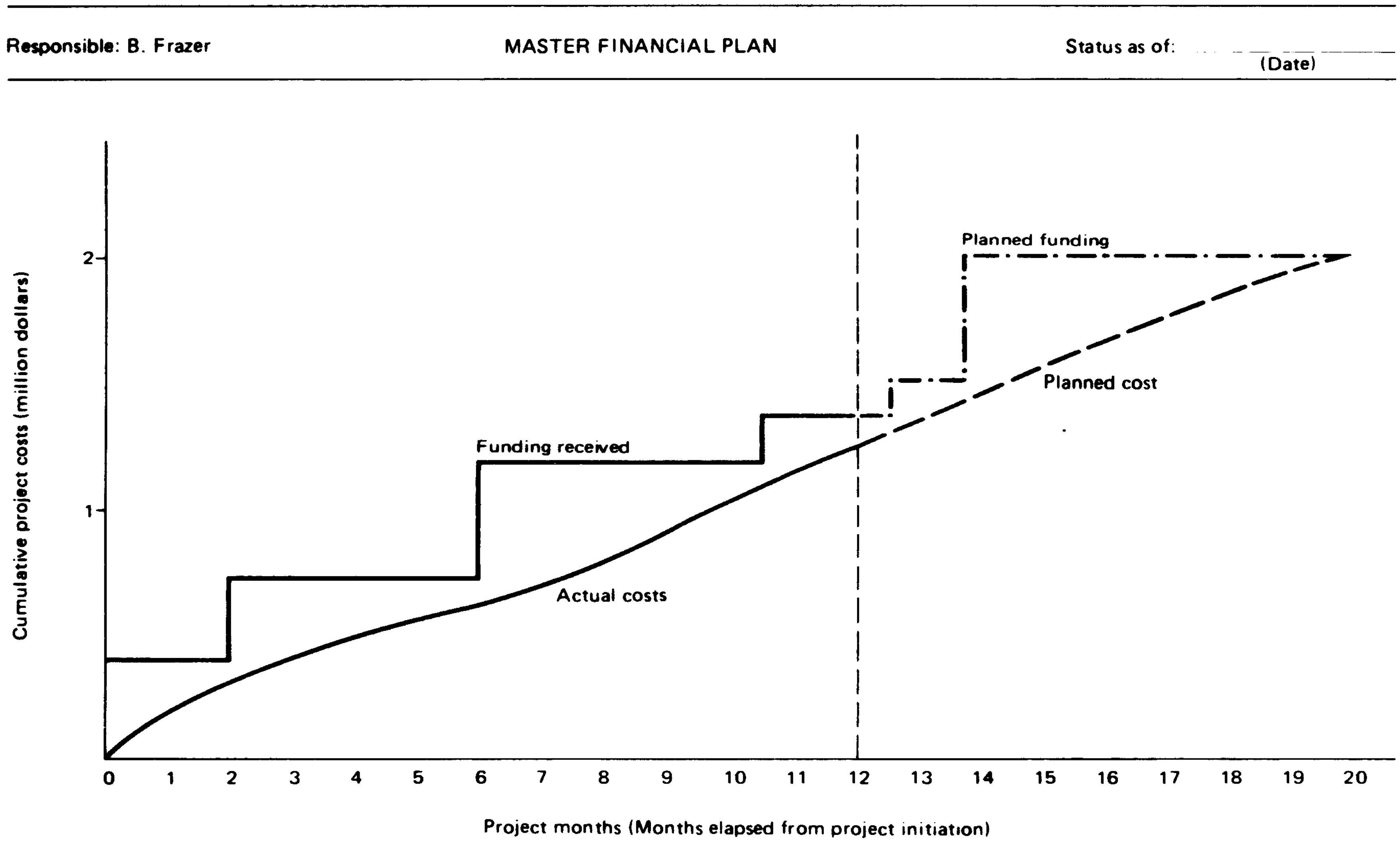


Figure 18. Project cost-trend analysis

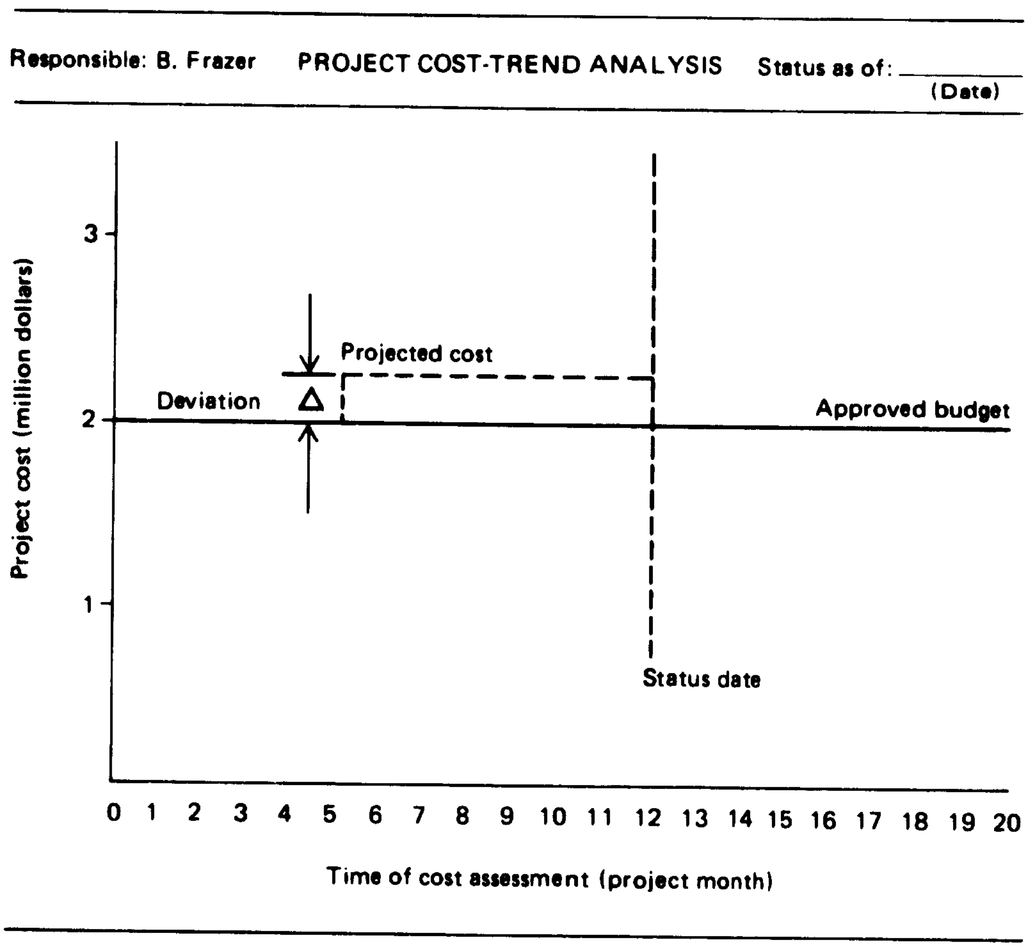
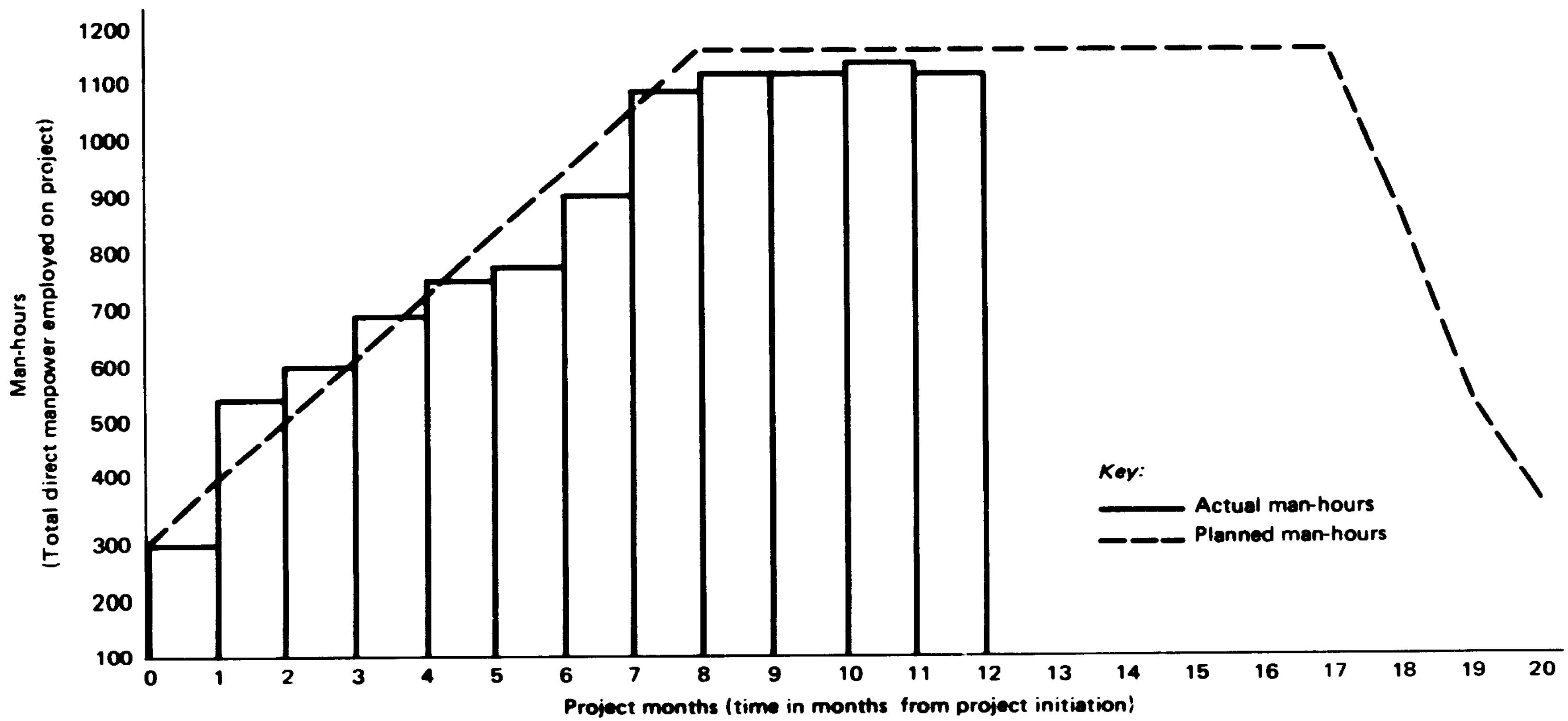


Figure 19. Manpower report

Responsible: T. Hines	MANPOWER REPORT	Status as of: ______ (Date)



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Planned	300	400	500	600	700	850	950	1050	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	850	550	330
Actual	300	550	600	685	750	770	900	1100	1130	1130	1140	1130									

analysis is based on breaking down the total resources planned for a given project or task and distributing them among the detailed activities or groups of activities that make up the work plan. This initial allocation takes place prior to project execution, and the resource planned for each activity becomes its "value".

As the project progresses and the performing unit completes activities it is credited with the predetermined "value" regardless of activity cost. By comparing the actual cost incurred with the accumulated "value" for all finished activities and an appropriate percentage for activities in process, one has a relative measure of the efficiency with which a performing unit is accomplishing its plan.

Should a change in project scope occur after the start of implementation (i.e. contract modification), the difference between the new estimated cost at completion and the current accrued cost must be reallocated to the uncompleted activities. (This type of analysis is not intended as a standard requirement for reporting. Optional use where benefits can be expected is recommended. Further development and evolution of this technique is encouraged.)

A simplified situation can be used to show how value of work can be measured using a milestone system and a correlation of schedule and cost data.

Two hundred milestones have been plotted in terms of planned cost and schedule in figure 20. As work progresses actual cost and schedule curves can be plotted. At the end of 12 months, the schedule has slipped 10 milestones as compared with the plan. By identifying the point on the number-of-milestones-scheduled curve (point *a* in figure 20) that compares with actual accomplishment, it can be seen that the schedule has been slipped the equivalent of about one-and-a-half months.

Since the cost plan has a direct relationship to the schedule plan (i.e. the budgets for the activities/milestones were summed up to determine the cost plan), it is possible to determine the planned value of work accomplished (PVWA) by finding the point on the cost plan that relates to the work completed (point *b* in figure 20). By projecting point *b* (PVWA) to the time-now line (point *c*) for the purpose of comparing it with the other data elements (planned value of work scheduled and actual cost), the present cost variance can be estimated (i.e. the difference between PVWA and AC). The schedule variance can also be determined (i.e. the difference between PVWS and PVWA).

Using the performance analysis discussed, it is possible to develop additional trend analyses as illustrated in figure 21. This chart becomes a part of the report to the project manager to assist in evaluating project performance. The PVWA of $1,250,000 is divided by the actual cost of $1,380,000 to obtain a performance index of 90.6 per cent; the estimated cost at completion for this project is thus $2,208,000.

Use of these indices must be qualified to the extent that they merely indicate trends, assuming that all basic factors continue without change. For this analysis to be effective, cost data must be available within a few days following the close of the accounting period. This enables the cost information to be related to current schedule information on a timely basis to ensure meaningful analysis. The value-of-work indicator must be used in conjunction with schedule analysis and cost analysis to obtain a complete view of project status.

Figure 20. Value-of-work chart

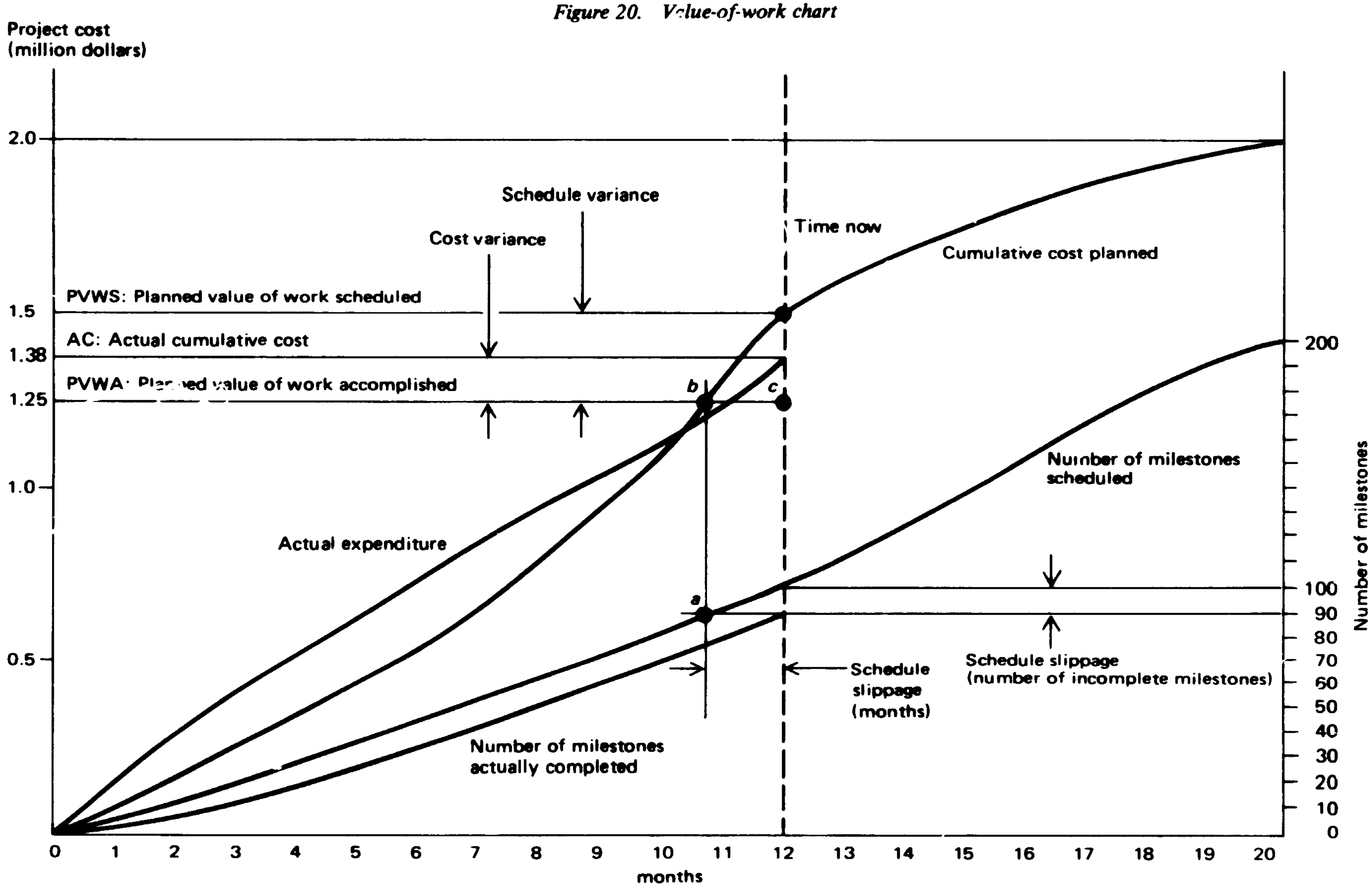


Figure 21. Value-of-work analysis

$$\text{Performance index} = \frac{\text{Planned value of work accomplished}}{\text{Actual cumulative cost}}$$

$$= \frac{\text{PVWA}}{\text{AC}}$$

$$= \frac{\$1,250,000}{\$1,380,000} = 90.6 \text{ per cent}$$

$$\text{Estimate at completion} = \frac{\text{Project value}}{\text{Performance index}}$$

$$= \frac{\$2,000,000}{90.6 \text{ per cent}}$$

$$= \$2,208,000$$

$$\text{Estimated contract overrun (underrun)} = \$2,208,000 - \$2,000,000$$

$$= \$208,000 \text{ overrun}$$

VI. A PLAN FOR ACHIEVING IMPROVEMENTS IN PROJECT IMPLEMENTATION

In the preceding chapters, the concepts of systematic preparation, processing and use of information for the initiation and implementation of projects have been described and illustrated. In this final chapter, a plan is presented that outlines the steps to be taken to obtain the benefits of adapting these principles within a developing country. This plan must be rather general because of the widely varying conditions that exist in developing countries. However, the basic steps will apply to essentially all conditions; they are recommended to any agency having a need to improve the manner in which it carries out development projects.

UTILIZATION OF PROJECT MANAGEMENT SYSTEM CONCEPTS

The concept of a project management system (PMS) has been presented as a solution to major problems associated with the systematic initiation and implementation of industrial development projects. Developing countries in general may find it very difficult to obtain information and assistance in utilizing the experiences of other countries and international organizations in this regard. To assist developing countries to use a PMS in project initiation and implementation, UNIDO suggests that government agencies assign an individual or group of individuals to investigate the techniques and applications of the system. The designated individual(s) should:

(a) Review available information on project management systems;

(b) Determine the preliminary feasibility of applying a PMS to new or existing development projects;

(c) Develop a work plan for applying appropriate elements of the PMS to selected projects;

(d) Secure approval of the work plan from the appropriate government authorities;

(e) Determine the types of assistance required and at what levels to use a PMS;

(f) Obtain the information and assistance required;

(g) Apply the PMS to development projects;

(h) Review and evaluate the applicability of the PMS to the initiation and implementation of current and future projects.

UNIDO is prepared to assist developing countries in taking all of the above measures and can be of particular assistance in the following areas:

(a) Assessing the types and levels of assistance required to meet the different circumstances and needs of individual countries;

(b) Identifying sources of PMS information;

(c) Identifying available PMS services for both manual and computerized systems;

(d) Identifying and discussing similar applications in other countries;

(e) Identifying sources for PMS training programmes;

(f) Organizing PMS workshops, training programmes and seminars;

(g) Organizing technical advisory missions to developing countries;

(h) Undertaking technical assistance projects in developing countries;

(i) Providing technical and application-oriented documents on project management systems.

It should be noted that UNIDO organizes training programmes and documents to provide information to executives, project managers and technical project personnel. Such training is oriented towards three levels of instruction relative to the levels of awareness, understanding and skill. Training is directed to each of the PMS phases defined for the initiation and implementation of industrial development projects.

Figure 22 gives a sample form for requesting the type of assistance that UNIDO can provide. The request must come from a Government. The form should be completed and returned to UNIDO through the Office of the United Nations Development Programme resident representative in the country.

A BUILDING-BLOCK APPROACH TO DEVELOPING AND INSTALLING A PROJECT MANAGEMENT INFORMATION SYSTEM

The modules of a project management information system are:

1. Pre-investment module
2. Financial module
3. Project definition and scope module
4. Action planning and control module
5. Resource planning and budgeting module
6. Contracting, work authorization and resource control module
7. Product information module
8. Environmental information module

In its training programmes, UNIDO includes instructions for using these modules. These categories of information must be available to an agency responsible for development projects in order to carry out its responsibility. Methods of preparing, processing, filing, retrieving and reporting or otherwise using the project management information within each module must also exist. Agencies that are

Figure 22. Form for requesting UNIDO assistance

Request from the Government of ( ) to the United Nations Industrial Development Organization (UNIDO) Vienna, Austria, for technical assistance in project initiation, implementation and construction[*]

Post title: One expert or a team of two or three experts in managing project initiation, implementation and construction (project management systems).

Duration: (The period in months during which the expert(s) will stay in the country.)

Date required: (The date the expert(s) will be required to start assignment.)

Duty station: (The city or town where the assignment will be mainly carried out.)

Duties: The expert(s) will assist the (name of agency or organization receiving the assistance) in:

(1) Reviewing the initiation and implementation of industrial projects and identifying the problems encountered;

(2) Reviewing the existing methods for programming and control of project initiation, implementation and construction and the information flows;

(3) Introducing an effective management information system including methods of programming and control of project initiation, implementation and construction and the necessary information flows required;

(4) Training of counterpart personnel in these areas;

(5) Recommending further UNIDO technical assistance deemed necessary.

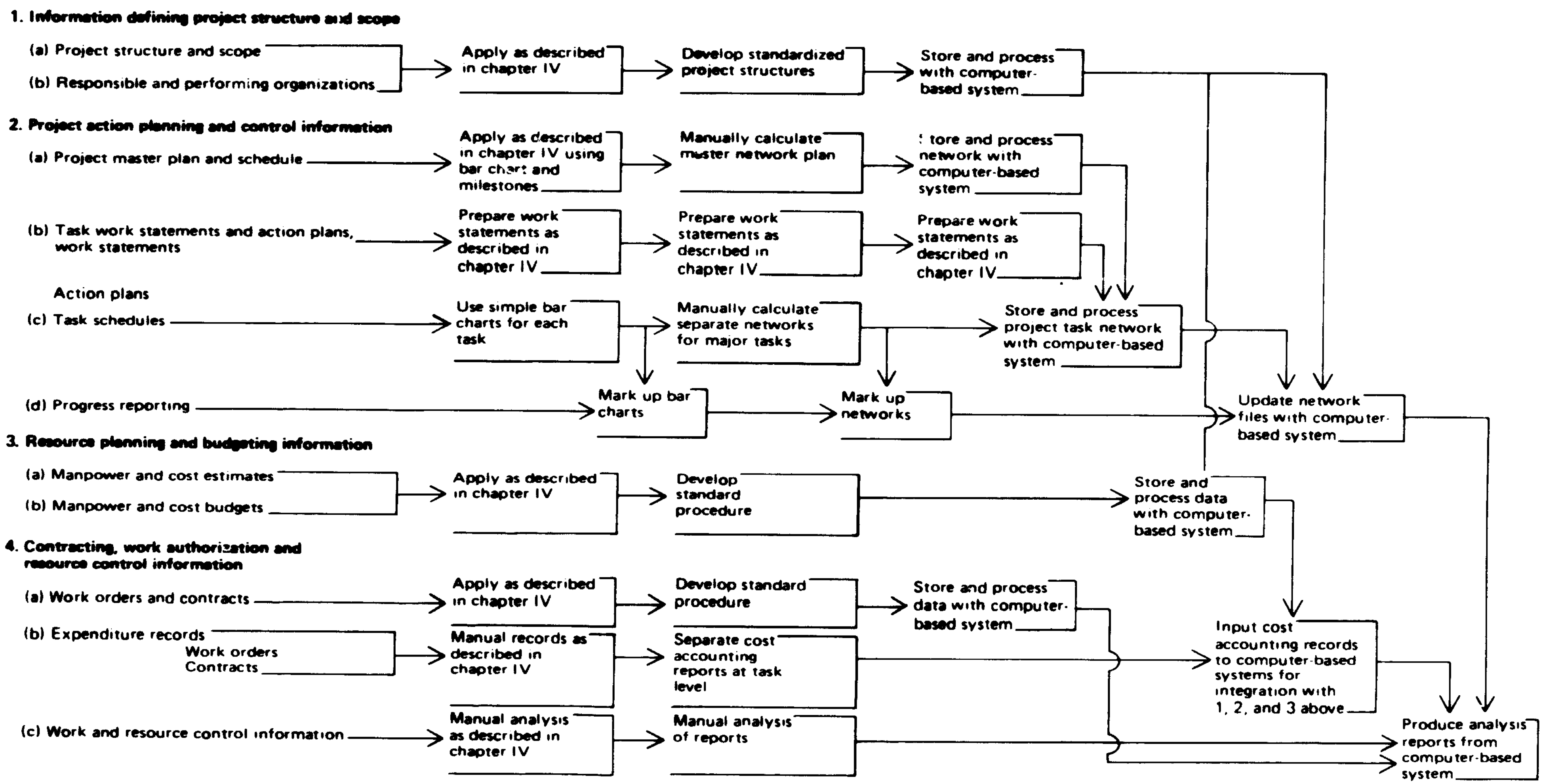
Qualifications of expert(s): University degree or equivalent in industrial engineering with extensive experience in management information systems for project initiation, implementation and construction.

Language: (The language to be spoken by the expert(s) such as English, French.)

Background information: (Some justification for the importance of the requested assistance as to the development of the country in general and that of the agency requesting the assistance in particular.)

[*The items included in this sample form are merely suggestive. Organizations interested in UNIDO assistance are free to change these items, to add to them, and to submit perhaps more than one request according to their needs.]

Figure 23. Sequential relationships of building blocks during evolution of a project management information system



currently carrying out development projects do have such information, at least to some extent and with varying degree of detail, and are usually applying some of the necessary methods.

What is needed is to organize the information along the systematic lines previously described, to improve the methods of preparing and using the information and finally to improve the adequacy of the information itself for each project.

It is not necessary or even desirable to make the transition to a full-blown PMIS in one step. The recommended approach is to view each of the eight modules listed above as a building block in the over-all system. Each one can be looked at individually, although there are, of course, interrelationships between them.

RESTRICTED DEFINITION OF PROJECT MANAGEMENT INFORMATION SYSTEM

The term "project management information system" usually refers to the four modules numbers (3) through (6) listed above.

Table 4 shows, in simple terms, the evolution of these four modules in each of three arbitrarily defined stages of system development. The elements identified within each module can be considered individual building blocks of the system. Each building block can be developed somewhat independently, although certain ones can move to a particular stage only after others have reached it.

Figure 23 portrays the sequential relationships between the various building blocks.

TABLE 4. EVOLUTION OF PMIS MODULES

	System development stage		
PMIS modules and building blocks	*1* *Initial*	*2* *Intermediate*	*3* *Advanced*
1. *Information defining project structure and scope*			
(a) Project structure and scope *(b)* Responsible and performing organizations	Apply as described in chapter IV	Develop standardized project structures	Store and process with computer-based system
2. *Project action planning and control information*			
(a) Project master plan and schedule	Apply as described in chapter IV using bar chart and milestones	Manually calculate master network plan	Store and process network with computer-based system
(b) Task work statements and action plans Work statements Action plans	Prepare work statements as described in chapter IV	Prepare work statements as described in chapter IV	Prepare work statements as described in chapter IV
(c) Task schedules	Use simple bar charts for each task	Manually calculate separate networks for major tasks	Store and process project task network with computer-based system

TABLE 4 *(continued)*

PMIS modules and building blocks	*System development stage* 1 *Initial*	2 *Intermediate*	3 *Advanced*
(d) Progress reporting	Mark up bar charts	Mark up networks	Update network files with computer-based system
3. *Resource planning and budgeting information*			
(a) Manpower and cost estimates *(b)* Manpower and cost budgets	Apply as described in chapter IV	Develop standard procedure	Store and process data with computer-based system
4. *Contracting, work authorization and resource control information*			
(a) Work and contract orders	Apply as described in chapter IV.	Develop standard procedure	Store and process data with computer-based system
(b) Expenditure records Work orders Contracts	Manual records as described in chapter IV	Separate cost accounting reports at task level	Input cost accounting records to computer-based systems for integration with 1, 2, and 3 above
(c) Work and resource control information	Manual analysis as described in chapter IV	Manual analysis of reports	Produce analysis reports from computer-based system

Annex I

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Annex II

MANAGEMENT CONTROL SYSTEMS

In addition to the value-of-work-analysis technique described in chapter V, the major current management control systems will be briefly discussed. Several network-based management control systems exist such as the Critical Path Method (CPM), Metra Potential Method (MPM) and Programme Evaluation and Review Technique (PERT). Since PERT is probably the most common of management control systems, it is considered below. Prior knowledge of the mechanics of PERT is assumed here, and the goal of the discussion is to examine PERT as a management control process. Extensions of PERT provide for control over cost, manpower and other required resources.

PERT OUTPUT

The basic PERT report typically includes the event number, its description, the expected and latest allowable times and slack (float). Where scheduled dates are supplied, the probability of meeting these is printed. The more sophisticated programmes provide for the inclusion of actual dates. Several options are provided, so that events may be listed in slack sequence, in sequence according to their earliest expected time or according to their latest allowable time.

In processing the sample network, the event-oriented approach was adopted. CPM and some of the newer PERT systems use an activity-oriented approach in analysing the same network. Input requirements under either system are similar, with the minor exception that activities are given a verbal description when activity-oriented output is desired.

The relative merits of event or activity orientation can be debated. As a rule, however, activity output will be of primary interest to personnel at the operating level, since their responsibilities are defined in terms of activities, while event output will be most useful to top management, which is concerned with attaining major milestones in the project.

One of the challenges of developing a PERT system is the necessity for sifting through the vast amount of data that can be generated and extracting that which is meaningful to management. The typical PERT programme, with only the slightest encouragement, will pour out pages of output by the thousands. It is obvious that selectivity is needed in order to adhere to the principle of management by exception or effective management.

The problem of selectivity has been attacked from several directions. Probably the simplest approach has been to predefine certain events in the network as being of interest to a particular level of management and to code the master records accordingly for report purposes. Another way has been to portray the output graphically, to produce a quick visual impression of project status. Flagging of particular items that are exceptions, such as unreported or overdue occurrences, has provided a useful check list for the project manager. Finally, some elaborate index systems have been developed, which compute a criticality index for each activity by means of a weighted combination of such measures as negative slack, low probability of attainment, and high variance in time estimation.

To be specific, the types of PERT networks that may be used are listed below. Various levels of management and numerous interrelationships among firms, agencies and departments are usually involved in project system control. In such an environment, with its variety of demands, a single network often will not suffice. Accordingly, variations have been evolved to handle various aspects of the planning and control process.

Detailed and operating level networks

Generally, each prime or associate contractor constructs and uses a network that covers his individual sphere of programme responsibility. If a portion of the project is subcontracted to another firm, that subcontractor in turn may be required to construct and use a network for his portion of the project. These networks are constructed in considerable detail and frequently comprehend even relatively minor activities and events. Such networks are known as operating, or detailed, networks. Since they often cover only a fragment of a project, they are sometimes also referred to as "fragnets" (fragmentary networks).

Integrated project networks

The detailed operating networks prepared by the separate firms and agencies may be combined or integrated into one comprehensive network encompassing all events in the entire project. Although perhaps not directly involved in detailed operations, the office responsible can monitor the progress of the entire project by using this integrated network.

Condensed, or summary, networks

Generally, detailed networks contain too much operating data for top project management or other interested parties monitoring the progress of the programme or project on a more aggregative basis. To accomplish this, a condensed or summary network is derived, which eliminates much of the detail yet retains the events of major significance. Such networks are frequently displayed in project control offices.

Accurate translations of activity time estimates must be made when the operating networks are either integrated or condensed. The integration and condensation processes involve identifying, recording, co-ordinating and storing interface events. Various computer routines are being developed to accomplish this complex and vital task. Figure 24[a] indicates the relationship among these various forms of networks. This diagram depicts condensation of networks prior to network integration. Either condensation or integration can occur first depending on the requirements of the levels of management.

MANAGEMENT ACTION

The success of a functioning PERT system should be gauged not simply by the quality of the reports it produces, but rather by the management response it stimulates. A good PERT reporting system will call to the attention of management areas in which scheduled project objectives are being threatened. Management, then, must take the necessary remedial action.

When it becomes apparent that a schedule cannot be met under the existing plan, it becomes necessary to devise a new plan. Activities along the critical path must be analysed from two points of view. First, it is possible that certain sequential activities can be performed in parallel. Originally, activities might have been scheduled sequentially to ensure that a previous task was performed successfully before a subsequent task was begun. These tasks may be scheduled simultaneously if the project manager is willing to assume the added risk.

The second and more usual alternative is to divert manpower or other resources from activities with large positive slack to those with zero or negative slack (float). The report showing activities sorted in slack sequence is very useful to the manager in determining the most feasible exchanges. In making these exchanges, however, he must ascertain the effect that they will have on the total network. As the critical path is shortened another path may become critical and in turn require attention. The usefulness of having a network model of the project is apparent at this point. The network can be processed by the computer as if the contemplated changes had actually been made and their full consequences can be projected. When used in this manner, the network becomes a simulation model.

By focusing the attention of management on activities that lie on the critical path or on near-critical paths, PERT relieves the manager of the burden of closely auditing the 80-90 per cent of activities that do not directly influence the duration of a project. It truly allows management by exception.

PERT EXTENSIONS

The term PERT alone is generally associated with planning and control of the time variable only. This forms the basis for a complete project control system; however, it can also provide the framework for extensions that allow control over other elements such as cost, manpower and other sources.

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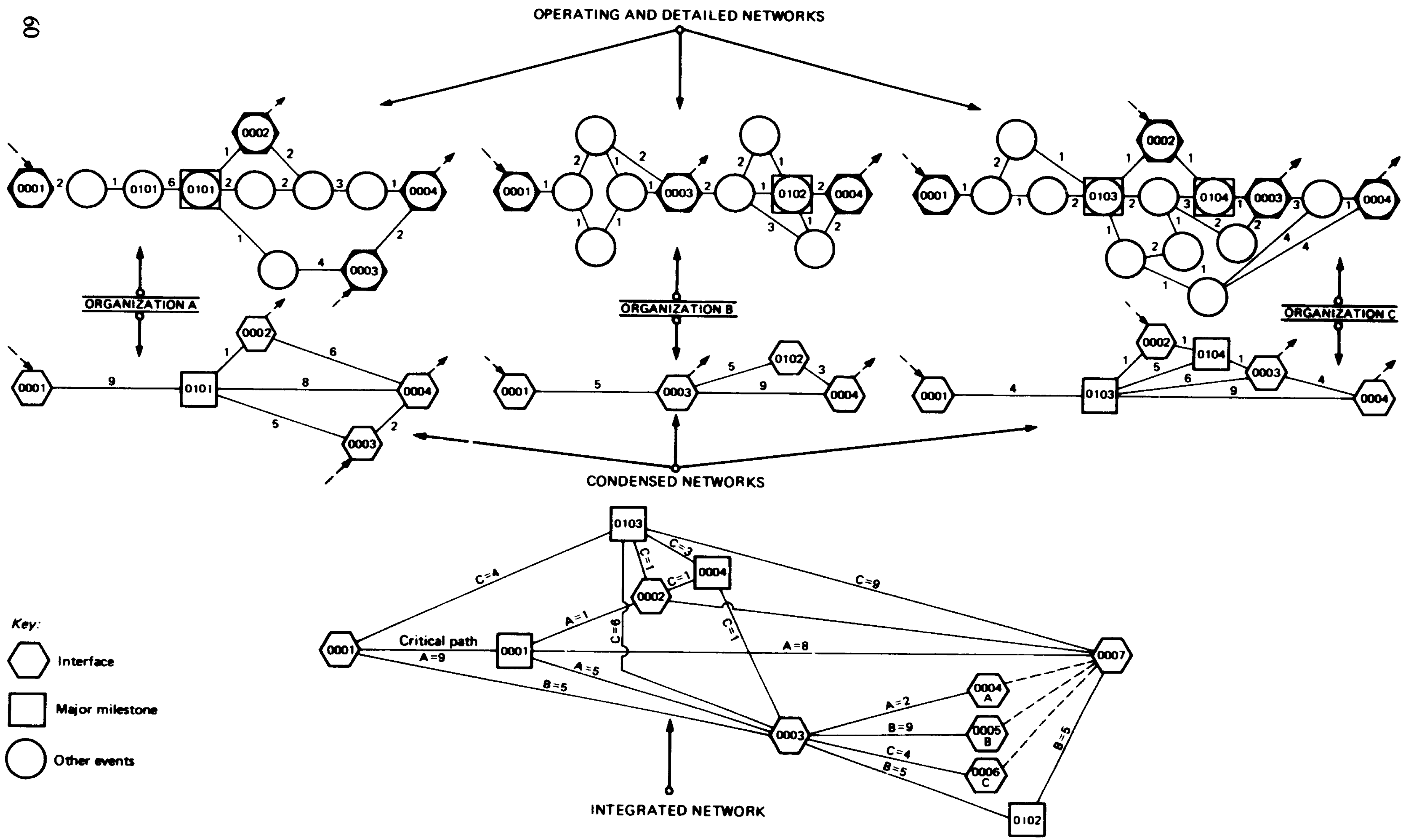
[a]D. I. Cleland and W. R. King, "Systems, organizations, analysis, management: a book of readings", J. N. Holtz, ed., *Project Planning and Evaluation* (New York, McGraw-Hill, 1969), p. 351.

Figure 24. Relationships among networks



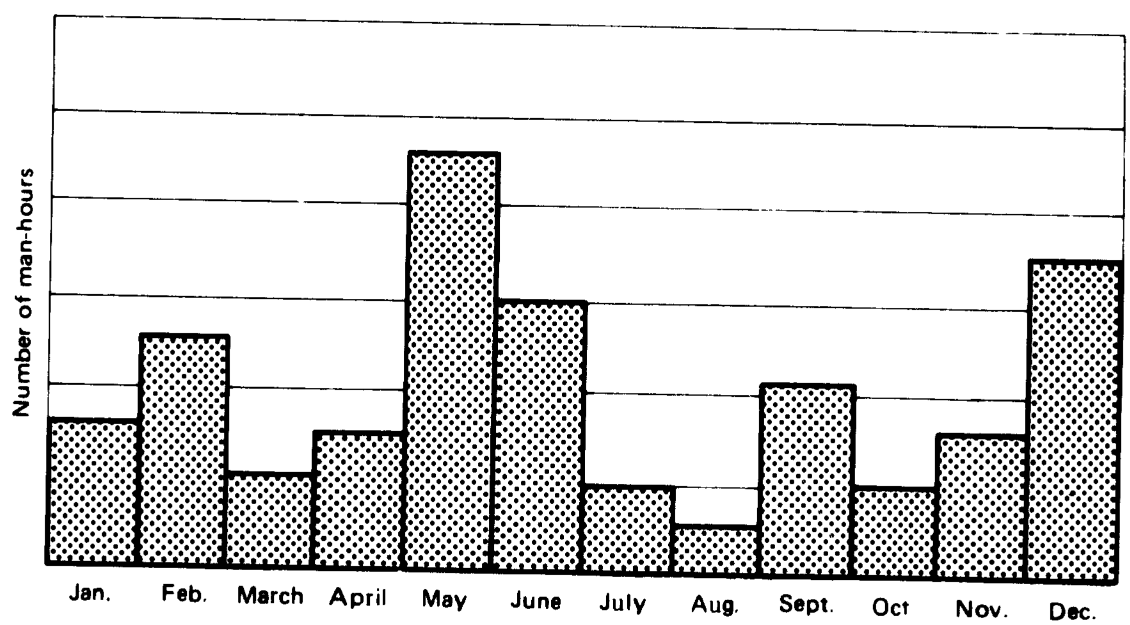
PERT/Cost

In general, it is necessary to weigh the costs of a project. Even when time is the overriding factor, costs must also be considered. The PERT/Cost procedure requires cost data as input in addition to the time data required by basic PERT. These cost data are generally collected for small groups of related activities rather than for single activities, so as not to impose an undue accounting burden.

Cost estimates are obtained only after a satisfactory schedule has been developed, since any schedule change normally affects cost. Labour is estimated by entering the man-hours required for each category of skill. The computer converts this input to money figures, such as dollars, by applying the appropriate labour rates, which the computer can easily do. Material costs are estimated and overhead factors added. As the project progresses actual accrued costs are gathered for each cost collection point, and revised estimates are submitted as required. Several useful and informative reports can be generated from these data. The basic output is a status report, which combines time and cost data for each cost collection point. This enables the manager to identify activity groups that are contributing to actual or potential schedule slippages or cost overruns and also to compare the time and the cost status of any given activity group. In addition to the output obtained from a time-oriented network, this report shows the original cost estimate; the actual costs incurred; a revised estimate, if any; and the anticipated overrun or underrun. Provision is made for summarization of the time and cost data at various levels, so that each level of management is presented only with that amount of detail with which it is directly concerned.

The computer can be used to great advantage in projecting manpower needs for each category of skill. The time analysis of the network is used to determine the calendar period in which each activity will fall. The estimated man-hours for each activity are then distributed by calendar period within skill category. The summarized results can be displayed graphically (figure 25).

Figure 25. Histogram of manpower requirements, skill category XX

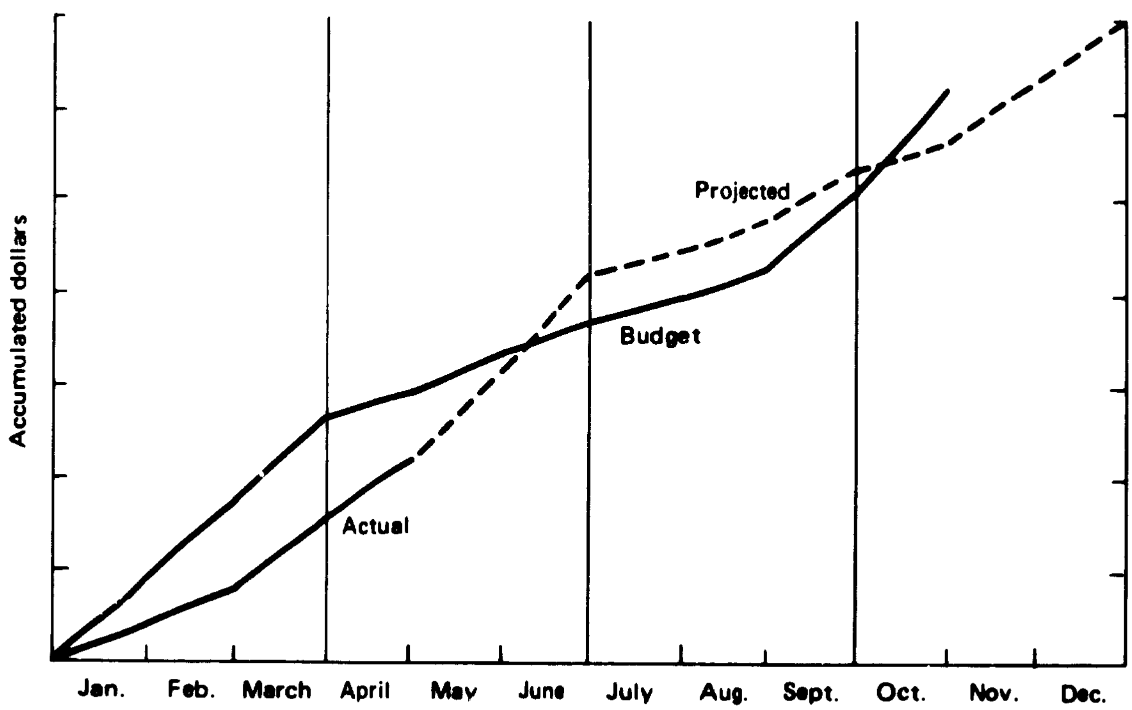


This projection is useful to the manager in predicting peaks in requirements for particular manpower skills. When future demand for a skill exceeds the supply, some action must be taken. The situation might be relieved by rescheduling activities, by adding overtime or by hiring additional personnel. The extent to which any of these alternatives serves to alleviate the problem can be predicted by using the simulation facility of the computer program.

In most projects, manpower is the most important resource. Frequently, however, other resources play a critical role in the achievement of project objectives. These may be machines, testing facilities or computer time. Where there is a possibility of an overload on any of these facilities, a projection similar ro that shown for manpower can be made.

Cost requirements for a project can also be projected in this same way. When costs are distributed by calendar period and accumulated, estimated and actual payout curves can be plotted (figure 26). At the beginning of the project, this projection is useful in determining the funding requirements of a selected schedule, so that the necessary money can be provided at the proper time. As work proceeds, the actual payout can be compared with the budget and the projected needs used as a basis for revising the funding schedule.

Figure 26. Rate of expenditure



Cost-time balancing

In selecting a suitable schedule for a project, numerous alternatives are usually considered, each with a different cost picture. Choosing the schedule that provides the best balance between cost and time is an arduous task when attempted by trial and error, and it is not surprising that computer techniques have been developed for this purpose.

In most activities involving manpower, a direct relationship exists between the cost and the time required for completion. Assigning additional personnel or scheduling overtime normally reduces the time requirements for an activity but increases the costs. Cost-time balancing requires two estimates of time for each activity and two of cost. Normal cost is defined as the minimum cost for a job, with normal time being the associated minimum time. Crash time is defined as the minimum possible time, with crash cost being the associated minimum cost. For example, a job might normally be completed in six weeks at a cost of $3,000. Expediting this job, so that it can be finished in two weeks, might involve a total cost of $7,000. The latter is the crash time and the crash cost. Figure 27 shows this relationship. The line connecting normal and crash points illustrates the assumption that there is a cost corresponding to any time between normal and crash.

A normal time and cost for the entire project can be obtained simply by summing the normal time on the critical path and cost estimates for the network. To calculate the total project cost for shorter times, the critical path is examined, and activities with lowest time per dollar ratios are expedited. As the time required along the critical path is reduced other paths in turn become critical and they, too, are examined. Sufficient points are obtained in this way to plot a direct cost curve for the entire project (figure 28). The addition of a manually evolved indirect cost curve gives the manager all the information he requires to select the project schedule that most closely balances his cost and time objectives.

Figure 27. Cost-time relationship for a given activity

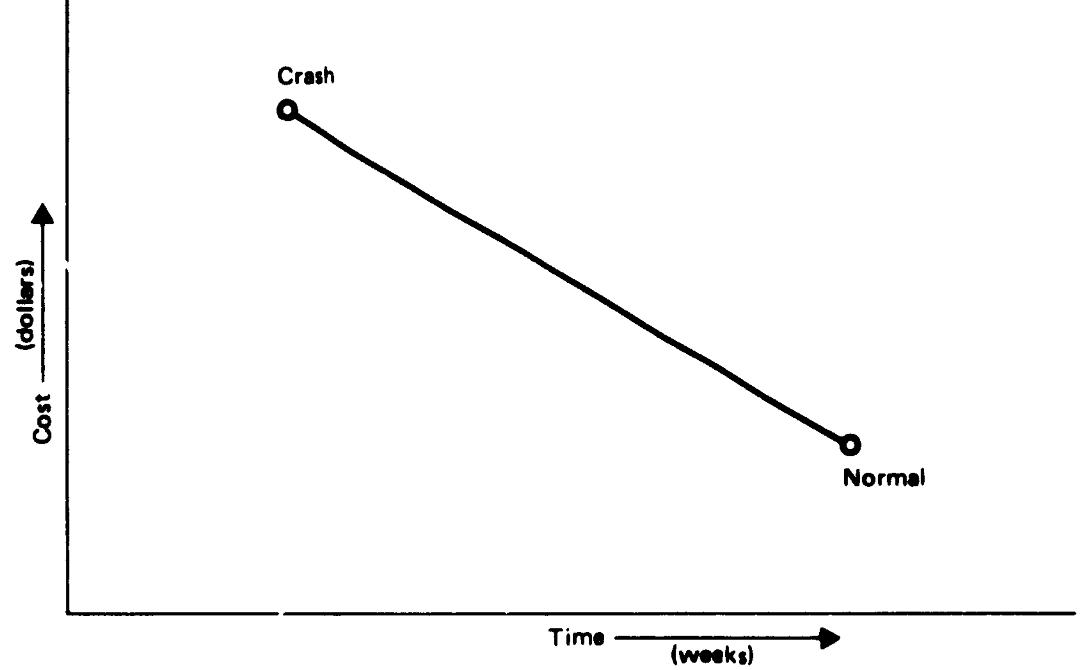
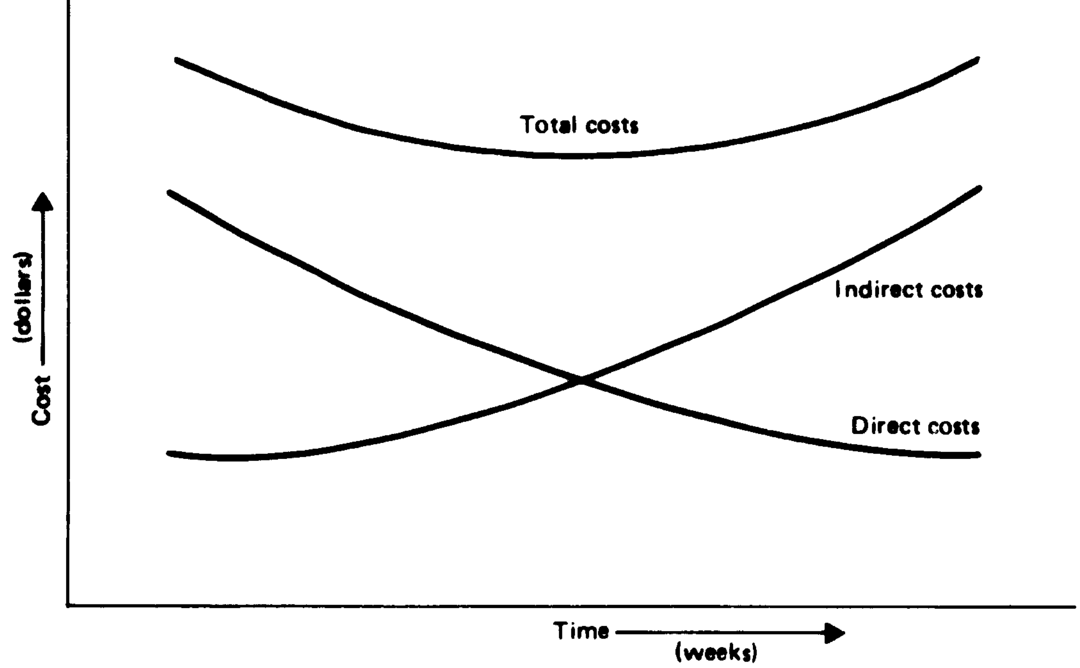


Figure 28. Total project costs



STATUS INDEX

A second management technique is the status index. This technique provides a relatively simple way to evaluate the status of a project taking into account both schedule and cost. (The index can be calculated for one activity or, more commonly, for the over-all project.) This technique is simple enough to enable necessary calculations to be performed on a slide rule or by hand.

The index used to evaluate status is derived as follows:

$$\frac{\text{Progress}}{\text{Scheduled progress}} \times \frac{\text{Budget}}{\text{Actual expenditures}} = \text{Status index number}$$

Basically, the status index is a means of relating actual progress and cost to the project plan. An index of 1.0 is par, and an index above that indicates better-than-expected progress for the money spent. Anything below 1.0 indicates less-than-expected progress for the money spent.

For example, suppose that one desires to evaluate the status of a project. The evaluation is made at any given time after the project is started. Consider a project on which 10 months of effort was to have been spent up to the present time when the evaluation is being made (scheduled progress =,10 months). Actual progress to the present is equivalent to only 7 months of effort; that is, the project is 3 months behind the plan (progress = 7 months). Also, the original budget planned for the effort up to the present is $5 million (budget = $5 million). The actual expenditures on the project up until the present have been 6 million (actual expenditures = 6 million). The status index for this project would be calculated as follows:

$$\frac{7 \text{ months}}{10 \text{ months}} \times \frac{5 \text{ months}}{6 \text{ million}} = 0.58$$

This status index is a measure of the progress achieved for the money spent. It shows the basic relationship between the budget (input) and the progress (output). Consequently, the status index can be viewed as a ratio of the project output to the input:

$$\frac{\text{Output}}{\text{Input}} = \frac{\frac{7}{10}}{\frac{6}{5}} = 0.58$$

The status index is merely a ratio or index for evaluation, and it is useful to indicate status or status related to some prior period (better or worse).

To determine where management attention is needed, more than the index is required. Progress on schedule can be examined in terms of the critical path or the stream of related activities whose progress is slowest in relation to the other activities of the project.

For example:

Project/task	*Float (months)*
Over-all project summary	8
Task A	- 3
Task B	- 2
Task C	- 8
Task D	- 5
Task F	+ 1
Task N	- 3

Task C is the "slowest" and therefore is the project limiting task, that is, the area where management attention is most necessary at the time the evaluation is made.

The status index can be applied at any level of detail in the project (for an activity or the over-all project as has been stated) where values of the variables cited above can be identified and substituted in the equation.

The status index for each of the various elements of a project may be charted for presentation purposes. The elements (tasks or sub-tasks) can be listed on the chart according to relative status index values (high to low, for example) as shown in table 5.

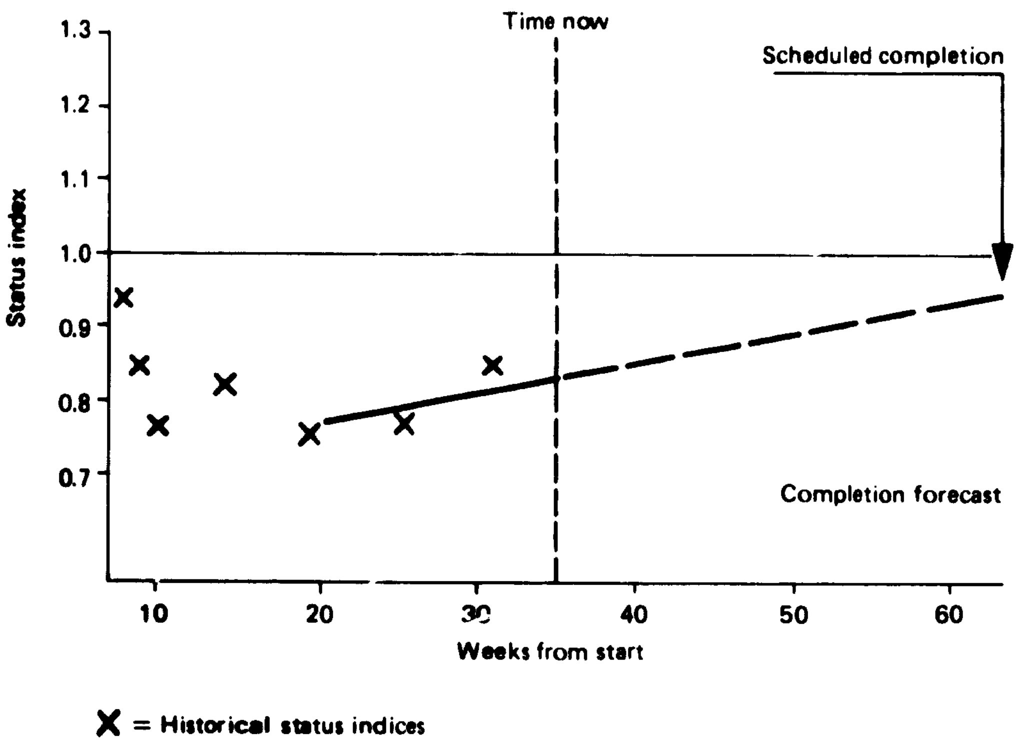
TABLE 5. STATUS INDEX VALUES

Status index	*Project element (task, sub-task)*	*Remarks*
1.2	2.1	Possibility of excess resources
0.9	3.1	Normal variance range
0.8	1.2	May require more resources
0.7	2.6	May require more resources
0.6	2.5	Immediate management action required

If 1.0 is par, the data charted above show that project element 2.1 is performing above par and should be reviewed to see whether excess resources have been assigned to this task. Project element 3.1 is below par, but within a normal variance range. Project element 2.5 has an index of 0.6, below par significantly enough to require immediate action by management.

Status indices can be used to forecast cost to completion, as shown in figure 29. After initial fluctuations have subsided, the least squares method or a similar technique can be used in the projection. In figure 29, 0.95 is the projected index at project completion. This means 100/95 of the original estimated cost is projected to occur. This is 105.3 per cent of the estimated cost, or a projected overrun of 5.3 per cent for the project.

Figure 29. Forecast cost using status indices



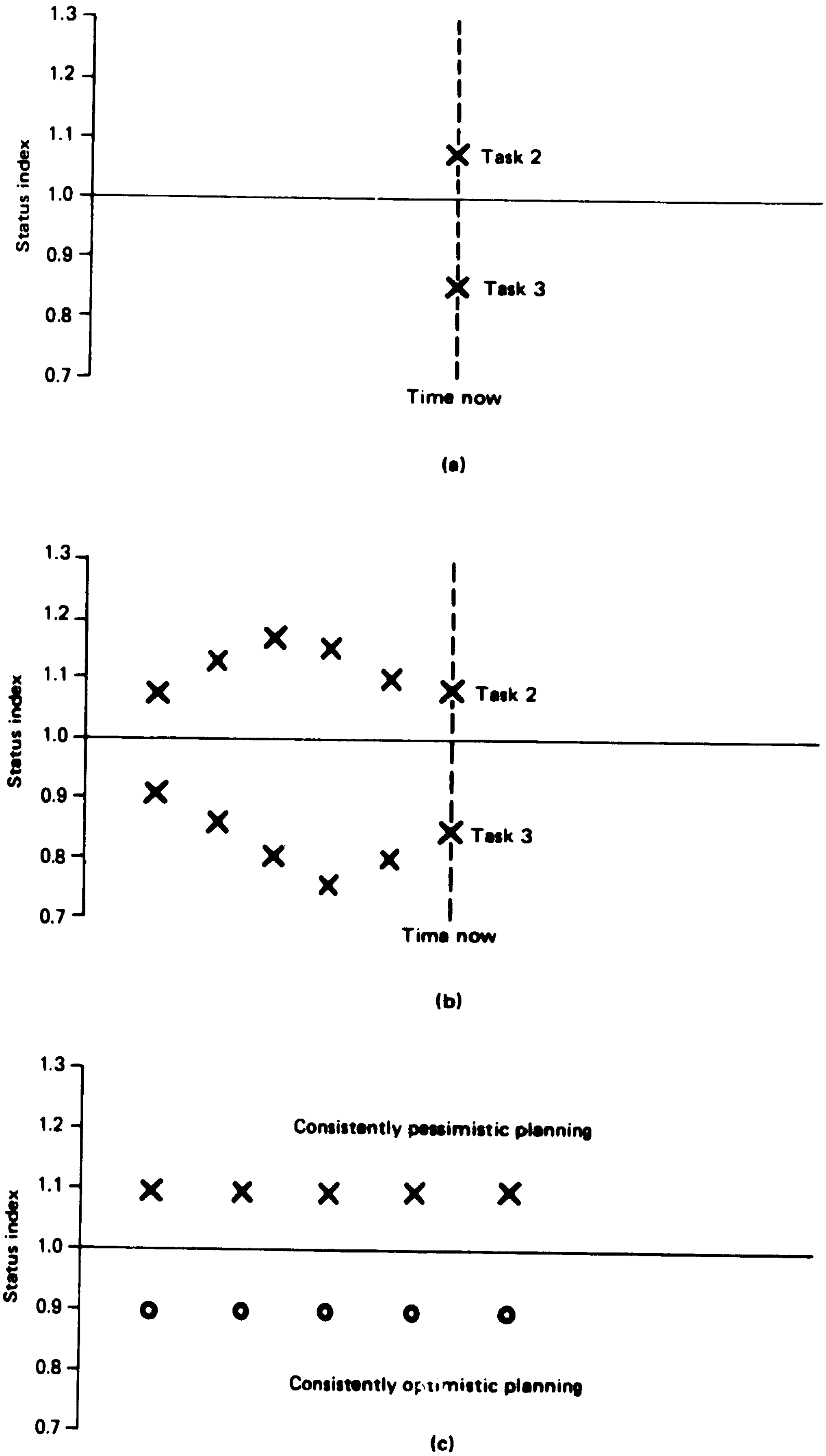
Trouble areas can be predicted by using the procedure shown in figure 30. Based on the information in figure 30a, the project manager would probably be concerned more with task 3 than with task 2, since task 2 shows a larger deviation from par performance (1.0) and especially since the performance indicated is below par. Figure 30b, however, shows that the status index, when tracked over time, indicates that task 2 is getting worse while task 3 is getting better. The point here is that it is necessary to have a history of progress (as opposed to an evaluation of progress at a certain date) to predict areas where trouble is present or may occur.

Historical comparison of the status index against the par performance index of 1.0, as shown in figure 30c, can be used to reveal how effective the planning was. A status index over time consistently above par (as shown by the X's) would indicate consistently pessimistic planning–more time and money have been consistently estimated for the project than are actually required. The converse is true for consistently optimistic planning, as indicated by the dots.

A pattern varying considerably (rather than being consistently above or below par as shown in figure 30c), reveals symptoms of performance deficiencies other than consistently good or bad planning; that is, the planning may be:

Pessimistic at the outset but improving
Excellent at the outset but increasingly going out of control
Erratic, with no discernible pattern

Figure 30. Interpretation of different status indices



EARNED VALUE

This section describes some optional graphic applications of the earned-value concept, which is identical in theory to the value-of-work analysis described in chapter V. The concept holds that an estimated value (the original budgeted value) can be placed on all work to be performed and, once the work is accomplished, that same estimated value can be considered "earned".

By knowing at any given time in the life of the project what part of the original "value" has been earned, the true status of the project can be determined by comparing the original value earned with the original plan for expending resources (dollars or time). If the original planned amount of resources has been expended to some given date and the work accomplished to date is equivalent to the original value, then the project status is par. If, however, the original planned amount of resources has been expended and the work accomplished to date has been greater than the original value, for example, the project status is above par, that is, more work has been accomplished to date than was originally expected with the given amount of resources.

To illustrate, consider figure 31. The resource to be expended here is time expressed in labour hours. The curve "planned man-hours" represents the original plan for using labour expressed in cumulative number of man-hours. The "planned equivalent work units" curve represents the original plan for producing work units expressed in number of units. The scale on the right side shows that this curve is in "cumulative equivalent work units". ("Equivalent" merely means that this curve shows the equivalent number of work units expected to be produced or implemented for a given number of labour hours. For example, at "time now" on the chart, about 5,400 man-hours was planned to this point; by projecting down from the "planned man-hours" curve to the "planned equivalent work units" curve, it can be seen that 5,400 man-hours is equivalent to about 10 units.)

To illustrate how project status is determined in terms of "earned variance", first compare "actual man-hours" to "planned man-hours". The "resource variance" as determined by this comparison shows that the project is ahead of plan, that is, fewer hours have been used to "time now" than were originally planned. This, however, is not a true measure of project status, since it does not take into account the "value earned" up to "time now".

Figure 31. Labour cost-schedule position

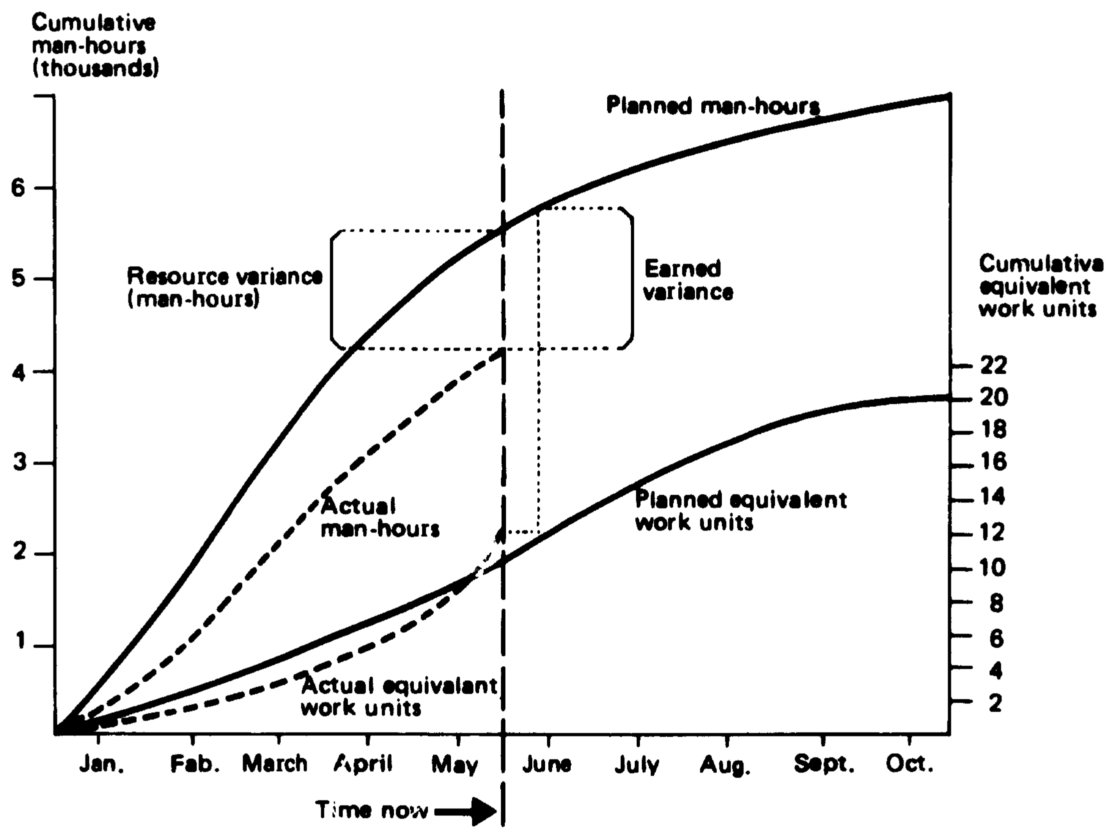


Figure 32. Labour dollars and overhead cost-schedule position

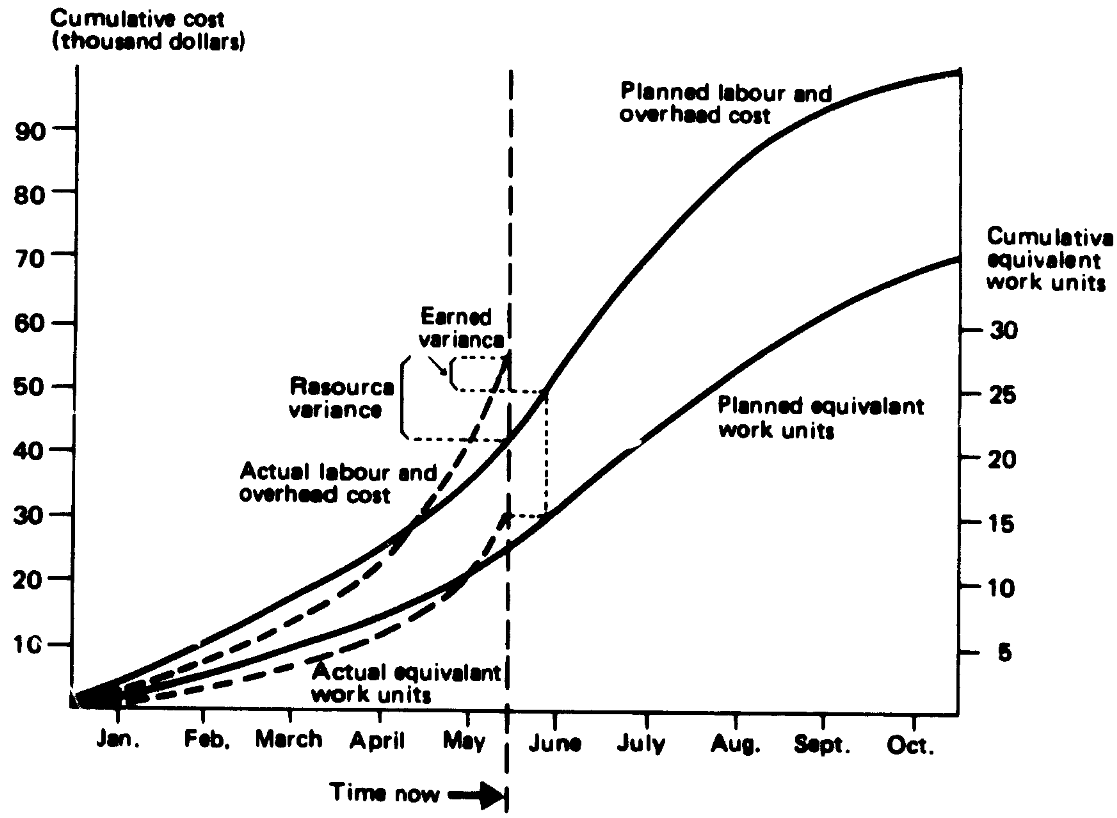
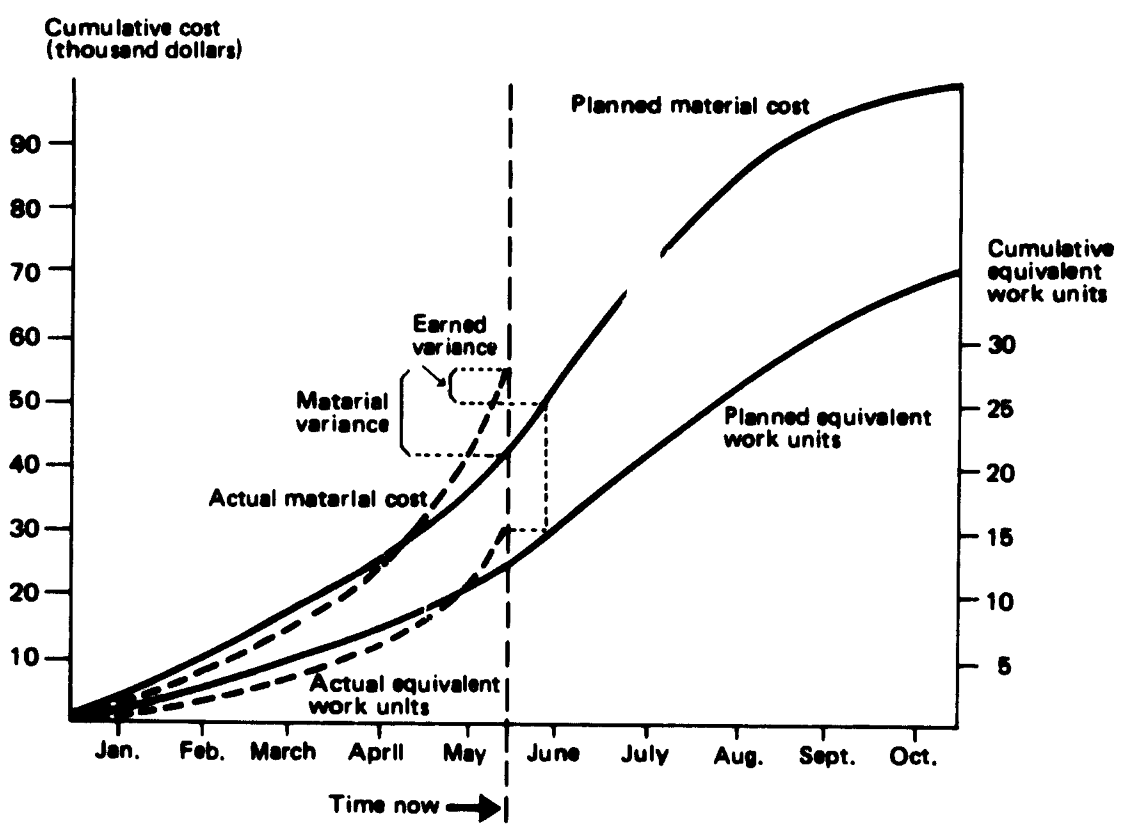


Figure 33. Material cost-schedule position



The "value earned" can be measured by comparing the equivalent number of work units actually produced with the number planned. In this example, actual production of equivalent work units is more than originally planned. By projecting from the actual equivalent work units curve over to the "planned equivalent work units" curve and then projecting from that point up to the "planned man-hours" curve, a point can be determined that equates the "planned man-hours" that would have been used to produce the "actual equivalent work units" up to "time now". The difference in this point on the "planned man-hours" line and the "actual man-hours" used to "time now" represents the true variance from planned and is the "earned variance" to date. The "earned variance" measures the amount of resources (labour hours) that have been "saved" from the amount originally planned up to "time now" as adjusted by the fact that more work units have been produced to "time now" than were originally planned.

Figure 32 shows the same principle operating in a case where more resources (labour and overhead) have been used than were originally planned. The "resource variance" is greater, however, than the more realistic "earned variance", which takes into account the fact that more equivalent work units were produced than were originally planned to "time now".

Figure 33 shows an identical situation for use of material resources. The resource variance is not a good measure of project status until the "earned value" of work units implemented has been considered. By projecting from the "actual equivalent work units" curve to the "planned equivalent work units" curve, and from that point up to the "planned material cost" curve, the "earned variance" is seen to be less than the "material variance". In other words, the true variance from plan based on earned value is less than the variance indicated only by the planned *versus* actual use of material resources.

Annex III

COMPUTER USE IN A PROJECT MANAGEMENT INFORMATION SYSTEM

When the activities in a project go beyond a certain number, the use of the computer becomes necessary. Several factors should be considered in using the computer, such as:

The size of the network, i.e. the number of activities involved
The complexity of the relationships among these activities
The frequency of the need for updating the computations
The availability of a computer and the cost involved
The availability of software packages for project management that can be utilized with the computer available

There are also several considerations in choosing a computer program to satisfy one's needs. These programs range from the very simple to the highly complex, such as PERT/Cost package. The choice of a computer program depends on the need for information required for decision making, such as:

Statistical analysis
Graphical output
Resource allocation
Cost allocation

The following list of some of the programs available for project management in the United States of America relates the program to the computer needed to run it. The capacity of the program is specified by the number of activities or events the programme can accommodate.

COMPUTER PROGRAMS

Computer	*Program name*	*Capacity*
Burroughs B200/B306	PERT/Time	900 events
Burroughs B5500	Time-PERT in Algol 60	524,288 events
Control Data 1604	PERT	3,000 activities
GE-115	Critical path method program	350 to 3,000 events
GE-215/225/235	Project monitor and control method (CPM/PROMOCOM)	999 events
GE-400/600	Critical path method program and CPM/monitor	3 000 events
Honeywell 400/1400 or 800/1800	PERT	3,000 activities
IBM 1401 and Sys. 360	Management control system	4,600 nodes
IBM System/360	Project control system/360	5,000 activities
IBM 1130	1130 Project control system	2,000 activities
IBM System/360	Project management system PMS/360	Varies (on Oklahoma State University system is 3,214,400 activities)
NCR-304 or NCR-315	PERT	5,000 activities
RCA 501	PERT	2,000 activities
UNIVAC 1107	PERT/Cost	Not given

Annex IV

STRENGTHS AND LIMITATIONS OF COMPUTERIZED PROJECT MANAGEMENT INFORMATION SYSTEMS

Many strengths and limitations are associated with computerized project management information systems and derivative systems, far too numerous to attempt to catalogue here. Relevant experience, however, may be epitomized in a few brief comments on PERT/Cost. The following have been cited specifically as significant advantages in the PERT discipline:

(a) It permits work breakdown structure;

(b) It permits effective integration of cost and time;

(c) It permits management by major exception rather than by exception only;

(d) It permits effective quantification of uncertainties;

(e) It is eminently visible;

(f) It lends itself to the management cycling process;

(g) The work breakdown structure is predicated upon true and discrete total management at each tier in the work breakdown structure. Each manager is accountable for cost, schedule and performance.

Significant limitations have also been cited in the PERT discipline as it is known today, some of which are:

(a) PERT is diagnostic; it deals only with effects, not causes;

(b) PERT supports the fiction of resource flexibility;

(c) It segregates planning from scheduling; effective measurement against a plan postulates schedule-costing, not objective-costing. Scheduling is not a programme management function; it is a general management function because the project manager does not own the resources he will need to complete the project successfully, although he can plan his project through the elapsed-time phase. He is dependent upon a pooled work unit;

(d) Project managers are frequently distracted by the slack-time fiction, so they are managing residual time, not the work;

(e) PERT never converts information to knowledge. Parenthetically, it could be asked if it ever could be expected to do so;

(f) Critical path is a misnomer. It actually is the elapsed time-determinant path, and it is only critical if it turns out that way.

These, then, are some of the strengths and limitations of the PERT system, as seen through the eyes of those who have witnessed the evolution of the PERT discipline and the evolution of many more PERT extensions. It has been suggested in the past that one of the major limitations in proj t control is the failure to get enough information to the right persons in time for them to take coırective action.

Operating reports should be developed according to areas of responsibility. The PERT/Cost output reports are so structured, but satellite and derivative systems frequently lose the inherent organizational relationships that the PERT/Cost system utilizes. Reports on the operating performance of a particular manager should cover only those items for which he is responsible or should clearly distinguish between such items and those beyond his control.

The level of responsibility to which the report is directed should dictate, to a large extent, the form and content of the report. To illustrate this idea, consider only the operating costs inherent in a single department during a month. The cost reports submitted to the department supervisor should detail the individual cost items, classified as controllable and noncontrollable. These reports should indicate both actual and budgeted costs for the month, and possibly the year to date, and the resultant variances. If preferred, noncontrollable costs may be omitted from the report. The report submitted to the plant manager or the general manager will include cost data for all the departments in his plant. These data may be summarized simply by broad functional classifications, such as materials, labour and overhead, variability or fixedness with respect to volume and controllability. The report submitted to the vice-president, for example, may include summaries of cost data for several departments. The data for individual departments within a plant may not be identified separately at all at this level of responsibility. The vice-president is not the one to take action to correct excessive consumption of materials in a department–there is no point in cluttering his report with such detailed information.

Although reports of operations directed to lower levels of management should clearly distinguish between controllable and noncontrollable data, they need not omit the latter. In fact, inclusion of information that is beyond a manager's present scope of responsibility may expand his perspective of the firm's operations and, thus, help him prepare for broader managerial responsibility in the future. Also, reports to a manager with results of the operations of other divisions as well as his own may help to stimulate healthy competition among divisional managers. This may be particularly beneficial in connexion with sales divisions. Care must be exercised, however, to ensure that such competition does not improve divisional performances at the expense of optimal company profit. This same rationale is applicable to programme management within a single division. The programme manager is responsible for planning his operation and planning the workload, but he does not own the resources he will need to implement the programme successfully over its life cycle. This latter function belongs to general management.

Management by exception is an approach to management that focuses attention on situations and operations that deviate from plans or from normal conditions. It is predicated upon a belief that management's limited and costly time is best spent in matters requiring corrective action or other improvement, not in reviewing satisfactory performance. Regular reports of operations, therefore, should be so constructed as to draw management's attention to variances beyond the established range of tolerance, for these are the variances that call for managerial action. This may be accomplished by placing such variances in a special column in the report or by putting some identifying mark next to them. The importance of reporting exceptions does not mean that satisfactory results are unimportant. Management, naturally, wants to know the results of operations, whether good or bad, but the bad results should be clearly identified.

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