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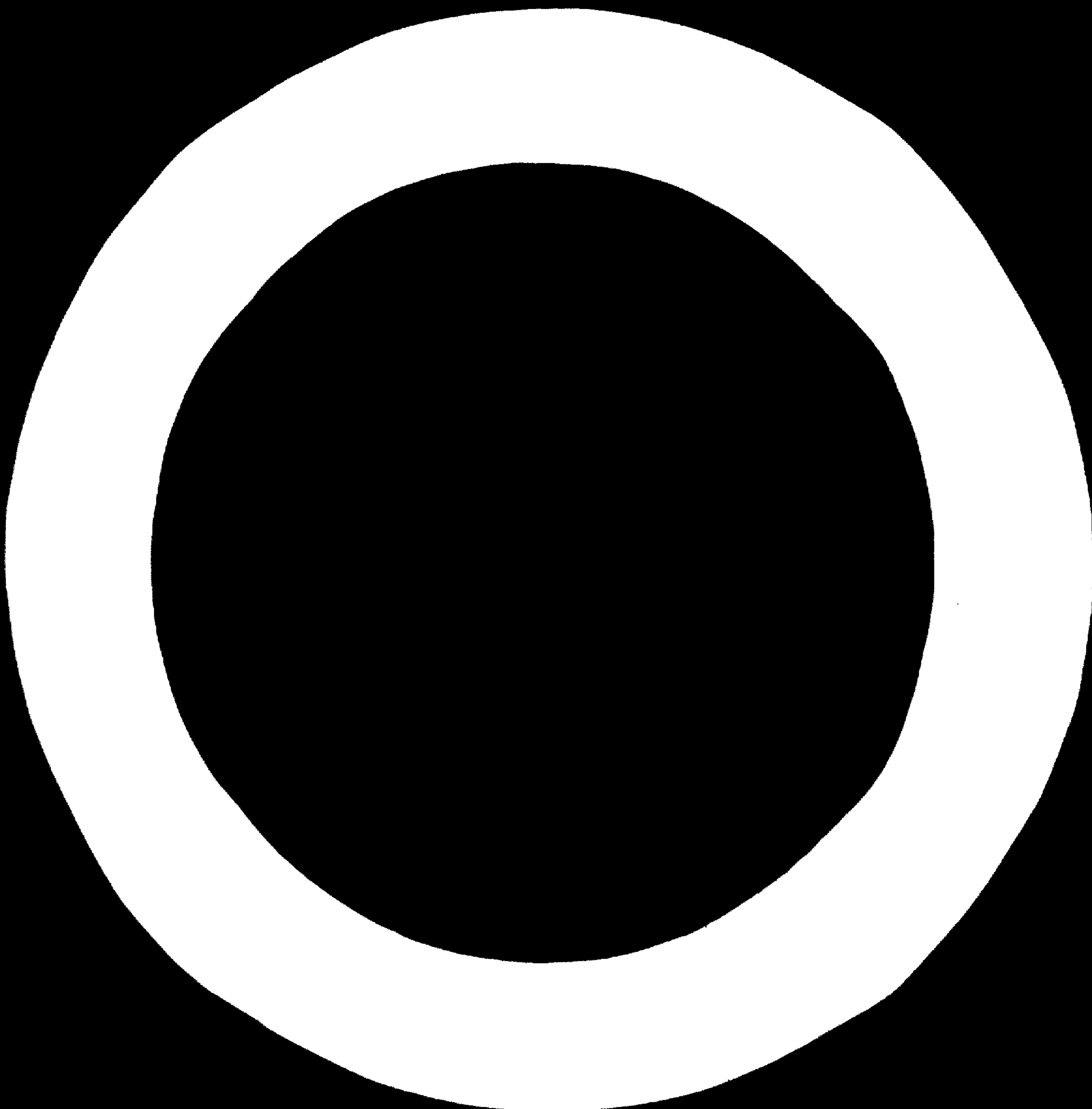

TABLE OF CONTENTS

		Page
	Preface	3
1.	Introduction and Summary	5
2.	The Need for Systematic Project Management (Systematic Planning and Implementation) of Industrial Development Projects	9
3.	Characteristics of Industrial Development Projects	14
4.	Preparation and Use of Information in Project Initiation	23
5.	Preparation and Use of Information in Project Implementation	29
6.	Methods for Control of Project Implementation	57
7.	A Recommended Plan for Achieving Desired Improvements in Project Implementation	75
	Appendix A: Management Control Systems	83
	1. PERT Output	83
	2. Management Action	88
	3. PERT Extensions	89
	4. Status Index	96
	5. Earned Value	103
	6. Cost Information	107
	7. Planned Output	109
	8. Line of Balance	110
	9. Strengths and Limitations of Control Systems	119
	Appendix B: Computer Use in PMIS	125
	Appendix C: Strength and Limitations of Computerised Project Information Systems	129
	Appendix D: Comments Expressed by Participants from Developing Countries	133
	Bibliography	135

TABLE OF FIGURES

		Page
1.	Phases, Stages and Objectives of the Development of Industrial Projects	16
2.	Types of Decision-making Bodies Involved with Project Management	17
3.	Documents to the Ready by the End of each Project Stage	19
4.	Responsible, Performing and other Related Organizations Involved in Electric Motor Factory Project (Project Environment)	28
5.	Organization Structure of ODINU Manufacturing Company	31
6.	Definition of Electric Motor Factory Project (Using a Project Breakdown Structure)	34
7.	Identification of Responsible and Performing Organization and Project Team Members	36
8.	Project Master Plan and Schedule - Electric Motor Manufacturing Factory Project	37
9.	Example of a Task Work Statement	40
10.	Task Action Plan - Segment of Project Network Plan for Factory Production Layout	41
11.	Resource Plan and Budget (Task Budget)	44
12.	Progress Related to the Plan and Schedule	47
13.	Up-dated Project Master Plan and Schedule - Electric Motor Manufacturing Factory Project	48
14.	Information Flows for the Management of Project Implementation	52
15.	Relationship between Information Requirements and Management Levels	56
16.	Schedule Symbols	61
17.	Milestone Status Chart	62

TABLE OF FIGURES
(Continued)

		Page
18.	Milestone Schedule Trend Analysis	64
19.	Narrative Report	65
20.	Master Financial Plan	67
21.	Project Cost Trend Analysis	68
22.	Manpower Report	70
23.	Value of Work Chart	72
24.	Value of Work Analysis	73
25.	Request Form for Obtaining UNIDO Assistance	78
26.	Evolution of PMIS Modules	81
27.	Sequential Relationships of Building Blocks During Evolution of a Project Management Information System	82
28.	Networks	86
29.	Manpower Requirements, Skill Category XX	91
30.	Rate of Expenditure	92
31.	Cost-Time Relationship for a Given Activity	94
32.	Total Project Costs	95
33.	Forecast Cost Using Status Indices	99
34.	Status Indices	100
35.	Labour Cost-Schedule Position	104
36.	Labour Dollars and Overhead Cost-Schedule Position	105
37.	Material Cost-Schedule Position	106
38.	Value Calculation	108

TABLE OF FIGURES
(Continued)

		Page
39.	Gun, Antiaircraft, Production and Material Status	111
40.	Gun, Antiaircraft, Production and Material Status	113
41.	Gun, Antiaircraft, Production and Material Status	114
42.	Gun, Antiaircraft, Production and Material Status	115
43.	PERT and Companion Cost System: Master Schedule	121
44.	PERT and Companion Cost System: Master Financial Plan	122
45.	PERT and Companion Cost System: Management Summary Report	123

How to Improve Industrial Project Planning and Implementation in Developing Countries

PREFACE

In various international occasions developing countries have been expressing their urgent need for a document describing and discussing in a practical way an effective operational approach to alleviating the problems being encountered in implementing industrial projects using certain management disciplines and tools adapted to their prevailing conditions. For this purpose UNIDO - which has been providing technical assistance in this field - organised an Expert Group Meeting on Project Planning and Implementation Information Systems, which was held in Vienna, 13-18 November 1972. The Expert Group comprised eleven experts from both developing and developed countries. The eleven experts participating in this Expert Group Meeting were:

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Richard L. SMITH	Associate Professor of Engineering Arizona State University Tempe, Arizona U.S.A.

The main objective of the meeting was to discuss and exchange views concerning the major problems being encountered by the developing countries in project planning and project implementation, programming and control and how to improve the situation through the development and application of certain management tools, namely project management information systems (PMIS).

1. Introduction and Summary

During the last two decades a great number of developing countries embarked on economic and industrial development planning. Unfortunately, many countries have been giving more attention to the formulation of development plans or programmes than to the course of action needed to implement them. In numerous situations not much effort has been given to the planning and implementation of individual projects which make up these programmes. Experience indicates that there is no formal approach to project planning and implementation in most of the developing countries. Consequently, project work has been falling short of expectations, resulting in lengthy delays and overrun of cost.

Industrial development projects are characterized by being non-repetitive, time-constrained and dynamic as they may involve a high degree of uncertainty and changes over time. They are further characterised by being influenced by a number of agencies or organisations (such as various ministries, investors and a host of other bodies) which constitute what is called the "project environment" and which are beyond the authority of project management. Accordingly, project management (management of project implementation) requires skills and techniques which are somewhat different from those called for by general management (management of existing industrial enterprises or establishments). Planning and control should cope with project characteristics previously mentioned. Rather than a well-defined organisation structure, the project manager must head a flexible, ever-changing organisation. Furthermore, continuous interaction with the project environment mentioned above is essential, for the resources the project manager requires are not under his authority. He has to co-ordinate the work of the various agencies participating in the implementation process and to report to them.

All the afore-mentioned factors dictate that project management needs a total approach or project management system (PMS) to project planning and implementation. A project management system may be viewed as having a number of interrelated functions, namely: organizing, planning, controlling, integrating and co-ordinating the process of project planning and implementation. In performing these functions a project management system calls for certain tools. One prominent tool is what came to be called project management information system (PMIS), in other words, information system for project planning and implementation.

On the basis of its discussions, the Expert Group has prepared the present document with a view to showing how to improve the planning and implementation of industrial development projects. This is achieved through a practical approach to systematic planning and implementation of these projects which is adapted to conditions prevailing in developing countries, thus meeting the long-standing need previously mentioned.

The document, in summary, presents and explains the following:

- There is a real need for improvement in existing methods of implementing industrial development projects (see section 2).
- Industrial development projects in developing countries present many problems which impede their completion on schedule and as originally funded (see section 3.1).
- A number of systematic project management methods which have been developed to overcome similar problems in similar project in more developed countries are available today; some of those are useful in developing countries (see section 3.2.3).
- The fundamental principles of systematic project management can be adapted to the developing country environment; this is described briefly in the report (see section 3.4).
- The best way to achieve understanding of systematic project management principles is through observation on a specific project; for this reason, a case example project is used in the report to illustrate how the principles are applied (see sections 4 and 5).

- The crux of systematic project management is project control; methods of controlling project implementation are described in some detail in the report (see section 6).
- To obtain the improvements described in the report, a carefully planned series of steps is necessary; a recommended plan for accomplishing this is presented in the final section of the report (see section 7).

The information included in the document can be of use to a great number of people at the various organizational levels, who are interested in project planning and implementation. For those who are directly responsible for or working in one or more of the stages of project planning and implementation such as project managers and others at similar organizational levels, project team members, functional staff of organizations dealing with project work, contractors, subcontractors and suppliers of machinery and equipment, the document, in its entirety, provides an operating model to improve project planning and implementation. Some techniques which are being used in programming and controlling the implementation of projects are included in the Appendices to this document. These Appendices may, therefore, be read by those who have prior technical knowledge in the subject matter presented therein.

For those who have no direct responsibility at the project level for planning and implementation of specific project such as executives in state planning organizations or similar bodies, secretaries and under-secretaries of state for industry, heads of development agencies or banks and members of the boards of companies dealing with project planning and implementation, sections 1, 2, 3 and 7 of this document are of value as they highlight some of the issues of special importance and should, therefore, aid in defining specific local problems.

Moreover, this document is so prepared to assist those responsible for project planning and implementation in developing countries in identifying their needs for the technical assistance which UNIDO can provide. UNIDO has been assisting developing countries in alleviating a multitude of problems and shortcomings encountered in this field.

2. The Need for Systematic Project Management (Systematic Planning and Implementation) of Industrial Development Projects

2.1 Statement of Need

Developing countries are faced with the immense challenge of organizing their resources and making decisions concerning the industrial development in order to meet the expanding requirements of their societies. Much effort has, in the past, been concentrated on the running of on-going OPERATIONS: tasks, functions and processes of a similar repetitive nature.

Man's striving for increased security, convenience and wealth, together with the evolution of science and technology have made him engage more and more in large one-time industrial ventures which often go beyond the scope of regular operations in a given institution. 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 referred to as PROJECTS. Projects, in comparison to "operations", have different management characteristics.

In OPERATIONS, the focal point of interest is usually the effective performance of tasks, functions and processes of the same or similar kind. The eventual purpose of the invested efforts or manufactured items is of secondary importance and frequently even unknown to the people involved.

In PROJECTS, the prime motivation is the efficient accomplishment of a final objective. For example, in an industrial project this final objective usually is the putting into operation of a factory meeting the previously established standards of performance, within the agreed time scale and the established budget. For the achievement of such a project objective, where time and money are important and different groups of people which are organisationally or physically dispersed have to work together, the traditional management methods and philosophies used in OPERATIONS become inadequate. For PROJECTS a different management philosophy is required. The contributing and participating people must be motivated so that they become primarily goal- or product-oriented. The attempt to fulfil this requirement leads to a constant battle against human shortcomings and conflicts of interest. It is the object of PROJECT MANAGEMENT to develop and apply adequate techniques, methods and systems which minimize or alleviate these problems.

The basic concept of project management is to plan, organise, 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 major objective, usually a substantial product, facility or system. The essential criteria for project management are:

- Clear, defined final objective;
- Organization of tasks, manpower, finances and other resources oriented towards the final objectives;
- Total technical, financial and schedule responsibility vested in project leadership;
- Constant consideration and thinking in terms of efficient accomplishment of the final objective.

The PROJECT MANAGEMENT SYSTEM, therefore, is the tool or mechanism which is used to develop a product, facility or system from its conceptual stage into reality. It consists of the organizations, policies, procedures, information, methods, systems and practices which are used to plan and implement projects.

2.2 Causes of Difficulties

The decision processes and time necessary to plan and implement a complex industrial development project have resulted in many situations where the government authorities arrive at a decision and later become discouraged when implementation of such projects does not achieve the established objective. The fundamental causes of the mentioned difficulties, which delay and increase the cost of implementing development projects, can be classified as political, environmental, economic and technical. Selected major causes in these categories are stated below for the consideration by developing countries when introducing practical improvements to the manner in which industrial development projects are planned and implemented.

2.2.1 Political Causes

- Political decision-making without sufficient consideration or availability of technical and planning information;
- Tendency of human nature to subscribe to political optimism and to overcommit.

2.2.2 Environmental Causes

- Unsuitability of existing administration structures and practices for efficient project work;
- Inefficient and complicated administrative and management decision-making and planning procedures;
- Emphasis on science and technology rather than on management, resulting in a lack of appreciation for systematic project planning and implementation;
- Difficulty in obtaining agreement and co-operation from many diverse public and private organizations which are needed for project implementation.

2.2.3 Economic Causes

- Incompatability of strategic objectives with socio-economical, economical, technical and other non-political objectives;
- Development plans and programmes not backed by well-studied and well-conceived projects;
- Not applying the systems approach when establishing development programmes which consist of a multitude of projects and operations involving common resources,

i.e. lack of co-ordination and co-operation between government bodies with different responsibilities (e.g. electric power plant project of Department for Energy not considering other industrial development projects of Department of Trade and Industry in pertinent area, etc.).

2.2.4 Technical Causes

- Failure of the technologist and the project planning community to adapt their planning approach to the political/environmental/strategic situation;
- Lack of common language between scientists, technologists, economists and politicians and failure of the technologist to present his information in an understandable form;
- Insufficient and not systematic project organization;
- Too much concentration on individual planning techniques instead of integrating all relevant techniques and methods into a comprehensive project planning concept;
- Inertia of planning system and inability to handle the dynamic characteristics of projects;
- Lag in the development and state of the art of project management methods and techniques compared to science and technology.

2.3 Outlook on Methodology

This document utlines the required methodology for utilising Project Management System concepts to alleviate many of the problems resulting from the causes stated above. It is believed that improved teamwork and co-ordination of politicians, economists and technicians will be accomplished 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 the awareness of the need for identifying specific management responsibilities and the subsequent development of a Project Management System which assists the executives in fulfilling their assigned responsibilitiss. Also recognized is the need for a Project 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 recognises 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.

3. Characteristics of Industrial Development Projects

3.1 Phases and Stages of an Industrial Development Project

When organizing the functions and responsibilities for project planning and implementation, it is important to have a clear picture of the various project phases and stages, the objectives and related tasks of each, the type of decision-making bodies involved and the extent of their desirable responsibility. In the context of this document, the project encompasses all tasks from the problem analysis 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 planning and preparation for 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, etc.) must carry out is the dividing of the project into a series of suitable phases.

When one has to conceive and build any product, facility or system, it must pass through the various phases and stages of evolution. This happens with any idea that must be turned into reality. As the management of a project usually entails the development of a product, facility or system from a notional idea into a finished operational entity, and as this involves various people working together and understanding each other, the rather sophisticated process of product or system evolution needs good organisation. Effective management of a project requires that the project be subdivided into components. One of the essential criteria for breaking a project up into manageable portions is by project stages.

Each stage possesses its own particular developmental characteristics and thus requires a changing emphasis on the various types of information and control procedures to assure effective management.

Based upon the maximum available knowledge about the entire project in a given project stage, the remaining stages must be planned and replanned such 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 in a systematic manner.

In Figure 1 is a table indicating the project phases and stages and pertinent objectives, which will meet the demands of most industrial projects. The planning structure may have to be adapted to the needs of the various projects. It is recognised that there is not always a clear-cut separation between the stages and that sometimes they even overlap. The essential point here is the clear and systematic organization of as many tasks and jobs as possible throughout planning 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 and an appropriate responsibility matrix is given in Figure 2.

1) Higher Authorities (Development Strategy and Policy, Target Approval)
2) State Planning Board
3) Project Execution Agency
4) Project Manager/Project Co-ordinator/Study Manager
5) Assistant Project Managers

	Phase No.	Stage	Objectives
Preparation or Initiation Phase	1	Identification of project idea (preliminary analysis)	Project(s) and programme goals identified and analyzed. Project objectives and preliminary global schedule and cost estimate determined.
	2	Preliminary selection	Notions and 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	Post feasibility evaluation Evaluation and decision	Decision on adoption of the most promising alternative solution. Funding provided.
Implementation Phase	5	Detailed project design and engineering; and initial project implementation, scheduling	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	Construction and Pre-operations (system implementation, start-up)	Completed, tested, "debugged" and accepted product, facility or system (optimum performance, time and cost).
Operation Phase	8	Operations (not a project phase but listed for interface purposes and programme continuity)	Product, facility or system operational at all times and optimum cost.

Figure 1. Phases, Stages and Objectives of the Development of Industrial Projects

	Stages of Industrial Development Project	Decision-making Bodies							
		Higher Authorities Council for Planning 1/	State Planning Board	Project Implementation Agency	Project Manager 2/	Assistant Project Manager	Con-tractors 3/	Subcon-tractors	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	Post feasibility evaluation Evaluation and decision	a	a	b	b				
5	Detailed project design and engineering; and initial project implementation, scheduling		c	a	b	b	b/c	c	c
6	Contracting and purchase			a/b	a	b	b	b	c
7	Construction and pre-operations (system implementation, start-up)			b	a	b	b	b	b

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

1/ Development strategy and policy, target approval
2/ or, Prime contractor
3/ or, Project co-ordinator

Figure 2. Types of Decision-making Bodies Involved with Project Management

6) Contractors, Prime Contractor
7) Subcontractors
8) Suppliers

The matrix in Figure 2 is only a guideline and may have to be adapted to the different types of projects and initiators' hierarchy. It is essential that only one body is given prime responsibility to the greatest extent possible within the same project phase and that all other supporting and/or assisting bodies co-operate closely and freely in a concerted teamwork effort.

The project stages can be classified into two major phases:

- Project initiation or preparation
- Project implementation

Project initiation phase has its impact on project implementation phase as the latter depends on the efficiency with which the work in the former is undertaken. Since project implementation is primarily based on project preparation, deficiencies resulted in the latter would affect the satisfactory undertaking of the former. The event which forms the interface between these major project phases is approval of the project for implementation and authorisation to spend major funds. This classification of stages together with the essential documents to be produced by the end of each relevant stage are indicated in the flow diagram of Figure 3. If this principle is followed, responsibility conflicts and/or gaps can be kept to the very minimum and communications between the various project participants are considerably improved.

3.2 Systematic Management of Projects

The systematic management of projects is frequently regarded as project management system. A modern project management system consists of a series of compatible and well-aligned organisation of responsibility and information mechanisms, procedures, tools, facilities, etc., which enable an efficient handling of all project matters throughout all phases and stages. It is somewhat comparable with a business enterprise.

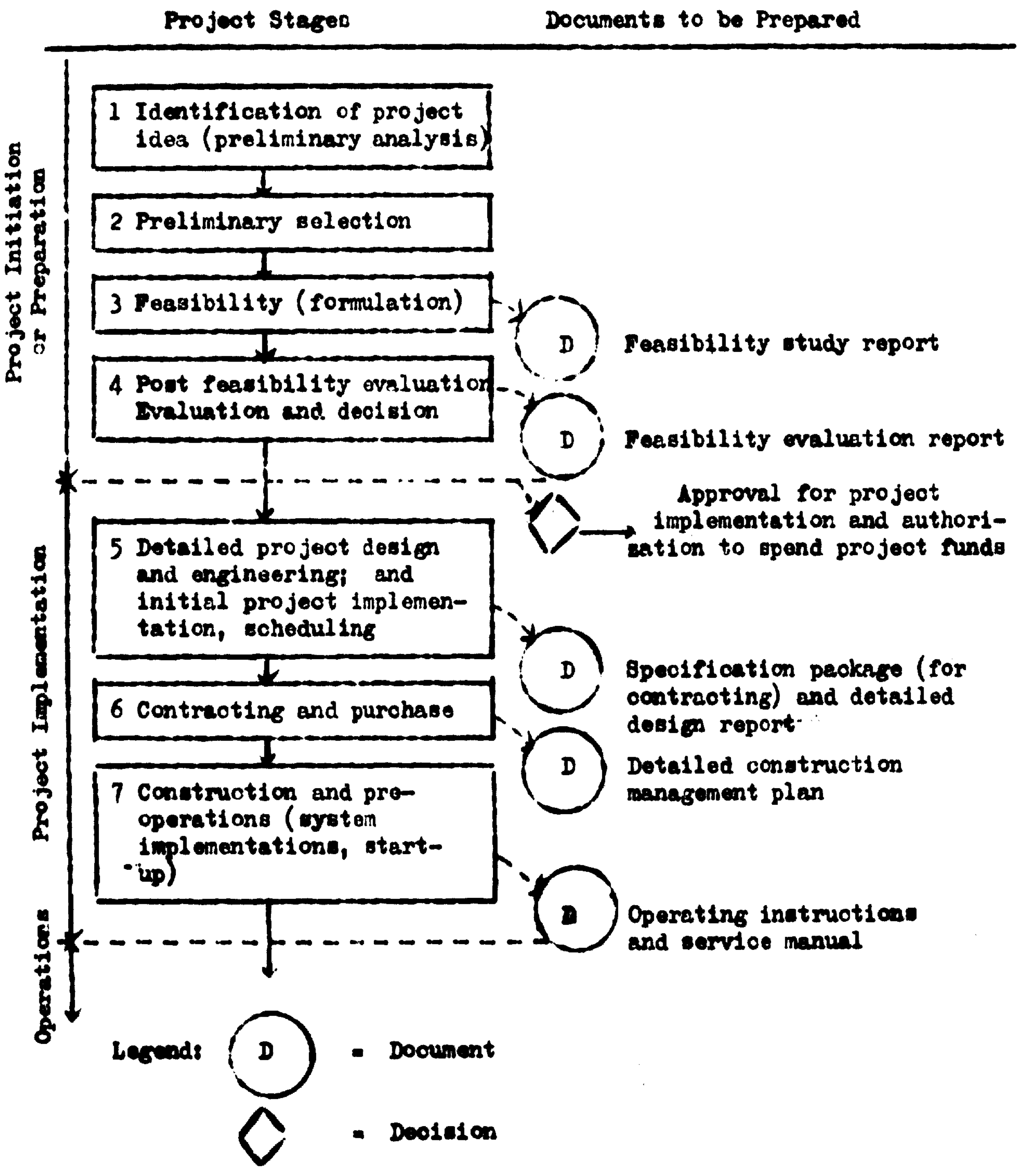


Figure 3. Documents to be Ready by the End of each Project Stage

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

a) Procedures, standards and specifications
b) Work breakdown structure (WBS)
c) Task descriptions
d) Project organization structure
e) Project staff
f) Communications
g) Information processing (manual and/or automatic)
h) Documentation

3.3 The Project Management Information System (PMIS)

3.3.1 General

Although the PMIS in the framework of a comprehensive project management system is considered a "subsystem", it shall, for the sake of simplicity in the context of this document, henceforth be called a "system".

The PMIS shall be considered a self-contained operational entity, which provides all relevant project participants and higher level decision making bodies with essential and meaningful project information to programme, schedule and control the project. A PMIS can only give the full benefit and be a real success if it is treated as an integral part of the total project management system.

3.3.2 Functions of PMIS

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

a) To develop plans, schedules and standards against which later on project execution can be measured;
b) To provide useful information concerning what is to be done and when each action should be taken, to all contributors to the project;

c) To generate and extract from the field all essential progress information;

d) To transmit the field information to the project management office;

e) To verify, analyse, compare and synthesise this information to obtain meaningful summaries, lists, graphs, tables and other suitable displays upon which significant conclusions can be drawn and sound decisions taken;

f) To convey the processed and reduced management information to the concerned management bodies and project staff, and to ensure that the information is assimilated by the recipients;

g) To revise and/or re-develop, upon appropriate management decisions, the project plans and standards;

h) To convey the revised information to all project contributors;

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

3.3.3 Constituents of a PMIS

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

a) People
- Implement;
- Operate;
- Use results.

b) Policies
- Enabling establishment of PMIS;
- Enforcing required discipline to maintain and operate.

c) Procedures
- Planning;
- Data preparation, collection;
- Data processing: Manual
  Computer-based;
- Data display;

- Project evaluation;
- Contact management;
- Simulation and analysis.

d) Facilities
- Office;
- Data processing;
- Project control room.

3.4 Consideration for PMIS Design and Implementation

The development, design and implementation of a PMIS has presented many problems. The size, complexity and decentralisation of today's industrial projects demand a systematic approach to the problem of management information and data handling. The individual methods of phased project planning, network analysis, work package cost control, etc., must be integrated, together with the human being into a comprehensive system - the PMIS. The difficulties in PMIS do not so much lie in the technical design and development, but 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 sections, these concepts are illustrated in a practical manner using a typical industrial development project as a vehicle. As demonstrated by this example, a useful PMIS can be completely manual, and does not depend on advanced computer-based systems. Each organisation implementing a PMIS should progress from the initial manual procedures to more advanced systems as their understanding, capabilities and the complexities of their projects increase.

4. Preparation and Use of Information in Project Initiation

In the following sections a case project is used to illustrate the application of the previously defined initiation stages of a PMIS as applied to an industrial development project. In reality, the details of the application of each phase would have to be determined for the specific needs of the project in question. The initial statement of the case project, necessary to illustrate the first few stages up to and including the Project Evaluation Stage, is defined as follows:

INITIAL STATEMENT OF THE ELECTRIC MOTOR FACTORY CASE PROJECT

"The government of a particular country is faced with the idea that it should in the future mass produce small electric motors. In order to properly 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. It is known that in the same country there already exists an electric motor manufacturing facility known as the ODINU Manufacturing Company."

4.1 Application of the Initiation Stages to the Electric Motor Factory Case Project

4.1.1 Identification of Project Idea (Preliminary Analysis) Stage

The higher government authorities who have developed the idea that an Electric Motor Factory should be built must confirm the initial needs, analyse those needs and state the requirements. Requirements to be considered include:

- Marketing requirements and plans;
- Specification of production plans (types of products, number of units, production rate, price, manufacturing cost, etc.);
- Formulation of the manufacturing processes (flow-diagrams, charts, etc.);

- Finance (funds required, sources, terms);
- Technical and economic requirements;
- Resources (manpower, materials);
- Schedules.

4.1.2 Preliminary Selection Stage

The State Planning Board shall consider the results of the "Identification of Project Idea (Preliminary Analysis) Stage" and turn those notional plans into alternative concepts. Development of alternatives and their resulting advantages and disadvantages could be presented as follows:

4.1.2.1 Alternative A

Expansion of the existing main plant of the ODINU Manufacturing Company at $1.5 million within 18 months from final decision to implementation.

Advantages:

1) Effective utilization of existing organization and facilities;
2) Capitalization on larger labour supply and use of present local personnel to train new manufacturing operators;
3) Easy transportation of raw materials, components and finished products from and to market;
4) No energy problem.

Disadvantages:

1) Over-concentration of industry in an already well-developed city;
2) Further aggravation of local traffic and housing problems;
3) Building, pollution and other restrictions.

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

4.1.2.2 Alternative B

Construction of a new plant in a small, less-developed town, 300 kilometers from home plant at $2.0 million and within 20 months from final decision.

Advantages:

1) Assists in developing a new region of the country;
2) Overcomes disadvantages related to overcrowding, traffic, housing, etc.;
3) Provides jobs for a growing population in new location;
4) Easy introduction of new manufacturing techniques, methods, processes, etc., and labour practices.

Disadvantages:

1) Separation from home plant; communication and transportation problems as well as increased overhead cost for factory management;
2) Possible rivalry between the two plants;
3) Higher investment cost and shortage of experienced labour;
4) Slightly longer time period to complete the project.

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

4.1.3 Feasibility (Formulation) Stage

In the feasibility study stage, it is necessary to further analyse the alternatives to sufficient detail in order to permit a sound selection of one alternative during the next phase. Elements of the analysis include the following items:

- Establishment of evaluation criteria and weighting factors (e.g. environmental, technical, economic and social, etc.);
- Performing cost versus benefit analyses;
- Operations research studies if necessary (simulation, linear programming, etc.);

- Development of rough, preliminary breakdown of the project elements;
- Development of bar chart schedules into rough, preliminary network plans using established networking procedures (PPS, CPM, etc.) covering all future stages including production start-up;
- Development of preliminary cost plans;
- Verification of financing sources, terms and conditions for each alternative;
- Clarification of the availability of project resources;
- Evaluation and assessment of the alternatives based on the established criteria.

4.1.4 Post Feasibility Evaluation (Evaluation and Decision) Stage

In continuing the discussion of the Electric Motor Factory Case Project, the higher government authorities shall consider the results of the "Feasibility (Formulation) Stage" and in joint consultation with all relevant decision-making bodies select the most suitable alternative. Items to be considered in this phase include:

- Distribution of the project study report with decision guidelines to all concerned;
- Consideration of the project study report in detail;
- Conducting meetings with relevant decision-making bodies for final selection and adoption;
- Making final selection of the alternative and obtaining the necessary approvals to proceed with the project implementation.

4.2 Practical Differences between Project Initiation Stages and Implementation Stages

While the project initiation stages in this example could be organised systematically in a sequential time dependent manner, it is not necessarily feasible for all the stages of project implementation. In Figure 1 the stages for project implementation were depicted as being sequential in nature because it is convenient and practical to think in this context about the tasks to be carried out. In practice the stages sometimes overlap or are not continuous in time; therefore, it is not always possible to apply the staged implementation approach in a strict manner. In reading the following sections concerning the application of systematic project management concepts to 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.

4.3 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 related to all appropriate agencies of the government. These relationships define the organisational project environment. The project environment for the case project is shown in Figure 4

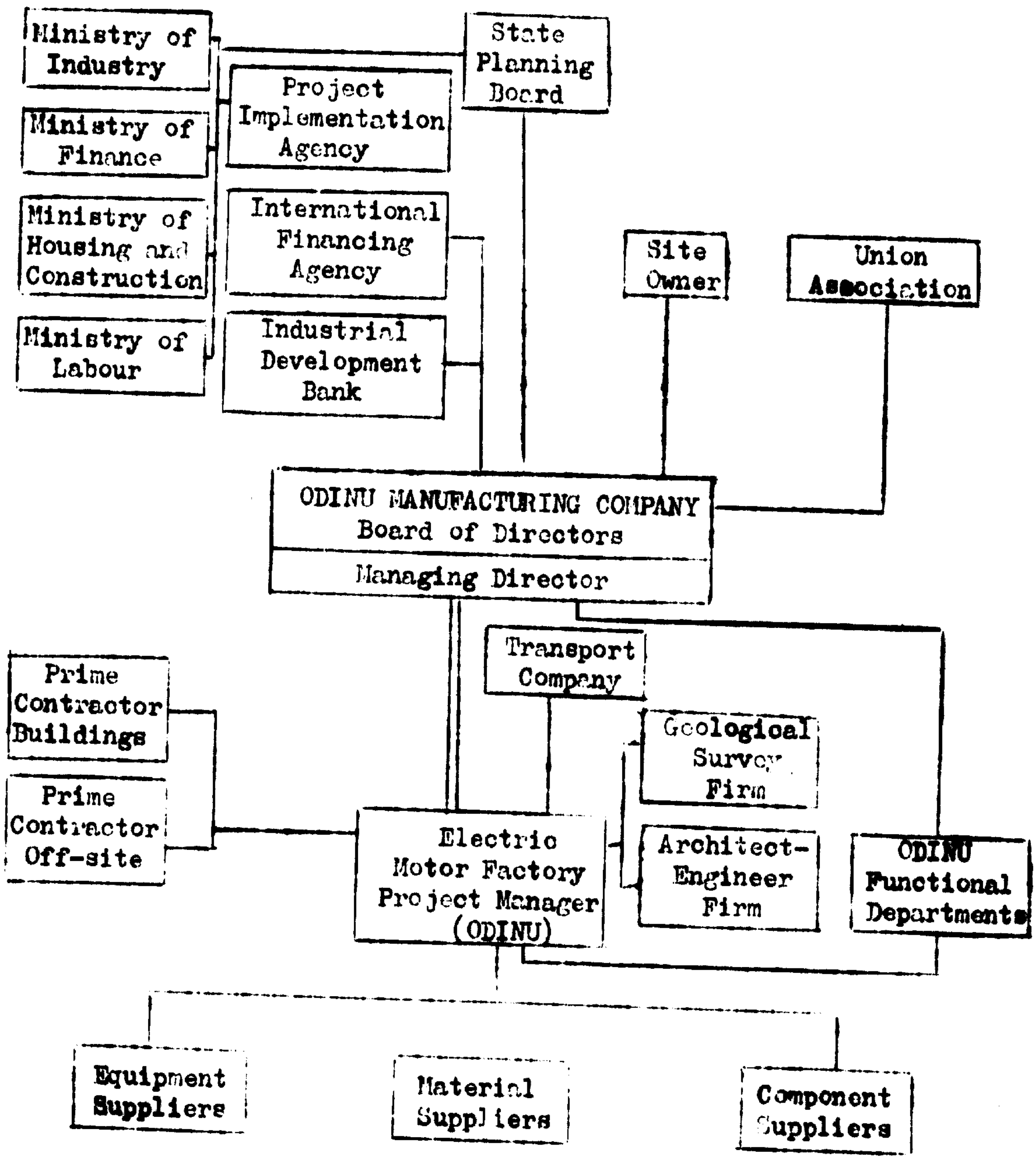


Figure 4. Responsible, Performing and other Related Organisations Involved in Electric Motor Factory Project (Project Environment)

5. Preparation and Use of Information in Project Implementation

5.1 Preparing and Using Information for the Electric Motor Factory Case Project

Many types of information are needed to implement industrial development projects. The requirement in this regard is to prepare and use this information in a systematic way, to assure that the project will achieve its technical objectives within planned cost, and as close as possible to original schedule.

In this section of the document the Electric Motor Factory Project will be used to illustrate the preparation and use of the needed information. The approach which is illustrated is systematic in nature, and later sections of the document will describe the flow of this information in systematic terms.

5.1.1 Start-Up of Project Implementation

The Board of Directors of the ODINU Manufacturing Company decided to proceed with implementation of the Electric Motor Factory Project following receipt of all necessary governmental and other approvals.

1) A shortage of qualified labour exists in the small city where the new plant will be located. This may require special actions and approvals of the Ministry of Labour and possibly the State Planning Board.
2) 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 dramatically after this Conference. Therefore, it is extremely important that all contracts be signed and approved, and production equipment ordered, prior to this Conference. If more detailed planning of the implementation stage indicates that this can not be achieved, the Board of Directors has resolved that the project will be deferred until after the Monetary Conference and re-evaluated at that time before initiating its implementation.

The organization of the ODINU Manufacturing Company is shown in Figure 5. On the day of the decision to proceed with implementation, ODINU's Managing Director appointed Mr. Clay as a full-time Project Manager for the new Electric Motor Factory Project. He was assigned the responsibility for the project. In a meeting with the new Project Manager and all ODINU Department Directors and Managers, the Managing Director stated:

"This Electric Motor Factory Project is very important to both the ODINU 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 ODINU 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 decision is necessary

"There will be many outside influences on the project which neither Mr. Clay nor I can control. But we have decided that, in spite of these uncertainties, we must plan and control the implementation of this project very systematically. For example, it is imperative that we have all contracts approved for construction and equipment prior to the International Monetary Conference to be held eight months from now. If it appears that we cannot achieve that milestone, then we will postpone all work on the project until the effects of the Monetary Conference are known."

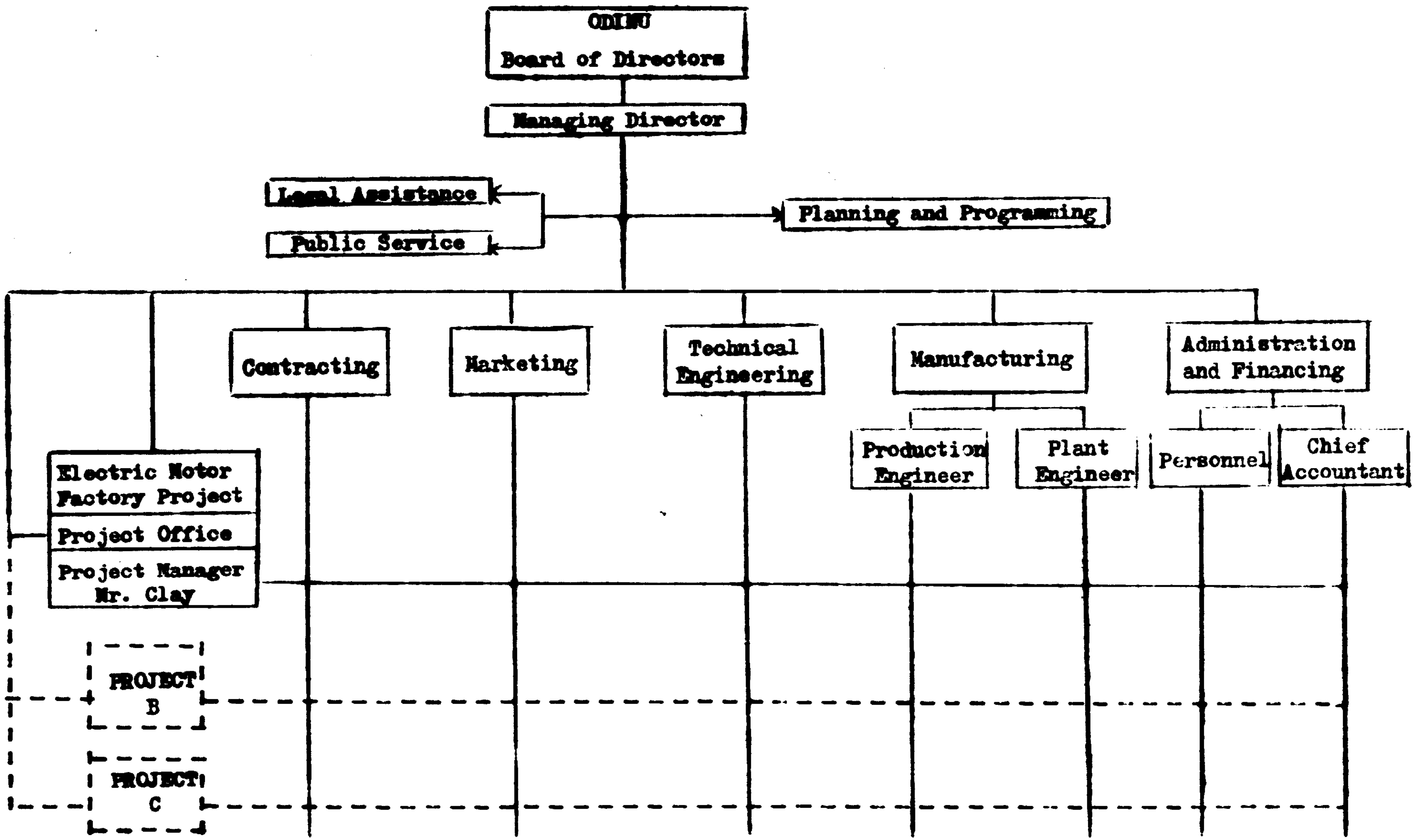


Figure 5. Organization Structure of ODINU Manufacturing Company

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

5.1.2 The Information Needed for Project Implementation

The information needed for project implementation consists of seven major types:

1) Project Financing Information
   a) Project Financial Plan;
   b) Progress reporting and document control.
2) Information Defining Project Scope and Breakdown
   a) Project structure and scope;
   b) Responsible and performing organization.
3) Project Action Planning and Control Information
   a) Master plans and schedules;
   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) Contracts and work orders;
   b) Expenditure records;
   c) Work and resource (funds, manpower) control information.
6) "Product" Information
   a) Descriptions, drawings and specifications;
   b) "Product" control information.
7) Environmental Information

Each of the seven types of information will be illustrated in the following paragraphs using the Electric Motor Factory Project. (It is of interest to note that each of these seven information categories may be considered to be a module of a Project Management Information System.)

5.1.3 Project Financing Information

a) Financial Plan

The financial plan for the project developed during the project initiation phase is revised as required, covering all costs throughout the period of project implementation. It includes identifying and synchronising the various sources of funds, the use of each category of funds, and the means of repayment.

b) Progress Reporting and Document Control

All documents needed to obtain release of funds and 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.

5.1.4 Information Defining Project Scope and Breakdown

a) Project Structure

What is needed here is a systematic, understandable and useful definition of the project. This information is prepared in the form of a project breakdown structure (PWS), which includes all elements of the project regardless of responsibility. Figure 6 shows the results of this planning step for the Electric Motor Factory Project. In this case, there are five components at level two, 17 elements at level three and 26 sub-elements or major tasks at level four. Further definition of the project could be carried out, resulting in the identification of additional elements (especially at level four).

It should be noted that this is not an organisation structure, 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 organisation will have responsibility for the work. In actual practice, more detailed descriptions of each element would usually be prepared.

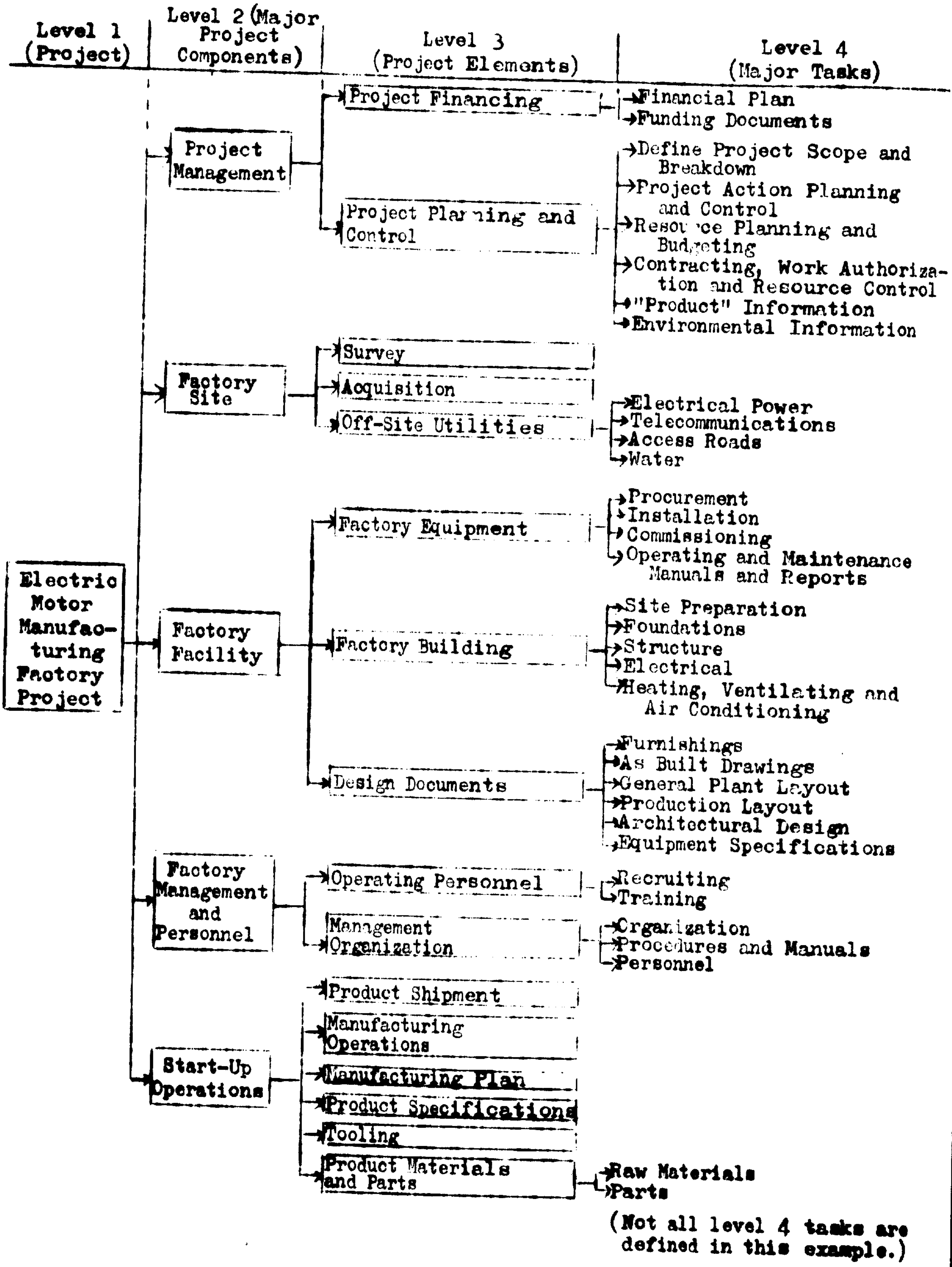


Figure 6. Definition of Electric Motor Factory Project (Using a Project Breakdown Structure)

b) Responsible and Performing Organizations

In addition to the departments identified in Figure 5, "Organization Structure of ODINU Manufacturing Company", many outside organizations will be involved in the project implementation actions. These organizations were identified in Figure 4 (page 28). A systematic way of showing how all of these organizations are related to the various elements of the project will produce significant benefits. This is accomplished by relating the organizations to the project breakdown structure shown in Figure 6. The result, partially illustrated, is presented in Figure 7, "Identification of Responsible and Performing Organization and Project Team Members".

Each individual who is 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 is successful.

In practice, specific names of every organization and project team member would be entered on the project breakdown chart. This chart is reviewed during its preparation by all these persons. A major benefit derived from this step is the conveying to every Project Team Member of a full understanding of the project scope and his specific responsibility in relation to the other team members.

5.1.5 Project Action Planning and Control Information

a) Master Plan and Schedule

Using the project breakdown structure and the information contained in the Project Feasibility Study, the Project Master Plan and Schedule is prepared. Figure 8 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.

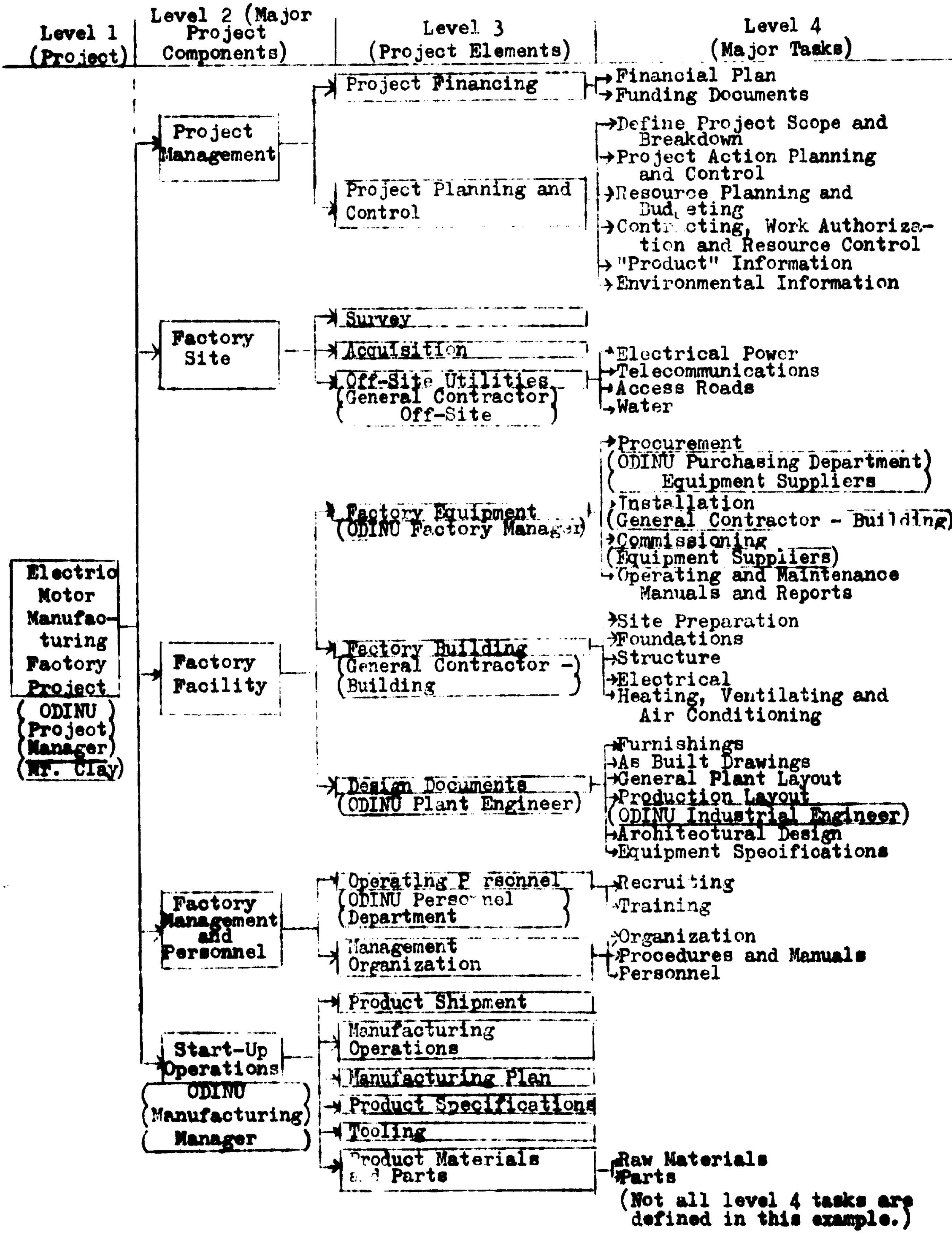


Figure 7. Identification of Responsible and Performing Organization and Project Team Members

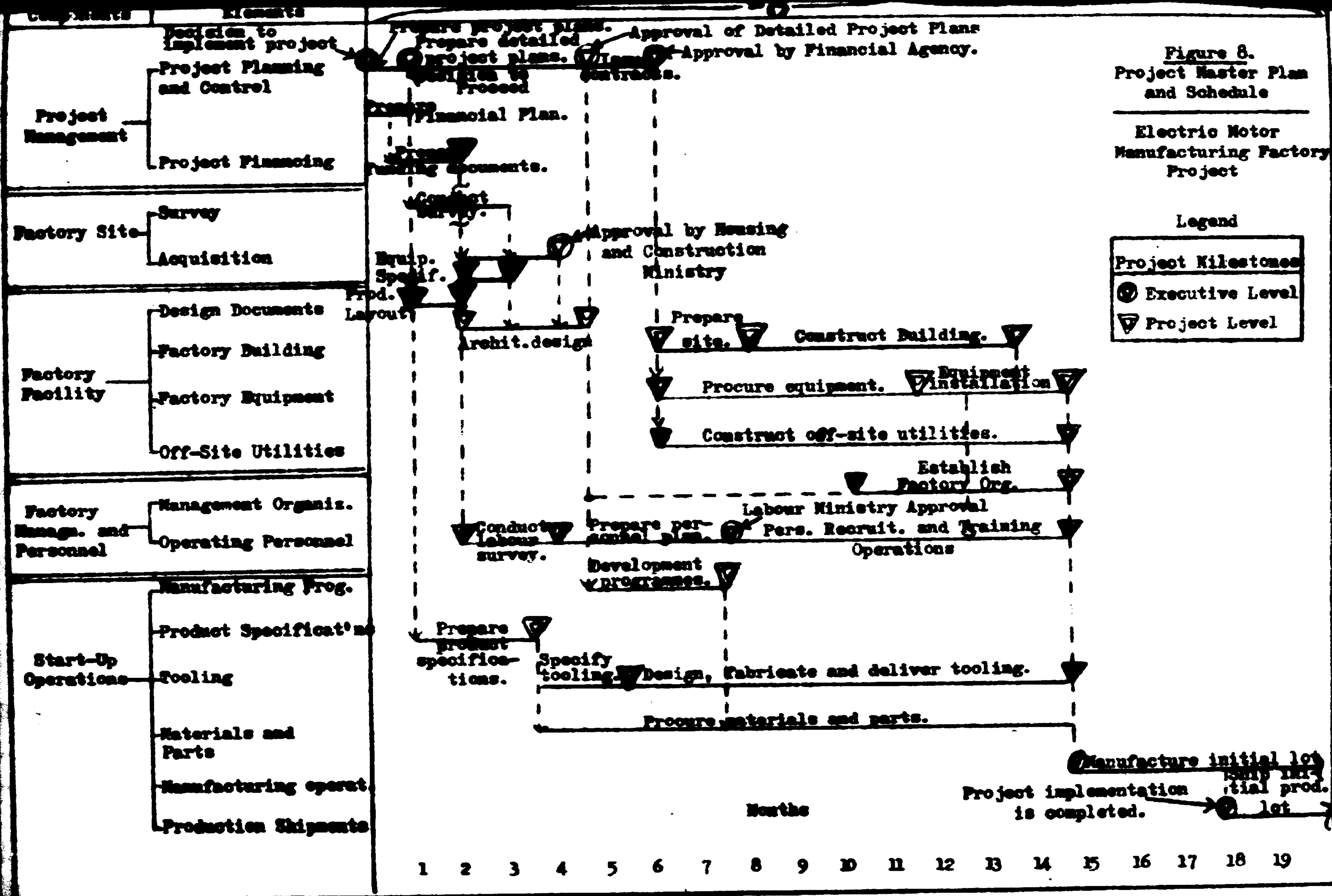


Figure 8.
Project Master Plan and Schedule

Electric Motor Manufacturing Factory Project

The milestones shown in Figure 8 are important elements of the plan. A milestone is a designation given to the occurrence of an event of particular importance to the project. Some milestones may be of greater significance than others. In Figure 8 nine "executive level" milestones are identified, plus 24 "project level" milestones. 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 Section 6 of this document.

The Project Master Plan and Schedule must portray all elements and tasks in the project, their key inter-relationships and all important decision, approval and authorization events. The initial Master Plan and Schedule is a target which will be confirmed as detailed task plans and schedules are established, and major contracts are approved by both parties. When detailed planning is complete, the Project Master Plan and Schedule becomes a fixed target which can be changed only by decision of the Project Manager or higher authority.

b) Task Work Statements and Action 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:

1) Its higher level "parent" element of the project breakdown structure;
2) Responsible and performing organizations and individuals;
3) Work statement;
4) Inputs or pre-requisites required to start the work;
5) Specific results to be produced;
6) Target scheduled start and completion milestone event dates, if known.

Figure 9 presents an example of a Work Statement for one task within the case example project.

An Action Plan for each task is prepared, reflecting the information contained 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, as suited to the complexity of the task and the overall 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 building construction in the case project, a separate sub-network may be prepared.

Figure 10 shows the portion of the detailed project network plan related to the task described in Figure 9. The overall 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 inter-relationships and time constraints between tasks.

c) Work Schedules

Analysis of the overall project network plan (if needed due 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 assure that the predicted times agree with the desired schedule. In some cases, re-scheduling of the tasks or even the project is required. (Extensive literature is available describing planning and scheduling with network plans.) After analysis and consideration of all factors, a firm Task Schedule is established, with dates for every task milestone as well as 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 later stages, each responsible person reports his actual progress for comparison

TASK WORK STATEMENT

PROJECT: Electric Motor Manufacturing Factory Project

PARENT PROJECT ELEMENTS: Design Documents (level 3)
Factory Facilities (level 2)

TASK: Prepare Factory Production Layout Plan

RESPONSIBLE: ODINU Plan Engineering Department, Mr. A., Department Manager

PERFORMING: ODINU Plant Engineering Department, Mr. B., Industrial Engineer

WORK STATEMENT:

Prepare a detailed, 1 to 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 — From Project Feasibility Study
3. Preliminary equipment specifications

RESULTS TO BE PRODUCED:

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

SCHEDULED DATES:

Start: 2 January 1973

Complete: 16 January 1973

Figure 9. Example of a Task Work Statement

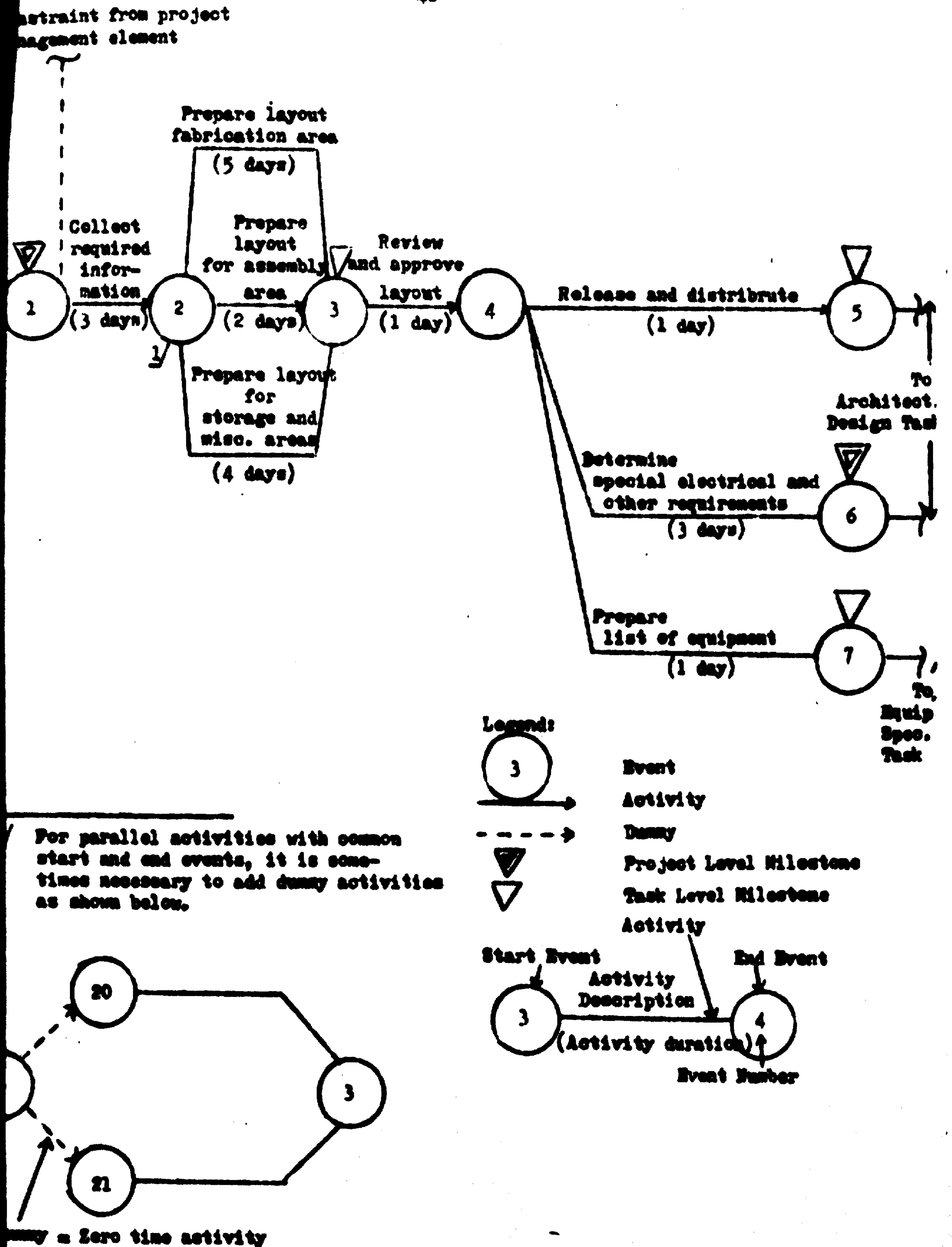


Figure 10. Task Action Plan
Segment of Project Network Plan for Factory Production Layout

to the plan and schedule. This is done by reporting:

1) Work Accomplished: Activities completed (with date of completion);
2) Work in Progress: Time required to complete in-progress activities:
3) Future Work: Any changes in duration, definition or sequence of future activities, reflecting additional knowledge acquired during the work to date.

These three steps require some further explanation. 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 10) has been completed on or before the "Status Date". (The "Status Date" is the effective date of the up-dating of the plan and collection of all required information)

In the second step, the status is reported of all activities which have been started but are not yet completed. The most vital information is not the "percentage complete" which is frequently emphasized, but rather is the amount of time required to complete each activity now is progress. In estimating this time to complete, the Project Team Member must be realistic, and base his estimation the rate of progress made to date and with available resources under the current conditions. If he uses a higher rate of progress, there must be some justification for this, such as additional people 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 to the plan should be made because of new information or improved understanding of the project. If major changes are required which may affect other tasks or the overall project, they must be integrated and analyzed by the Project Manager to determine their overall effect prior to approval and re-scheduling of tasks.

5.1.6 Resource Planning and Budgeting Information

a) Manpower and Cost Estimate

Using the Task Work Statement (Figure 9) and the Task Schedule, the responsible Project Team Member plans and estimates the resources (funds, skilled manpower, etc.) 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 11 shows this information for the Factory Production Layout Task.

5.1.7 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:

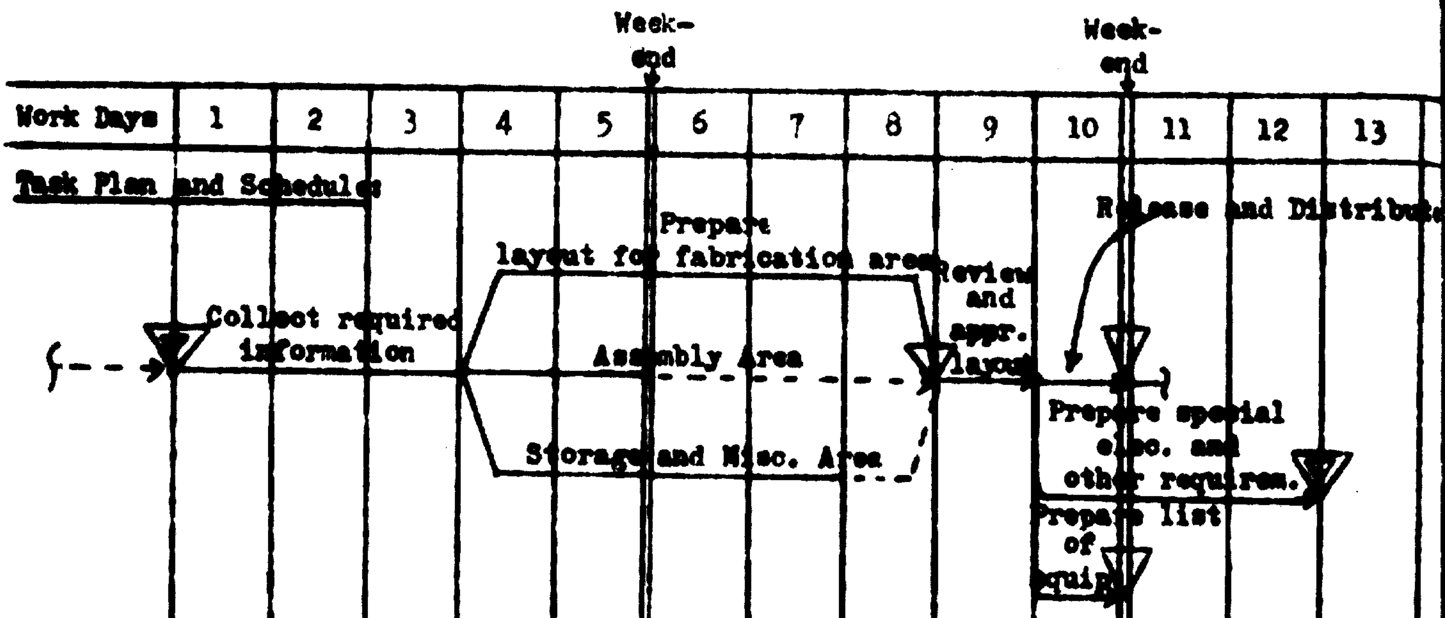
1) Task Work Statement (information as shown in Figure 9);
2) Task Milestone Event Schedule (from the Task Schedule);
3) Summary of the Task Budget (from Figure 11);
4) Approving, authorizing and accepting signatures:
   - Project Team Member (responsible person);
   - Functional Department Manager;
   - Project Manager.

For the Electric Motor Factory Project, Work Orders were issued for the following tasks:

1) Development of project financing information;
2) Development of project planning and control information;
3) Preparation of general plant layout;
4) Preparation of factory production layout;
5) Preparation of equipment specifications;
6) Preparation of product specifications;
7) Issuance of contracts;

Work Days	1	2	3	4	5	6	7	8	9	10	11	12	13

Task Plan and Schedule:



Manpower Plan and Budget:

	1	2	3	4	5	6	7	8	9	10	11	12	13
Senior Industrial Engineer	1	1	1	1	1	1	1	1	1	1	1	1	
Industrial Engineer		1	1	1	1	1	1	1	1	1			
Draftsman				1	1	1	1	1	1	1			
TOTAL	1	2	2	3	3	3	3	3	3	3	1	1	

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

Figure 11. Resource Plan and Budget (Task Budget)

8) Preparation of personnel plan;
9) Recruitment and training of personnel;
10) Establishment of factory organization;
11) Development of manufacturing plan;
12) Specifying or designing of tooling;
13) Procurement of materials and parts;
14) Manufacturing of initial production lot;
15) Shipment of initial production lot.

Contracts are required for formally authorizing the execution of major tasks to be performed by organizations outside the company. For the case project, contracts were prepared, reviewed, approved and issued, based on the Task Work Statement and Budgets established for:

1) Site survey;
2) Site acquisition (land purchase);
3) Architectural design;
4) Building construction;
5) Production equipment procurement;
6) Tooling procurement;
7) Production equipment installation;
8) Off-site utilities construction;
9) Production materials and parts procurement.

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. As a simple illustration, for the Factory Production Layout Task, this information would appear as follows:

Work Day	1	2	3	4	5	
Budgeted Manpower	1	2	2	3	3	(from Figure 11)
Actual Manpower Expended	1	1	1	2	3	(reported by responsible Project Team Member)
Difference[2/]		-1	-1	-1		3 man days below budget

2/ (-) means underspent; (+) means overspent.

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

c) Control Informati n

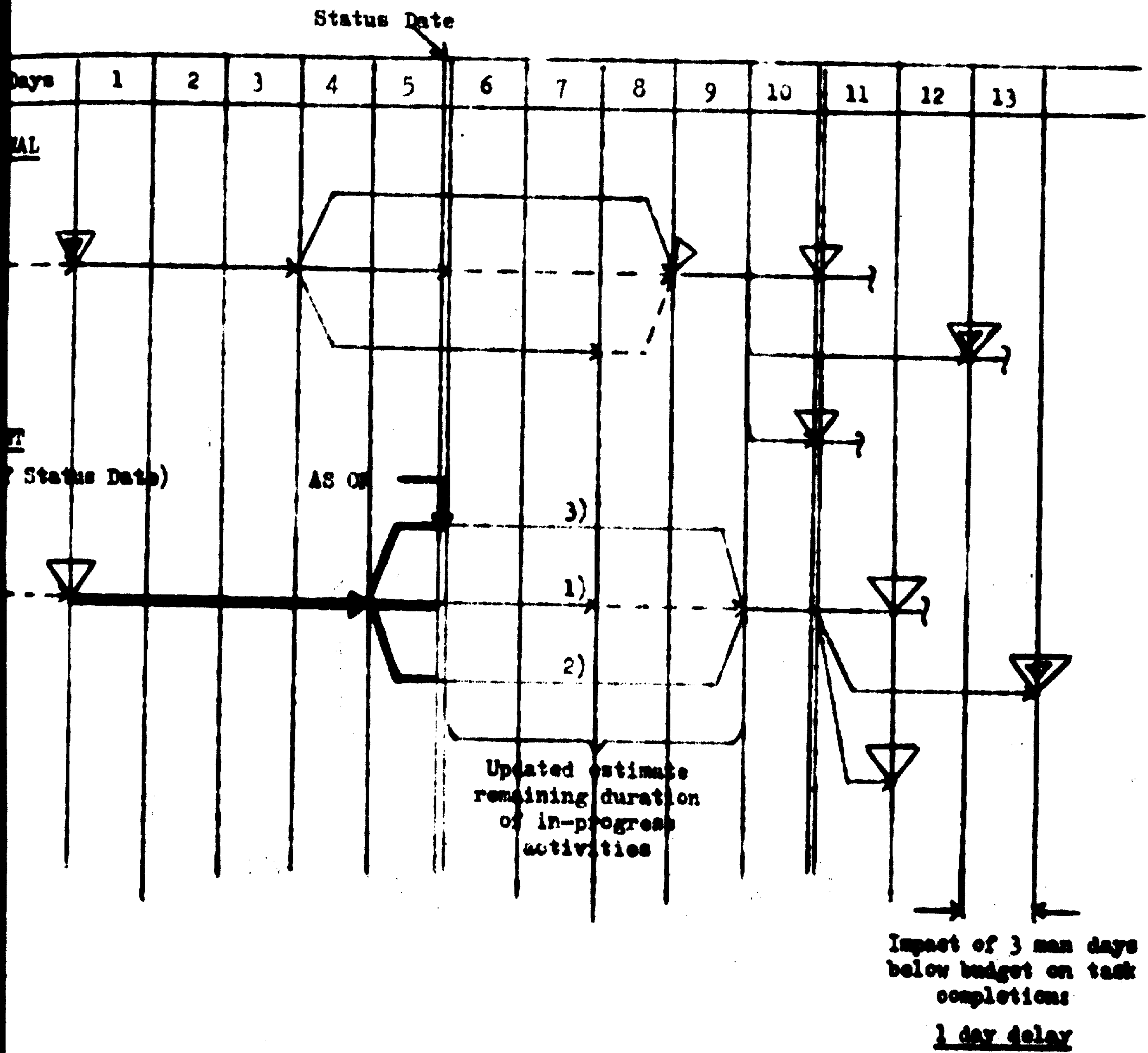
1) Task Control

The above comparison of actual expenditure with the budget generates valuable control information. In the example used, the expenditure is three man-days below budget This immediately raises the question whether or not the task is falling behind schedule as a result. The physical progress report (described earlier in paragraph 5.1.5-d) 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 in-progress activities. Using the network from Figure 11, the effect of actual progress on the future plan becomes evident, as shown in Figure 12. In this case, the entire task will be delayed by one work day, apparently as a result of the three man-day shortage of the manpower expenditure.

2) Project Control

Figure 13 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 (up-dated) estimate to complete.

Summ ries of this informatic can be made for ach 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 overall project total, as represented in Figure 13. Reporting of task information to the Project Manager and higher levels is discussed in Section 6, which describes control methods for use by the Project Manager.



1) Delayed for two work days.

2) Delayed for one work day and has become critical.

3) Delayed for one work day and retained criticability.

Figure 12. Progress Related to the Plan and Schedule

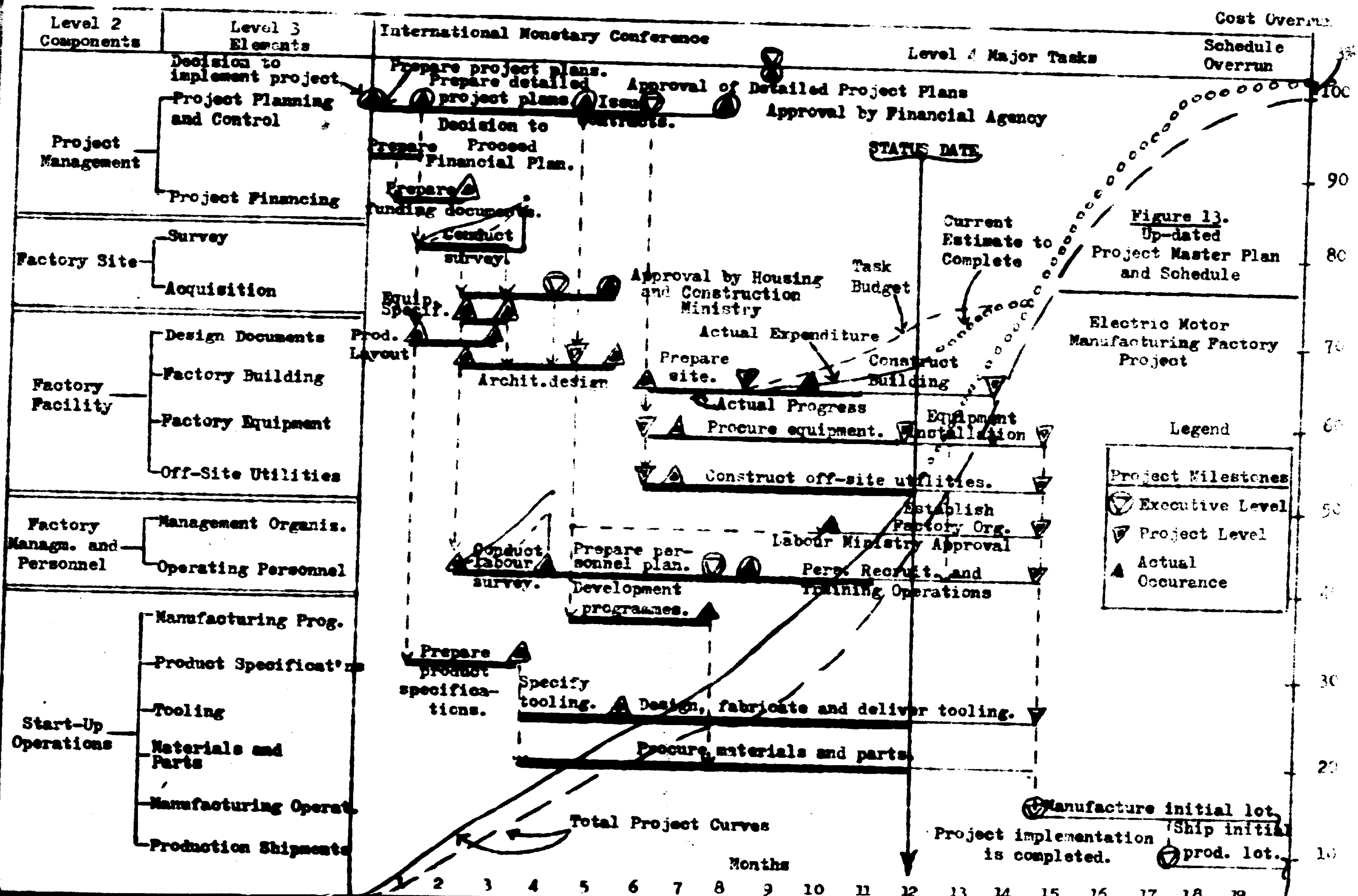


Figure 13. Up-dated Project Master Plan and Schedule

Figure 13 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 in order 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 Section 6.

5.1.8 "Product"[3/] Information

a) Descriptions and Specifications

The case project will produce the following primary end results:

1) An operating factory, including site, building, equipment, materials, tools and operating manuals;
2) Access roads, water, electrical and telecommunication facilities;
3) A management organization, including personnel and procedures;
4) Trained operating personnel;
5) One lot of finished electric motors (the first production lot).

Information regarding these general products would include:

1) All drawings, site plans, specifications, contracts, etc., related to the physical facilities;
2) Management charts, records, policies and procedures related to the operation and management of the factory;
3) Personnel records;

3/ The word "product" is used here in a very broad, general 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, consumable products, etc.

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

In addition to these end item products, a number of intermediate products of the project are created. These include:

1) Management plans and schedules;
2) Financial plans;
3) Funding documents;
4) Preliminary factory and equipment specifications and drawings;
5) Temporary facilities;
6) 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, careful control of changes in specifications, contract terms and conditions, budgets plans and schedules must be exercised. Each proposed change must be reviewed and approved prior to 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 generate significant increases in contract costs.

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:

1) Revision of the architectural plans, at additional cost;
2) Revision of the construction contractor's cost estimate, plans and schedules, at additional cost;
3) Revision of the construction contract;
4) Delay in project completion due to:
   - Legitimate effect of the design change;

- Absorption of the contractor's own delays under the guise of the design change delay; this removes any possibility of the Project Manager forcing the contractor to accelerate his work to recover such delays.

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

5.1.9 Environmental Information

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

5.2 The Flows of Information During Project Implementation

Section 5.1 dealt with categories of information needed during project implementation. It is now necessary to consider the generation of information flows to identify the type of information with the appropriate level of management and the specific point in time during implementation at which the flows occur.

5.2.1 Flows During Project Implementation

Figure 14 shows the project management information flows during the implementation phase. Information from the field (project work performed) is passed for storage in information files and then analysed.

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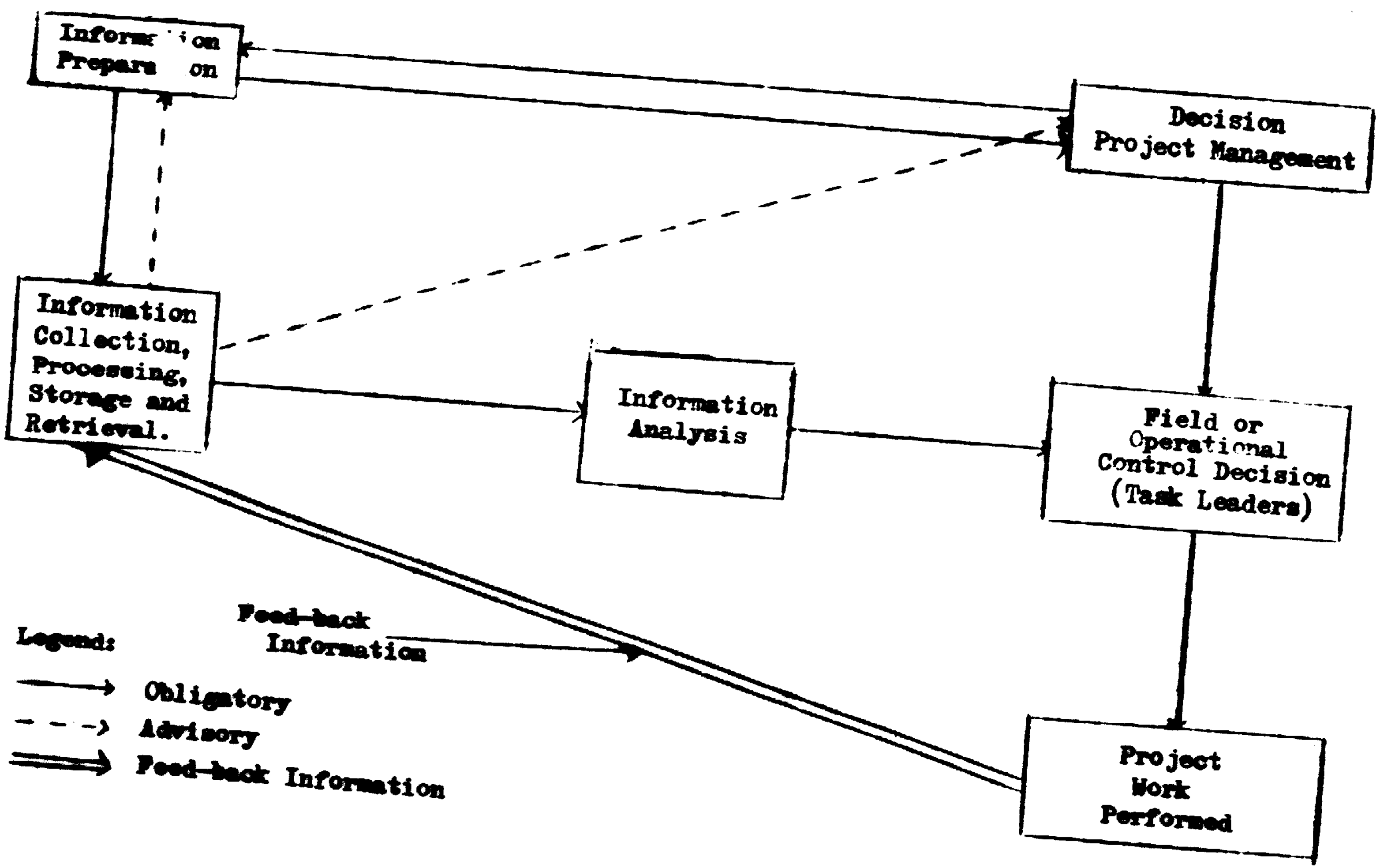


Figure 14. Information Flows for the Management of Project Implementation

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 there are also external bodies that can be equated with task leader, 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 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 field work performed, operational control decisions (Task Leaders) and the project management decisions form the Project Management Control System (PMCS).

5.2.2 Identification with Management Levels

The quantity of information to be provided to each decision-maker depends on his needs. However, it is also related to the relative position of the decision-maker in the hierarchy of the decision environment In general the functions of management are considered to be planning, control and operations.

5.2.3 Specific Times When Information Flows Occur

Figure 8 shows the milestone events of the Project Master Plan and Schedule. Information at the project level milestones will be acted upon by the Project Manager and only if serious overrun of cost, time or resources is involved will decisions at executive level be involved.

Superimposed upon the milestone control concept is the routine project up-dating procedure at time intervals. This need not be constant time intervals, indeed it is probable that at critical stages during project implementation frequent up-dating will be called for whereas at other stages monthly up-dating will be adequate. At routine or regular up-dates, the Project Manager will receive reports from the field via the information filing and analysis functions of the PMIS. Exception reports to executive level will be generated only if overrun is serious and problems are imminent or likely to occur. Contractors and other related organizations are to be contacted at routine up-dates.

The above information flows are predictable and pre-defined at the planning stage either as milestones or as part of the up-date schedule. However, superimposed on this scheme is the random input of information from interrelated organizations. At executive level, this could result in considerable revision of project plans. In the case study one such event is given as an International Monetary Fund Meeting. Figure 7 lists the important external organizations in the case of the ODINU 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 in terms of deviations from the project master plan will be dealt with at his level for minor modifications. They will be referred to the ODINU Manufacturing Company's Board of Directors when a major change of plan is involved.

Other inputs for higher level consideration will be conducted by a specifically assigned Director from ODINU Manufacturing Company and, possibly after a full Board meeting, the instructions for a major project plan revision(in the extreme case possibly an abandonment of the entire project) will be passed to the Project Manager for execution.

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

1) Executive Level deals mainly with policy making and strategic planning; this activity involves setting objectives and determining resources to be applied to the project. The decisions involved occur at irregular times and the inputs required are usually staff studies and external factors in addition to internal reports

related to achievements. The information systems here are of the inquiry nature and simulation is frequently used.

2) Project Level is management control and as such will involve allocation of resources to tasks, measuring performance and executing control. The decisions involved are rhythmic, 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.

3) 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 such information system is Action.

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

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

2) Integrated network plan, used to combine into one comprehensive network all events in the entire project (Middle Management and Project Manager);

3) Condensed or summary network plan: Detailed networks contain too much operating data. A summary or condensed network eliminates much of the detail yet retains the milestones of major significance to top management.

Figure 15 illustrates these relationships.

Level	Main Responsibility	Functions Related to Planning, Scheduling and Executing	Project Management Information					
			Characteristics	Frequency	Input	Processing	Output	Control
Executive Level	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 Level	Management Control	-Develop detailed schedules -Allocate resources to tasks -Make rules and instructions -Measure performance -Detect unfavourable trends and implement corrective action	-Line oriented -Judgemental -Primarily internal -Regular	-Periodic -Quarterly, monthly, fortnightly, weekly, daily	-Summaries -Exceptions	-Regular reports -Date banks	-Decisions -Procedures	-Integrated network plan -Medium number of milestones
Task Performance Level	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	-Actions	-Detailed network plan -Larger number of milestones

Figure 15. Relationship between Information Requirements and Management Levels

6. Methods for Control of Project Implementation

This section will describe some of the methods that can be used for controlling project implementation. These methods include a set of formal reports to be prepared periodically. The purpose of these reports is to summarize and integrate task level information and present it to project and higher level management. The objective of this periodic reporting is:

1) 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;
2) To provide high level 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 4, within a contractor's effort, for example. 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 decision (see Figure 4). 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 these kinds of responsibility but are not presented in this report.) The methods described here are based on summarising the detailed information from the task level to give the project manager:

1) An assessment of status of the project and its significant elements (as opposed to each detailed activity);
2) An indication of potential problem areas (again in relation to significant elements, say, project milestones, as opposed to detailed activities).

To illustrate, in the case of the ODINU Manufacturing Company, the project manager will receive in his periodic reports status on project milestones, "Building Construction Completed" being one example. He will be made aware of progress made on building construction progress, how many weeks ahead or behind schedule, when the construction is expected to be complete and a brief discussion of significant problems. This <u>summary</u> information is taken from more detailed information from the task level which is not needed by the project manager, but which is needed and used at the task level by the contractor in day-to-day management. The Task Leader would have several intermediate, task level milestones to measure progress on building 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;

▽ Finish Work Completed.

These task level milestones will be useful to the Task Leader, but status information on the 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 offered as suggested possibilities. These can be and should be modified to fit the particular project implementation situation. The report for the project manager prepared on a periodic basis might contain the following

6.1 Schedule Analysis

Milestone events will provide the core for schedule reporting. As already mentioned, the number of milestone events will vary with management levels. For example, two project level milestones were identified for the task "Factory Production Layout" shown in Figure 8. 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 milestone events have been identified for each of the tasks in the project, the number of task level milestones for the Electric Motor Manufacturing Factory Project could be on the order of 200. The total number of project level milestones or major activities would be about 24 as shown in Figure 8. Of these 24, nine would be of interest for reporting to executive levels.

In order to facilitate the reporting mechanism, a code will be established for identifying the various reporting levels of milestones as follows:

Symbol	Associated Management Level	No. of Milestones in Case Study Example
	Executive	9
	Project	24
	Task	200

It is intended that approval authority would be specified and related to the various levels of milestones. To illustrate, accomplishment of the task, "Factory Production Layout", would be the responsibility of the respective Task Leader. He would, therefore, have the authority to change the schedule for any of the task level milestones within his scope of responsibility. However, a schedule change on either of the two project level milestones associated with his task would require the approval of the project manager. (Note that the significance of such a procedure is enhanced with larger tasks than shown in the example. Nonetheless, the formal recording of schedule decisions accommodated here is worthwhile for all projects, regardless of size.)

Figure 16 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 include:

1) Milestone Status Chart (Figure 17)

This chart lists all the project level and executive level milestones and their status. Status is indicated according to the symbols specified in Figure 17. 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.

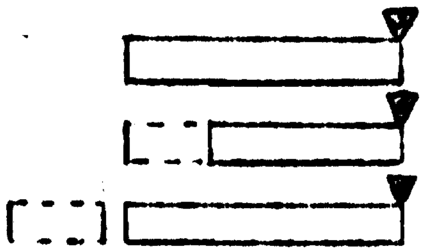
The types of information communicated can be illustrated by examining Figure 17. The milestone "Building Construction" was late by more than two months as indicated by the dashed lines. Approximately one and a half months of work have been accomplished on the task as represented by the darkened portion. The task remains two months behind schedule indicated by the open bar between the darkened portion and the "status date" line. The project schedule has not changed but remains at 13½ months represented by the open triangle. The Task Manager is recommending a change of the schedule to 15½ months

Milestones

1. Executive Level (or outside approval)
   Project Level
   Task Level
2. Scheduled Completion Date
3. First Schedule Revision
4. Actual Completion Date
5. Rescheduling Request
6. E-Best Estimate of Completion Date (from detail schedule system)

All symbology following applies to all three levels but will be shown for the project level only as an example.

Activity Bars

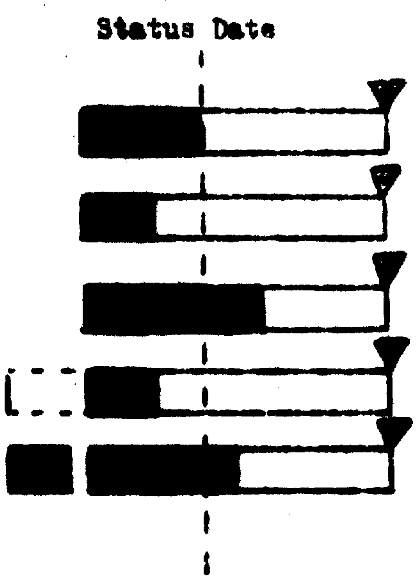


Activity Initiation

Initiation on Schedule

Late Initiation

Early Initiation



Activity Progress Toward Completion

Activity on Schedule

Activity Behind Schedule

Activity Ahead of Schedule

Late Initiation - Behind Schedule

Early Initiation - Ahead of Schedule

Figure 16. Schedule Symbols

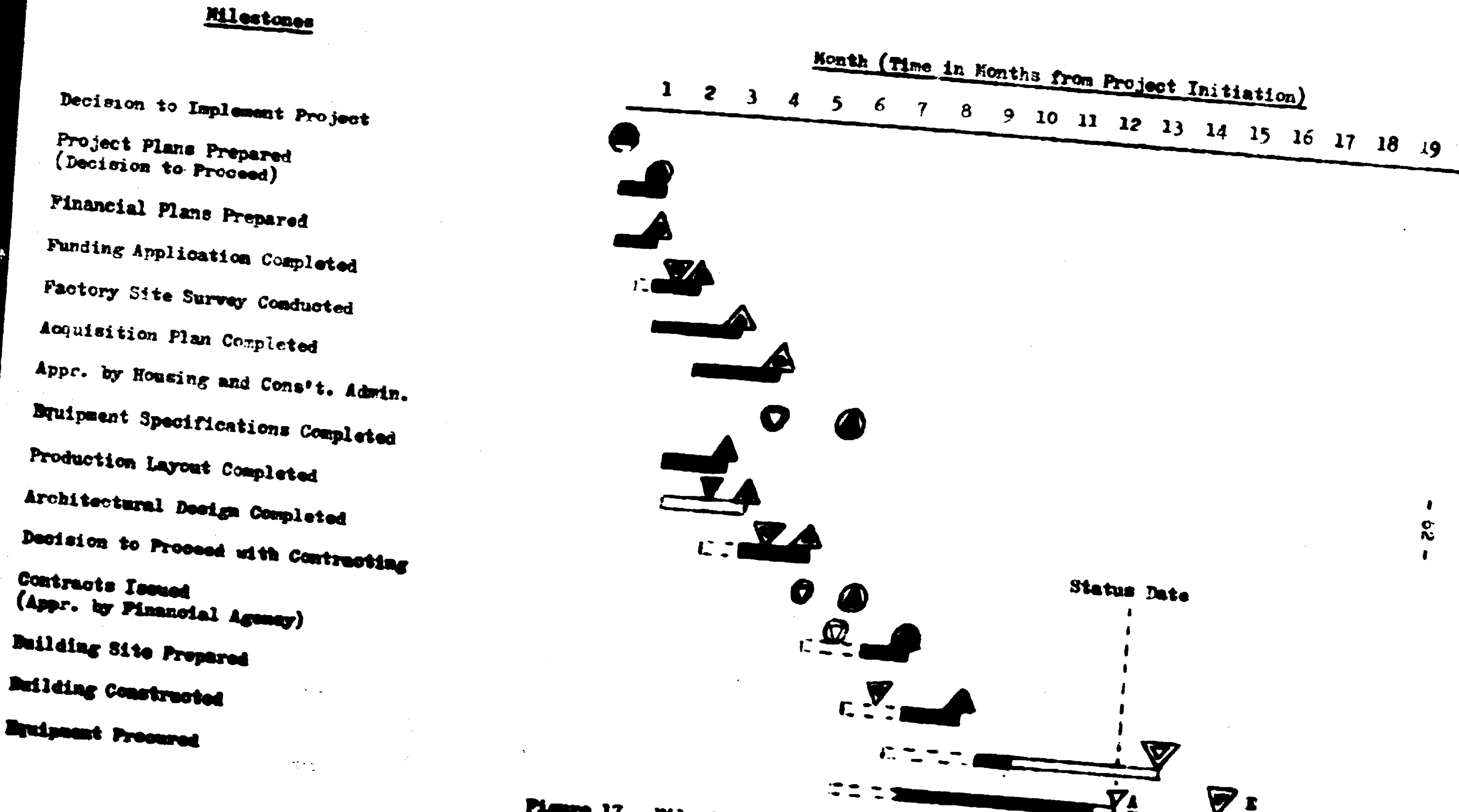


Figure 17. Milestone Status Chart
(Continue to Include all Project and Executive Milestones.)

as shown by the triangle with an "x" inside. The "E" gives the best estimate of milestone completion as indicated from task level detailed scheduling system (planning network, for example).

2) Schedule Trend Chart (Figure 18)

The purpose of this chart is to give a quick view of the history and outlook for a few select milestones of particular interest at the time of the report to the project manager. On the chart (Figure 18), the milestone events being considered are shown at the top of the chart. 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 completion (shown in months). The dark trend line represents the schedule completion date of the milestone. (As shown, the milestone "Personnel Recruited and Trained" was rescheduled at "month 3" of the project. The dashed trend line represents the best estimate of completion calculated from a detailed schedule system (network planning, for example). (As shown, the best estimate of completion as determined from detailed schedules has continually moved further away from the original schedule.)

3) Narrative Report (Figure 19)

This report gives a brief summary description of project status, potential problems, etc., with a brief 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 milestone events). For example, the building construction is behind schedule. This is mentioned along with the fact that there appears to be no possibility of speeding up the work in order to complete the building on time. A four-week slip of the schedule is therefore recommended. The critical area is also discussed. For example, although the building is behind schedule, a more critical area is the recruiting of personnel. This is noted and the point

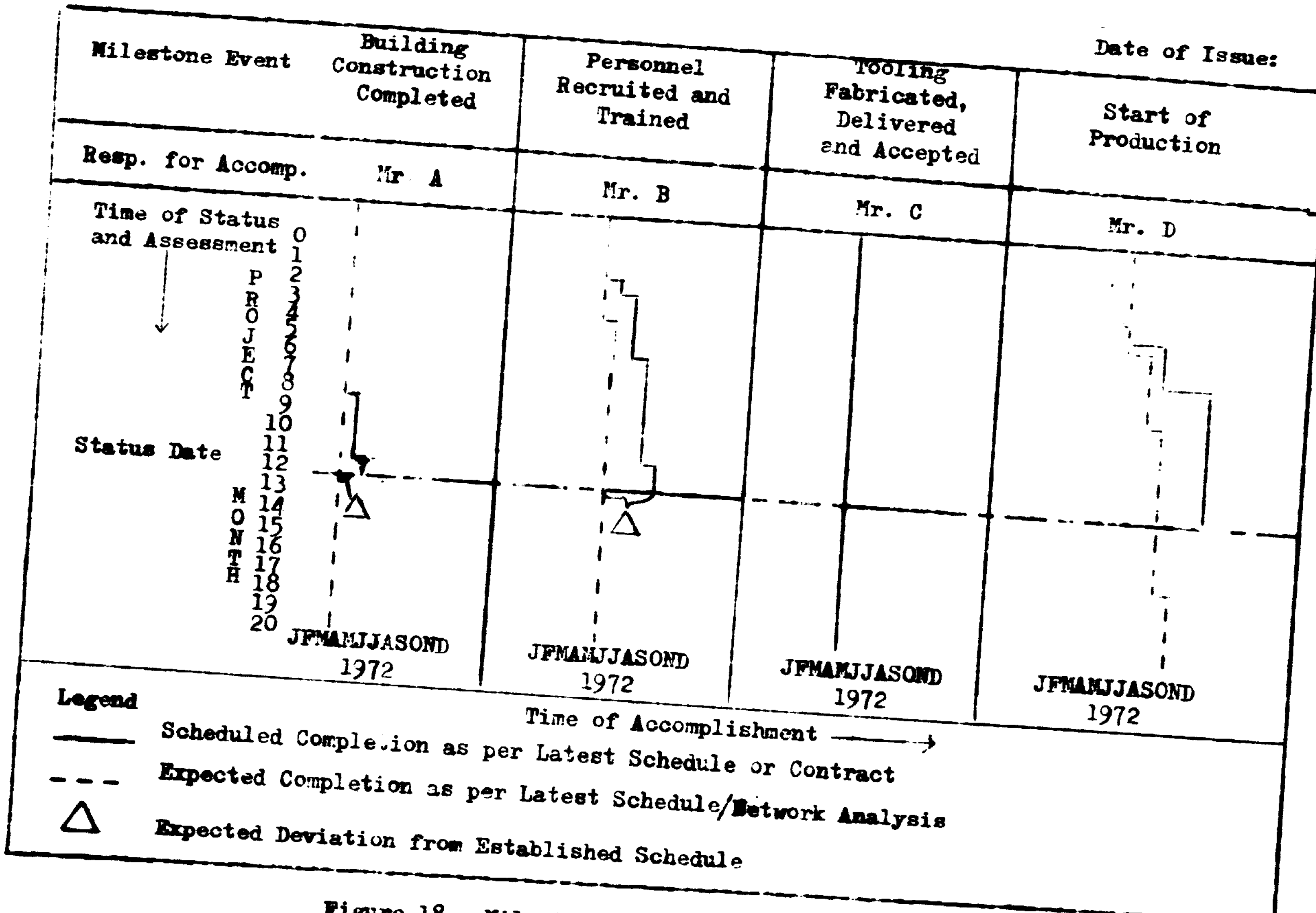


Figure 18. Milestone Schedule Trend Analysis

RESP: J. Foster STATUS AS OF: 24 June 1972 (Date)

Summary Outlook

- Tooling design is in progress and continues on schedule with no foreseen problems in meeting schedule.
- Foundation structure for the building has been completed within two weeks as scheduled. However, delays in earlier events caused late initiation of building construction. No possibilities have been identified for reducing the overall 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, resulted in a delay in the original schedule for training. The expected date for completion of personnel recruitment and training is now 2½ 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 slip).

Recommendations

- Overall project schedule should be slipped four weeks since there is no apparent way to speed up building construction. Increased emphasis 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.

Figure 19. Narrative Report

is made that this task directly affects the date at which factory production should begin. Recommendations are described along with suggested solutions to problems and critical areas. The above three reports must be considered together to make an overall schedule analysis of the project.

6.2 Cost Analysis

The reports provided to the project manager to assist in cost analysis are:

1) Master Financial Plan (Figure 20)

This is a graphic presentation of actual project costs to date, planned costs for the remainder of the project, funding received to date and funding requirements through the remainder of the project (all identified on chart).

This chart is provided for an overview of the history and outlook for the project's costs and funding plan. This plan corresponds to the overall budget plan for the project as shown in Figure 13. However, if desired by the project manager, the same plan could be developed for the individual tasks as indicated also in Figure 17

2) Cost Trend Analysis (Figure 21)

This analysis is a simple history and outlook of projected total cost to complete the project. The vertical scale is the number of months from project initiation. The horizontal scale is the projected cost of the total project in millions of dollars. 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 graphically show in one plan the trend of projected cost of the project for comparison with the approved budget.

RESP. B. Fraser

MASTER FINANCIAL PLAN
Cumulative Project Costs

STATUS AS OF: ____________
(Date)

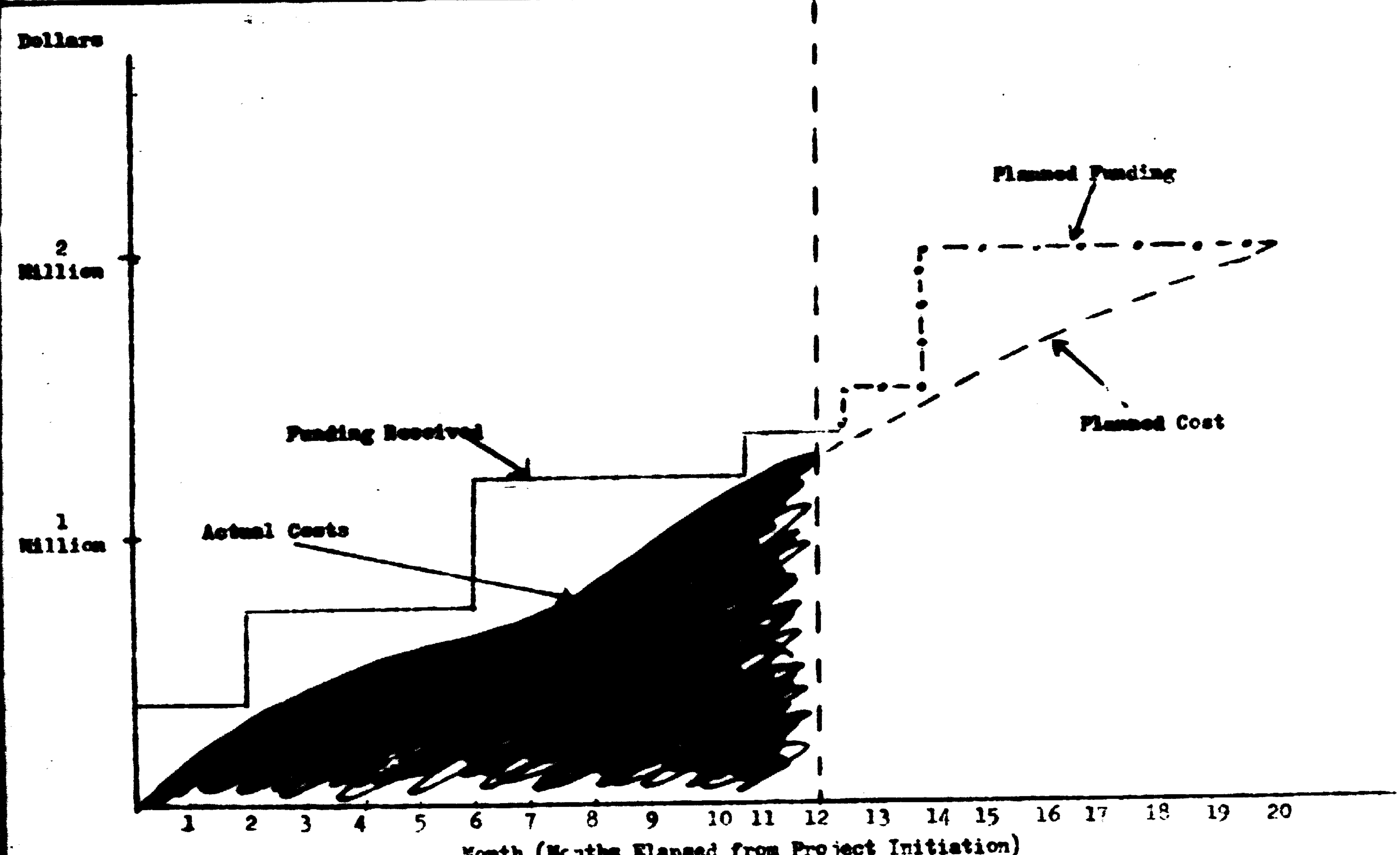


Figure 20. Master Financial Plan

RESP. B. Fraser

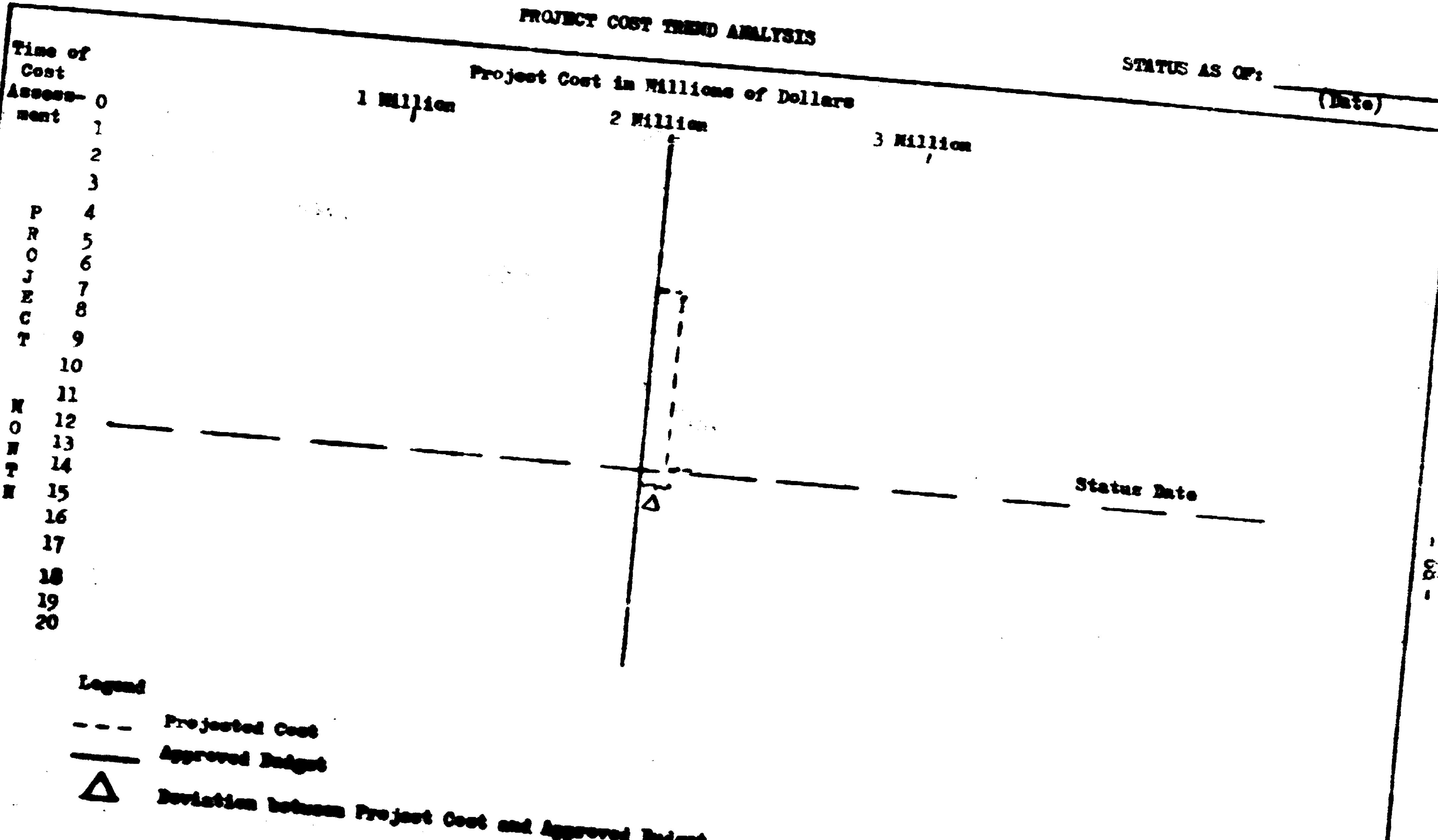


Figure 21. Project Cost Trend Analysis

6.3 Manpower Analysis

The purpose of manpower analysis is to assist in analyzing manpower utilisation. A graphic representation of the direct manpower utilised on the project and a monthly projection of requirements is used as shown in Figure 22. The solid vertical bars represent actual direct manhours charged to the project. The dashed lines represent the planned manpower levels by month. This report aims at comparing actual manpower with the manpower plan. Any significant deviations can be examined by the project manager in discussion with Task Members.

6.4 Value of Work Analysis

This type of analysis assists the project manager in correlating schedule and cost information and then in evaluating project performance. A value of work index is therefore to be calculated. The general concept of work 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 which make up the work plan. This initial allocation takes place prior to project execution and the resource planned for each activity becomes its "value".

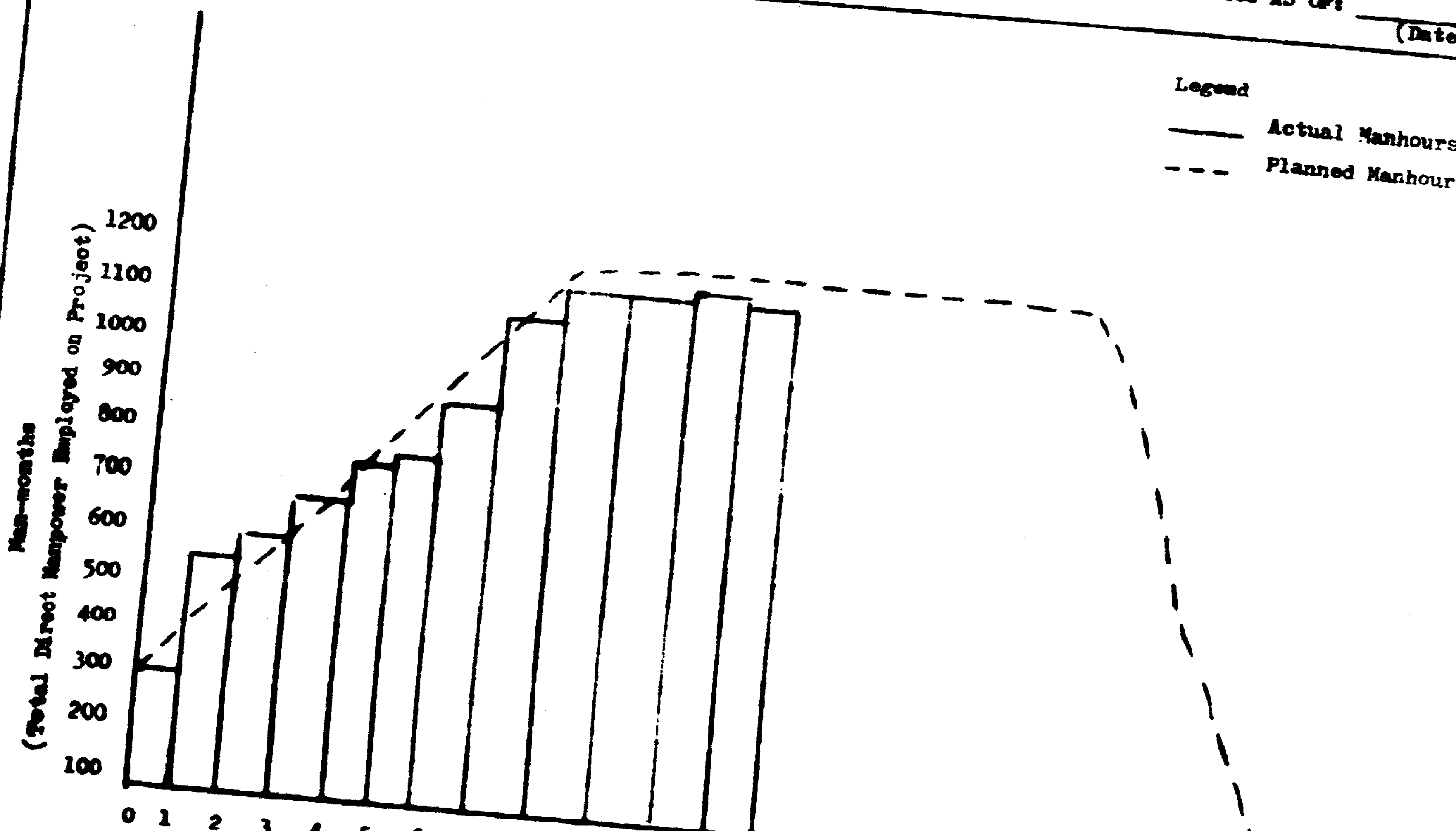
As the project progresses and the performing unit completes activities, it is credited with the predetermined "value" regardless of activity cost. By comparing the actual cost incurred with the accumulated "value" for all finished activities and an appropriate percentage for activities in process, one has a relative measure of the efficiency with which a performing unit is accomplishing its plan. The percentage complete of activities currently being worked on is derived by comparing the total time planned for an activity with the time it has been in process

Should a change in project scope occur after the start of project implementation (i.e. contract modification), a reallocation

RESP. T. Hines

MANPOWER REPORT

STATUS AS OF: ______
(Date)



Month	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	695	750	770	900	1100	1130	1130	1140	1130									

Project Months (Time in Months from Project Initiation) to the uncompleted activities of the difference between the new estimated cost at completion and the current accrued cost must be accomplished. (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.

In Figure 23, 200 milestones have been plotted in terms of planned cost and schedule. As work progresses, actual cost and schedule curves can be plotted. At the end of twleve months, the schedule has slipped 10 milestones as compared to the plan. By identifying that point on the schedule plan, i.e. the number of milestones scheduled curve (point a in Figure 23) 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 point b on the cost plan that relates to the work completed. By projecting point b (PVWA) to time now, 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 24. This chart becomes a part of the report to the project manager to assist in evaluating project performance. The PVWA of $1.25 million is divided by the Actual Cost of $1.38 million to obtain a Performance Index of 90.6 per cent; we determine the Estimated Cost at completion for this project to be $2.208 million.

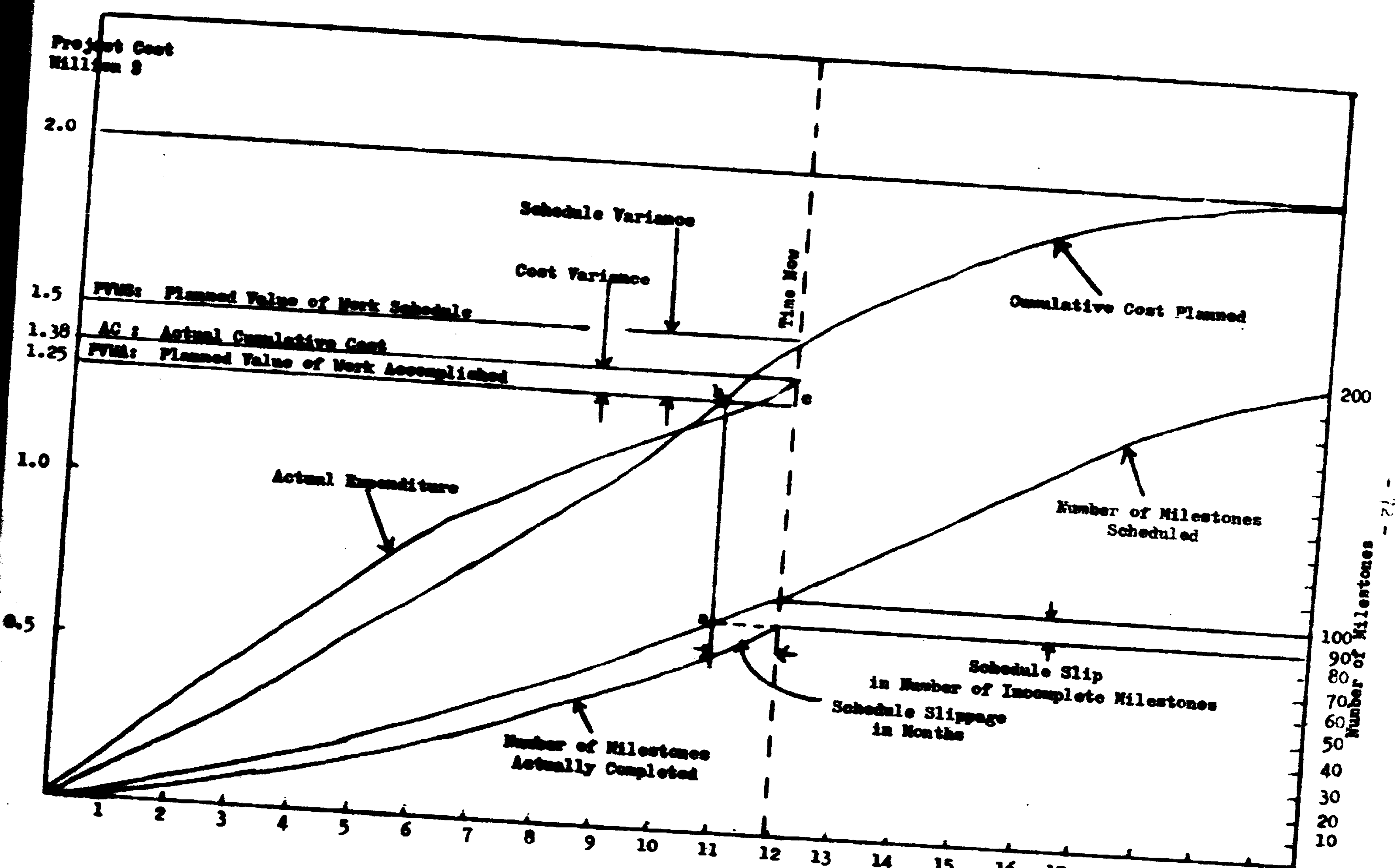


Figure 23. Value of Work Chart

$$\text{PERFORMANCE INDEX} = \frac{\text{Planned Value of Work Accomplished}}{\text{Actual Cumulative Cost}}$$

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

$$= \frac{1.25}{1.38} = 90.6\%$$

$$\text{ESTIMATE AT COMPLETION} = \frac{\text{Project Value}}{\text{Performance Index}}$$

$$= \frac{\text{2 Million}}{90.6\%}$$

$$= 2.208$$

$$\text{ESTIMATED CONTRACT OVERRUN (UNDERRUN)} = 2.208 - 2.0$$

$$= \text{0.208 Million Dollars Overrun}$$

Figure 24. Value of Work Analysis

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 have a complete view of project status.

7. A Recommended Plan for Achieving Desired Improvements in Project Implementation

In the preceeding Sections the concepts of systematic preparation, processing and use of information for development project initiation and implementation have been described and illustrated. In this final Section, a recommended plan is presented which outlines the steps to be taken to obtain the benefits of adapting these principles within a developing country. This recommended plan must be rather general, because of the widely varying conditions which exist in various countries. However, the basic steps presented 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.

7.1 Utilization of "Project Management System" Concepts

The concept of a "Project Management System" (PMS) has been presented as a solution to major environmental economic and technical needs and problems associated with the systematic initiation and implementation of industrial development project. Developing countries in general may find it very difficult to obtain information and assistance in utilizing the experiences of other industrialized nations in this regard. In order to assist developing countries to utilize the PMS approach to systematic initiation and implementation, UNIDO suggests that government agencies assign an individual or individuals to investigate the techniques and applications of the Project Management System concept. This designated individual(s) should pursue the following plan of action:

1) Review available information on Project Management Systems.

2) Determine the preliminary feasibility of applying Project Management System concepts to new or existing development projects.

3) Develop a work plan for applying appropriate elements of the Project Management System approach to selected projects.

4) Secure approval of the work plan from the appropriate authorities in the government agencies.

5) Determine the types and levels of assistance required to utilize Project Management System concepts.

6) Obtain the information and assistance required to utilize a Project Management System.

7) Apply Project Management System concepts to development projects.

8) Review and evaluate the value and applicability of Project Management System concepts as an approach to systematic initiation and implementation for current and future development projects.

As it has been providing assistance to developing countries in the field of project management systems, UNIDO is prepared to assist developing countries in all of the above steps and can be of particular assistance in the following areas:

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

2) Identifying sources of Project Management System information;

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

4) Identifying and discussing similar applications in other countries;

5) Identifying sources for PMS training programmes;

6) Conducting UNIDO sponsored PMS workshops, training programmes and seminars;

7) Organizing and directing technical advisory missions to developing countries;

8) Organizing and directing technical assistance projects in developing countries;

9) Providing technical and application-oriented documents on Project Management Systems.

It should be noted that UNIDO training programmes and documents are organised to provide information to executives, project managers and technical project personnel. Such training is oriented toward three levels of instruction relative to the knowledge levels of awareness, understanding and skill. Training is directed to each of the PMS phases defined for initiation and implementation of industrial development projects. Included in such training programmes are instructions for the utilization of the following modules of a Project Management Information System (PMIS):

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.

The above modules provide the basis for a building block approach to the realization of a Project Management Information System as discussed in the following Section.

In order to assist developing countries to obtain the type of assistance outlined above from UNIDO, a request is shown in Figure 25 This request should be completed and returned to UNIDO by interested agencies, through the Office of the United Nations Development Programme Resident Representative in the country. UNIDO will then provide the requestor with detailed information and assistance relative to his specific needs.

United Nations Industrial Development Organization

Request
for

Project Management System Assistance

Name of Requestor
Address ______________________
Official Position ______________________
Description of Industrial Development Projects ______________________

Types of PMS Information Desired*

	Knowledge Level		
	Awareness	Understanding	Skill
Executive			
Project Manager			
Technical			

*Check Each Box Where Information is Desired

Types of Assistance Desired

Documents ________ Experts ________
Training ________ PMS Services ________

Figure 25. Request Form for Obtaining UNIDO Assistance

7.2 A Building Block Approach to Developing and Installing a Project Management Information System

The modules of an overall project management information system, as presented in the preceding sections, 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;

An agency responsible for development projects must have these types of categories of information available to them in order to carry out this responsibility. There must also exist methods and procedures to prepare, process, file, retrieve and report or otherwise use the project management information within each module.

Those agencies which are currently carrying out development project do have such information, at least to some extent and with varying degree of detail, and usually have some of the needed procédures in operation.

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

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

7.2.1 Restricted Definition of Project Management Information Systems

The term "project management information system" is usually applied in a somewhat restricted fashion, and in this usual sense it refers to the four modules numbers 3) through 6) listed above.

7.2.2 Three-Stage Evolution of PMIS

Figure 26 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 as individual building blocks of the system. Each building block can be developed somewhat independently, although certain ones depend upon others reaching a particular stage before they can move to that stage.

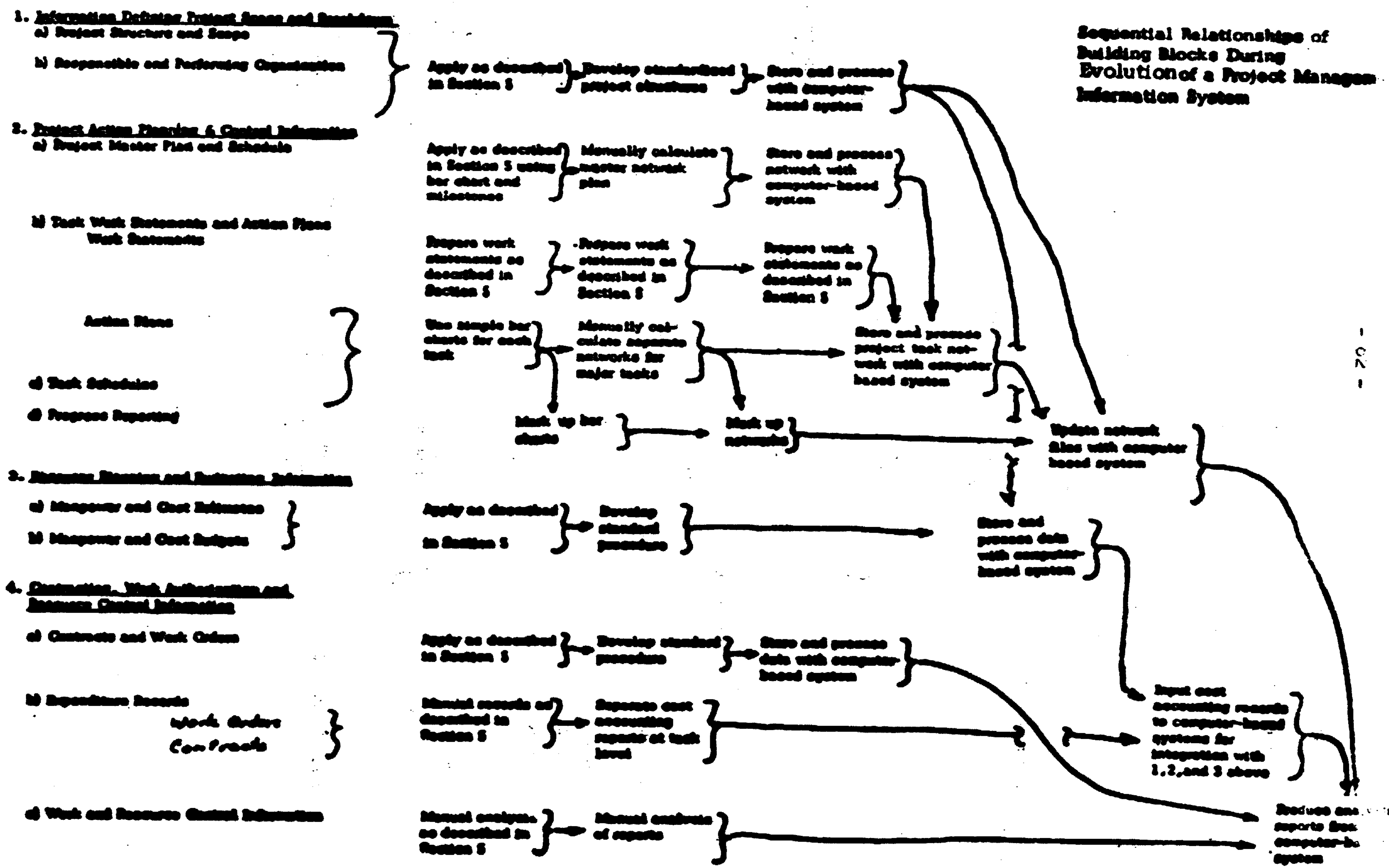
Figure 27 portrays the sequential relationships between the various building blocks.

...IS Modules and Building Blocks	System Development Stage 1 Initial	2 Intermediate	3 Advanced
...ormation Defining Project Scope and Breakdown			
Project Structure and Scope; Responsible and Performing Organisation	Apply as described in Section 5	Develop standardised project structures	Store and process with computer-based system
...oject Action Planning & Control Information			
) Project Master Plan and Schedule	Apply as described in Section 5 using bar chart and milestones	Manually calculate master network plan	Store and process network with computer-based system
) Task Work Statements and Action Plans: Work Statements	Prepare work statements as described in Section 5	Prepare work statements as described in Section 5	Prepare work statements as described in Section 5
Action Plans; 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
d) Progress Reporting	Mark up bar charts	Mark up networks	Update network files with computer based system
Resource Planning and Budgeting Information			
a) Manpower and Cost Estimates; b) Manpower and Cost Budgets	Apply as described in Section 5	Develop standard procedure	Store and process data with computer-based system
Contracting, Work Authorisation and Resource Control Information			
a) Contracts and Work Orders	Apply as described in Section 5	Develop standard procedure	Store and process data with computer based system
b) Expenditure Records: Work Orders, Contracts	Manual records as described in Section 5	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 Section 5	Manual analysis of reports	Produce analysis reports from computer-based system

Figure 26. Evolution of PMIS Modules

Figure 27.

Sequential Relationships of Building Blocks During Evolution of a Project Managem[ent] Information System



APPENDIX A

Management Control Systems

In addition to the "Value of Work Analysis" technique described in the case study, the major current management control systems will be briefly discussed. PERT is probably the most common of management control systems. This section assumes prior knowledge of the mechanics of PERT and the goal of the discussion here is to examine PERT as a management control process. Extensions of PERT provide for control over cost, manpower and other required resources.

1. PERT Output

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

In processing the sample network, the event-oriented approach was utilised. 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 attainment of major milestones in the project.

One of the most challenging aspects of developing a useful 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 spill out pages of output by the thousands. It is obvious that discrimination and selectivity is needed in order to adhere to the principle of management by exception.

The problem has been attacked from several directions. Probably the simplest approach has been to pre-define 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 exception items, such as unreported or overdue occurrences, has provided a useful checklist for the project manager. Finally, some elaborate index systems have been developed, which computer 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 used in weapons system requisition are listed below. Various levels of management and numerous interrelationships among firms, agencies and military offices 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.

1.1 <u>Detailed and Operating Level Networks</u>

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 utilized by operating networks, or detailed networks. In addition, since they often cover only a fragment of a project, they are sometimes referred to as fragnets (fragmentary networks).

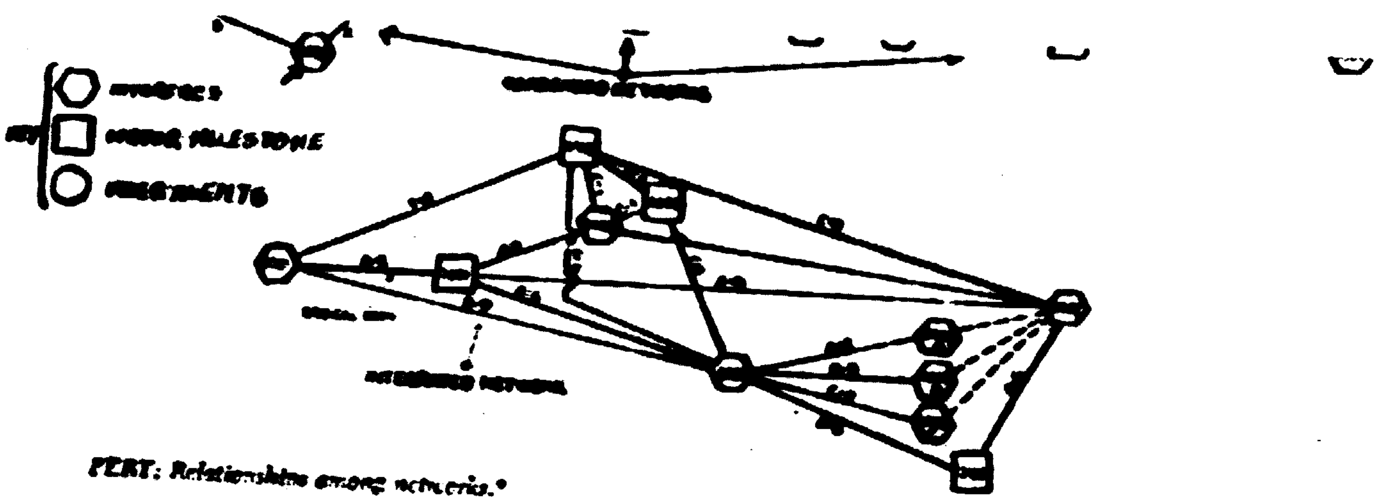
1.2 Integrated Project Networks

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 involved can exercise management surveillance over the progress of the entire project through use of this integrated network.

1.3 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 on a more aggregative basis. To accomplish this, a summary or condensed network is constructed which eliminates much of the detail, yet retains the events of major significance. Such networks frequently are 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. The relationship among these various forms of networks is indicated in Figure 28. This diagram depicts condensation of networks prior to network integration. Either condensation or



*PERT: Relationships among networks.**

* Adapted from Planning and Control Techniques and Procedures (PCT), Headquarters, U.S. Army Materiel Command, AMC Regulation 11-26, vol. 2, August 1963, Fig. II-3-3.

Figure 26.

integration can occur first depending on the requirements of the levels of programme management.

2. Management Action

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

When it becomes apparent that a schedule requirements cannot be met under the existing plan, it becomes necessary to devise a new plan. Activities along the critical path must be analyzed from two points of view. First, there is the possibility that certain sequential activities can be performed in parallel. Originally, activities might have been scheduled sequentially to provide assurance that a previous task was performed successfully before proceeding to a subsequent task. It might be possible to schedule these 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. 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 management attention 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 to 90 per cent of activities which do not directly influence the duration of a project. It truly allows management by exception.

3. 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 which allow control over other elements such as cost, manpower and other sources.

3.1 PERT/Cost

In general it is necessary to weigh the costs attached to a project. Even when time is the overriding factor, costs considerations must be included. The PERT/Cost procedure requires as input cost data in addition to the time data required by basic PERT. This cost data is 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 will normally affect cost. Labour is estimated by entering the manhours required for each manpower skill category. The computer converts this input to dollars by applying the appropriate labour rates. 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. A number of useful and informative reports can be generated from this 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 which 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 summarisation 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.

A projection of manpower needs for each skill category is developed by the computer. The time analysis of the network is used to determine the calendar period on which each activity will fall. The estimated manhours for each activity are then distributed by calendar period within skill category. The summarised results can be displayed in graphical form (Figure 29).

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

In most projects, manpower constitutes the most important resource. Frequently, however, other resources play a critical role in the achievement of project objectives. These might be machines, testing facilities or computer time. Where there is a possibility of an overload on any of these facilities, a project similar to 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 30). 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 can be used as a basis for revising the funding schedule.

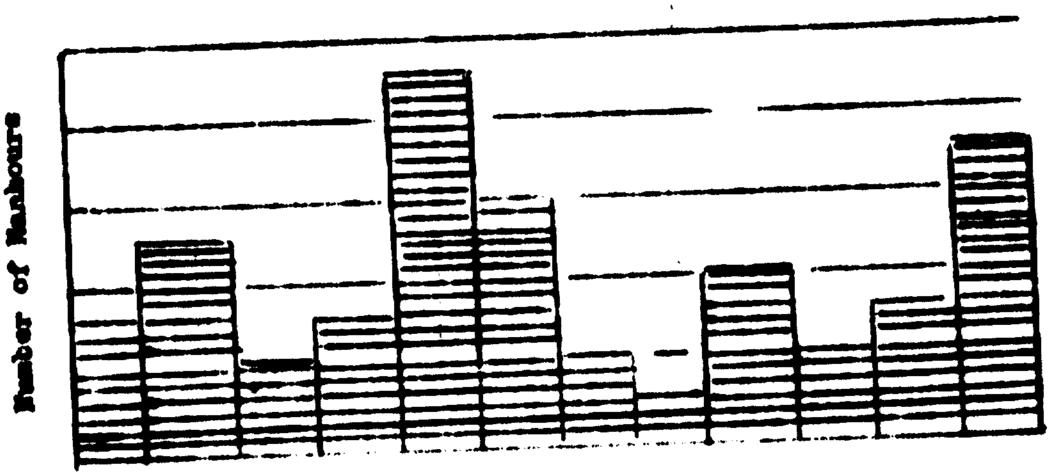


Figure 29. Manpower Requirements, Skill Category XX

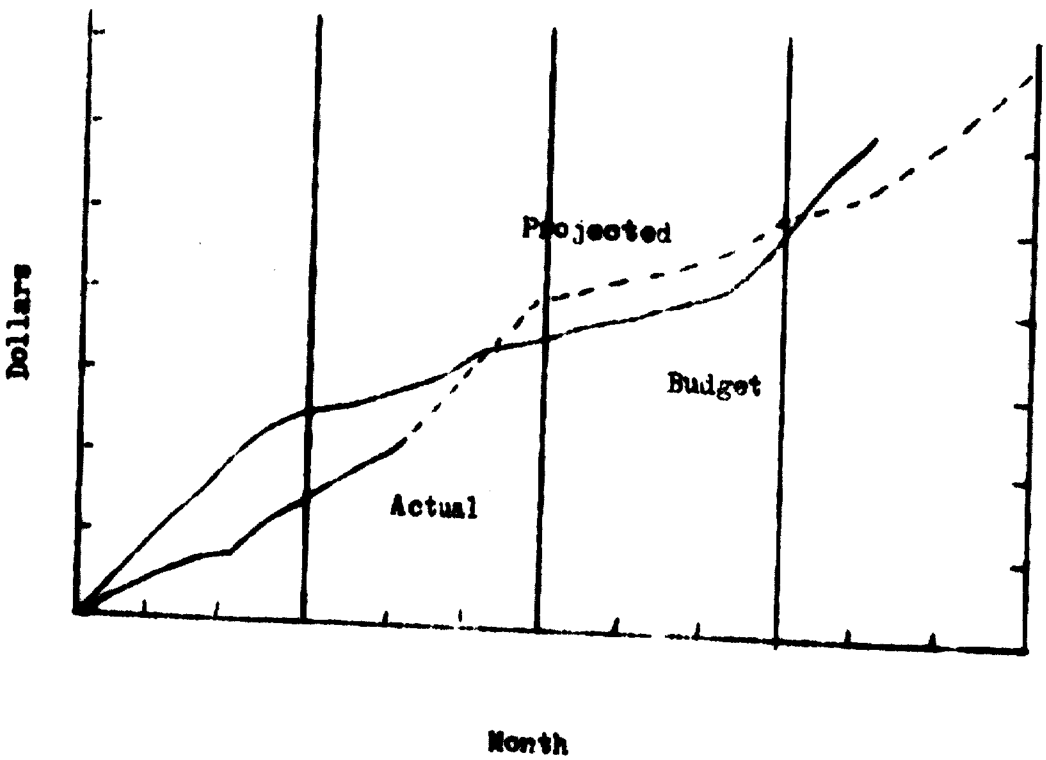


Figure 30. Rate of Expenditure

3.2 Cost-Time Balancing

Selection of a suitable schedule for a project generally involves consideration of numerous alternatives, each with a different cost picture. Choosing the schedule which 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.

Most activities involving manpower reveal a direct relationship between cost and the time required for completion. Assigning additional personnel or scheduling overtime normally reduces the time requirements for an activity while incurring increased costs. Cost-Time balancing programmes require 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 31 shows this relationship. The line connecting normal and crash 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 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 32). The addition of a manually evolved indirect cost curve gives the manager all the information he requires to select the project schedule which most closely balances his cost and time objectives.

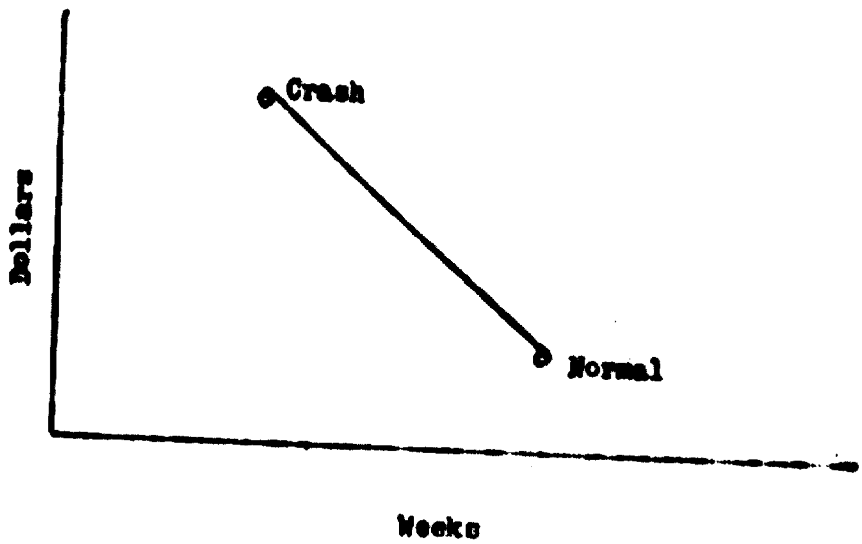


Figure 11. Cost-Time Relationship for a Given Activity

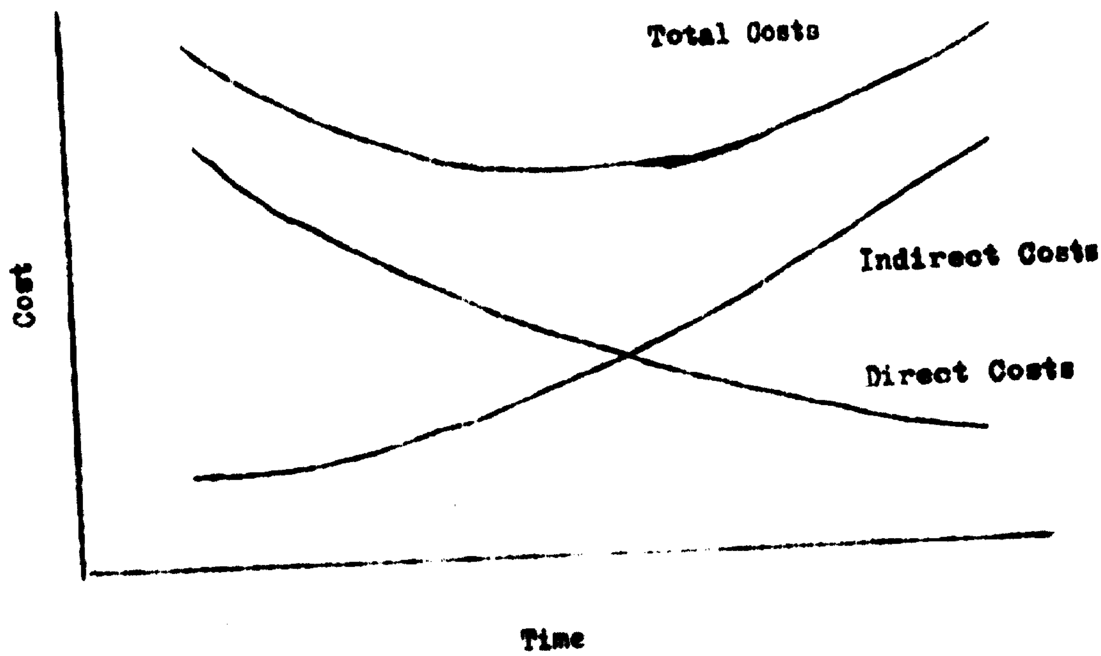


Figure 32. Total Project Costs

4. Status Index

A second Management technique is known as the Status Index. The Status Index permits:

1) Measurement of the adequacy of technical performance for the money spent;
2) Details to identify trouble spots;
3) Forecasting of trouble spots.

The index is derived as follows:

$$\frac{\text{Progress}}{\text{Scheduled Progress}} \times \frac{\text{Budget}}{\text{Actual Expenditures}} = \frac{\text{Status Index}}{\text{Number}}$$

The basic relationship is between the budget (input) and progress (output). Consider the following:

$$\frac{\text{Output}}{\text{Input}} = \frac{\frac{7T_a}{10T_p}}{\frac{6 \text{ million } E_a}{5 \text{ million } E_p}} = \frac{7}{10} \times \frac{5}{6} = .6$$

where a = actual, p = planned, T = time in months and E = expenditure in dollars.

This index in itself is only useful to indicate:

1) Status;
2) Status related to some prior period (better or worse).

To determine where management attention is needed, progress can be measured in terms of the limiting path or the stream of related activities whose progress is slowest in relation to the other related efforts in the programme.

For example:

Project/Task	Slack
Overall Project Summary	-8
Effort A	-3
Effort B	-2
Effort C	-8

Project/Task	Slack
Effort D	-5
Effort E	+1
Effort N	-3

Effort C is the "slowest" and therefore is the project limiting effort, that is, the area where management attention is most necessary at the time the reading is taken.

The progress/schedule variable in the equation can be written:

$$\frac{F_w}{T_w - S_w} \qquad (1)$$

where F_w = effort (in weeks), T_w = planned project time (in weeks) and S_w = slack (in weeks), or when using milestones instead of slack:

$$\frac{F_w - B_w}{T_w} \qquad (2)$$

where the variable B_w (Weeks behind schedule) is used instead of S_w or when using time to date; that is, considering the total programme instead of planned total project time:

$$\frac{E_w}{E_w - S_w} \qquad (3)$$

Consider now the original equation:

$$\frac{\text{Input}}{\text{Output}} = (N) \times \frac{\text{Budget}}{\text{Actual Expenditures}}$$

where (N) = equation (1) or (2) or (3).

The Status Index can be applied at any level of detail in the work breakdown structure where values for the variables cited above can be identified and substituted in the equation. Indicated below is the relative criticality with reference to progress versus cost by level of effort.

Status Index	End Item	End Item S/D	Remarks
1.2	2	2.1	Possibility of excess resources
0.9	3	3.1 3.3 3.4	Normal variance range
0.8	4	1.2 1.4 2.2	May require more resources
0.7	1	2.5 2.6	
0.6	5		Immediate management action required

Forecasting cost to completion can be accomplished using status indices as shown in Figure 33. After initial fluctuations have dampened out, the least squares method or a similar technique can be used in the projection. In the example above, .95 is the projected index, which means 100/95 of the original estimated cost of a 5.3 per cent overrun will be required to complete the project.

Predicating trouble areas can be accomplished through the examples shown in Figure 34. Based on the information in Figure 34.a alone, the project manager would be likely to concern himself more with Task 3 than with Task 2. Conversely, the example in Figure 34.b shows how progress, when tracked over time, would indicate that Task 2 is getting worse while Task 3 is getting better. An extension of the above historical comparison with the plan is shown in Figure 34.c. This can be used to reveal the degree of planning effectiveness - for more realism. Variations in patterns, of course, will reveal symptoms of performance deficiencies other than consistently good or bad planning; that is,

1) Pessimistic at the outset but steadily improving;

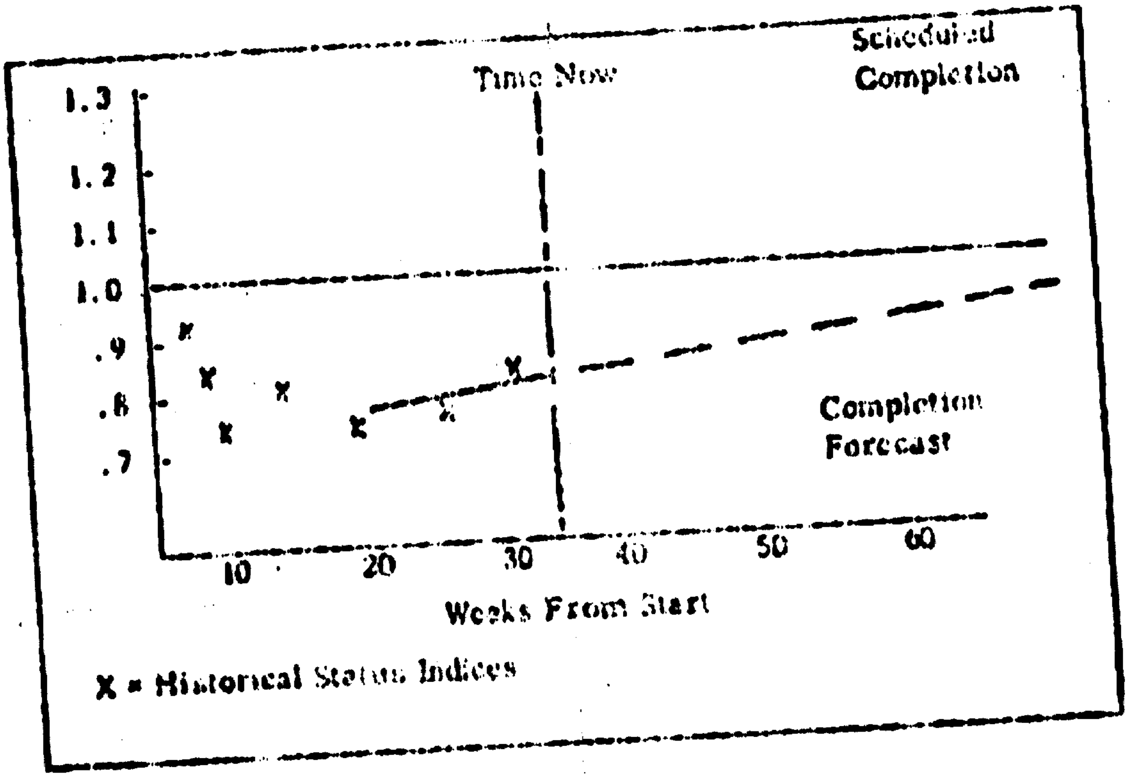


__Figure 33.__ Forecast Cost Using Status Indices

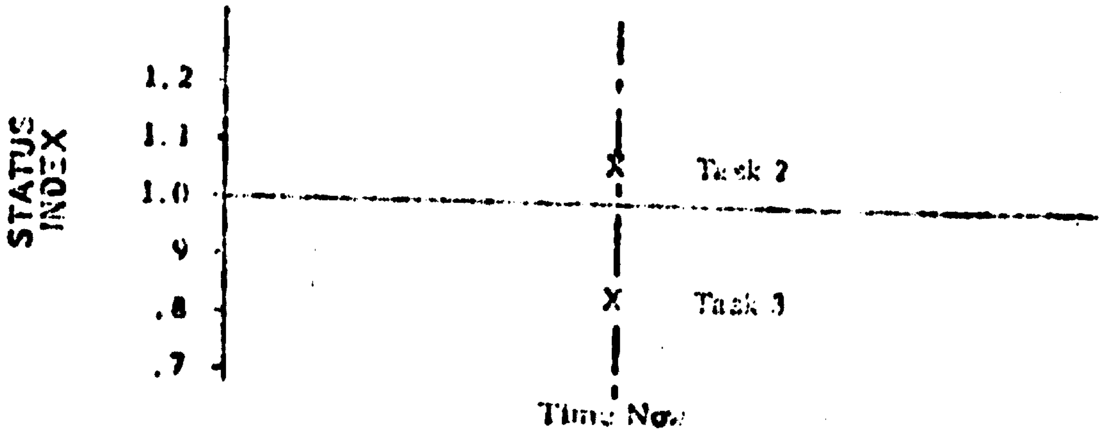


Figure 34.a

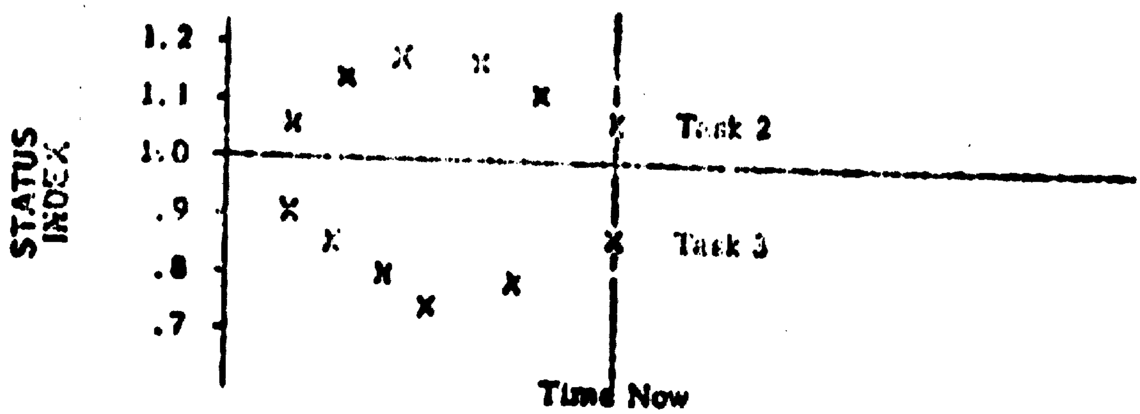


Figure 34.b

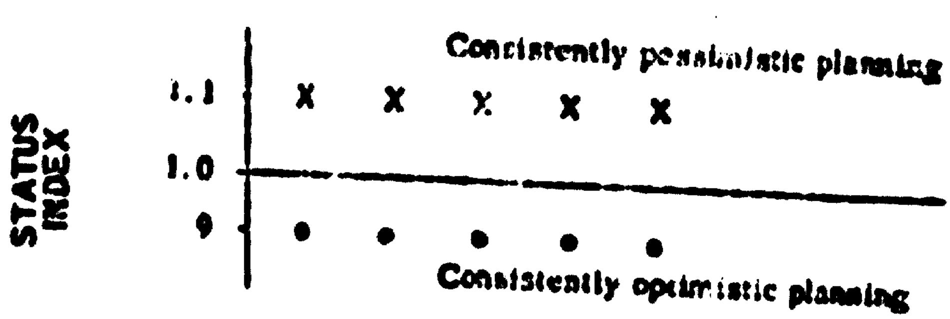


Figure 34.c

Figure 34.

2) Excellent at the outset but increasingly going out of control;

3) Erratic, with no discernible pattern.

Technical performance, one of the most elusive measurements, can at least be approximated through another application of the Status Index. A Performance-Cost Index can be derived from the formula:

$$\frac{Z_A}{Z_P} \times \frac{B}{E}$$

where Z = Technical Performance

A = Actual

P = Planned

B = Budget

E = Expenditures.

If, for example, tests are 2/3 successful versus the plan and the budget expenditure ratio is 3/2, the Performance Index is $2/3 \times 3/2 = 1.0$.

Task	P-C Index	PR-C Index
Memory	.7	.9
Processor	9	.8
Input/Output	1.2	1.3
Power	1.3	.9

The above relationships would suggest that, in the Memory and Input/Output, true progress is behind milestone porgress with a related unfavourable impact on cost. Consistently higher performance over progress, as indicated in the power supply, might be symptomatic of overdesign.

The collective impact of budget, expenditures, schedule and technical performance and their interaction must be evaluated by a programme manager so he can be effective. This, then, is one other technique that can help to pre-digest information and expedite its conversion into programme management action.

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.

5. **Earned Value**

Another management system, or more accurately, a series of related optional graphic applications of the "value" concept, is known as earned value. Essentially, it is the PERT/Cost "Value of Work Performed" expressed as a percentage or index. This can be derived, purportedly, without all the computer inputs and gyrations commonly required in PERT/Cost.

Earned value holds that an estimated value can be placed on all work to be performed and, once the work is accomplished, that same estimated value can be considered "earned". Figures 35, 36 and 37 show some of the many applications for this concept.

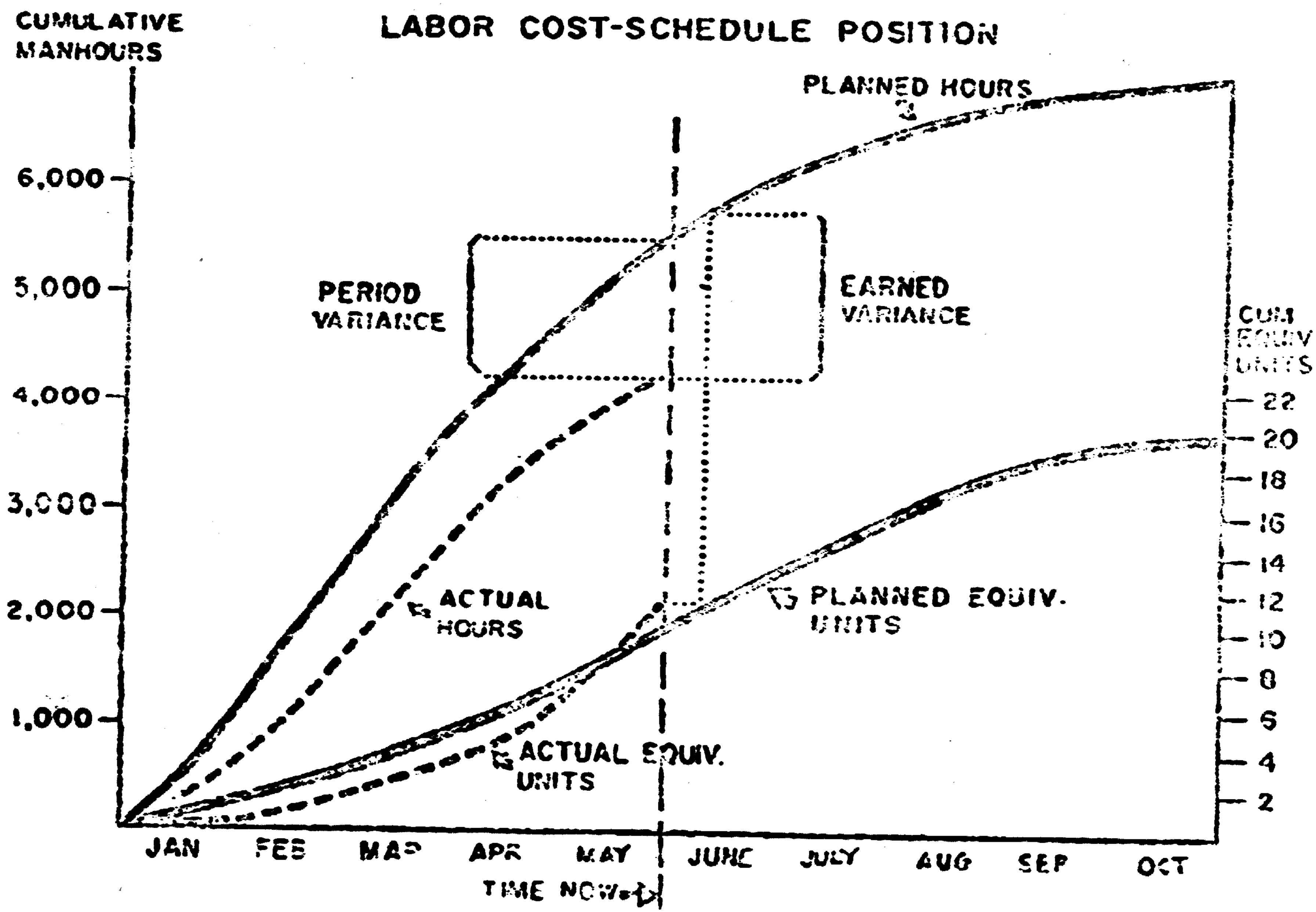

LABOR COST-SCHEDULE POSITION
CUMULATIVE MANHOURS
6,000
5,000
4,000
3,000
2,000
1,000
PLANNED HOURS
PERIOD VARIANCE
EARNED VARIANCE
ACTUAL HOURS
PLANNED EQUIV. UNITS
ACTUAL EQUIV. UNITS
22
20
18
16
14
12
10
8
6
4
2
JAN
FEB
APR
MAY
JUNE
JULY
AUG
SEP
OCT
TIME NOW

Figure 35.

LABOR DOLLARS AND OVERHEAD COST-SCHEDULE POSITION

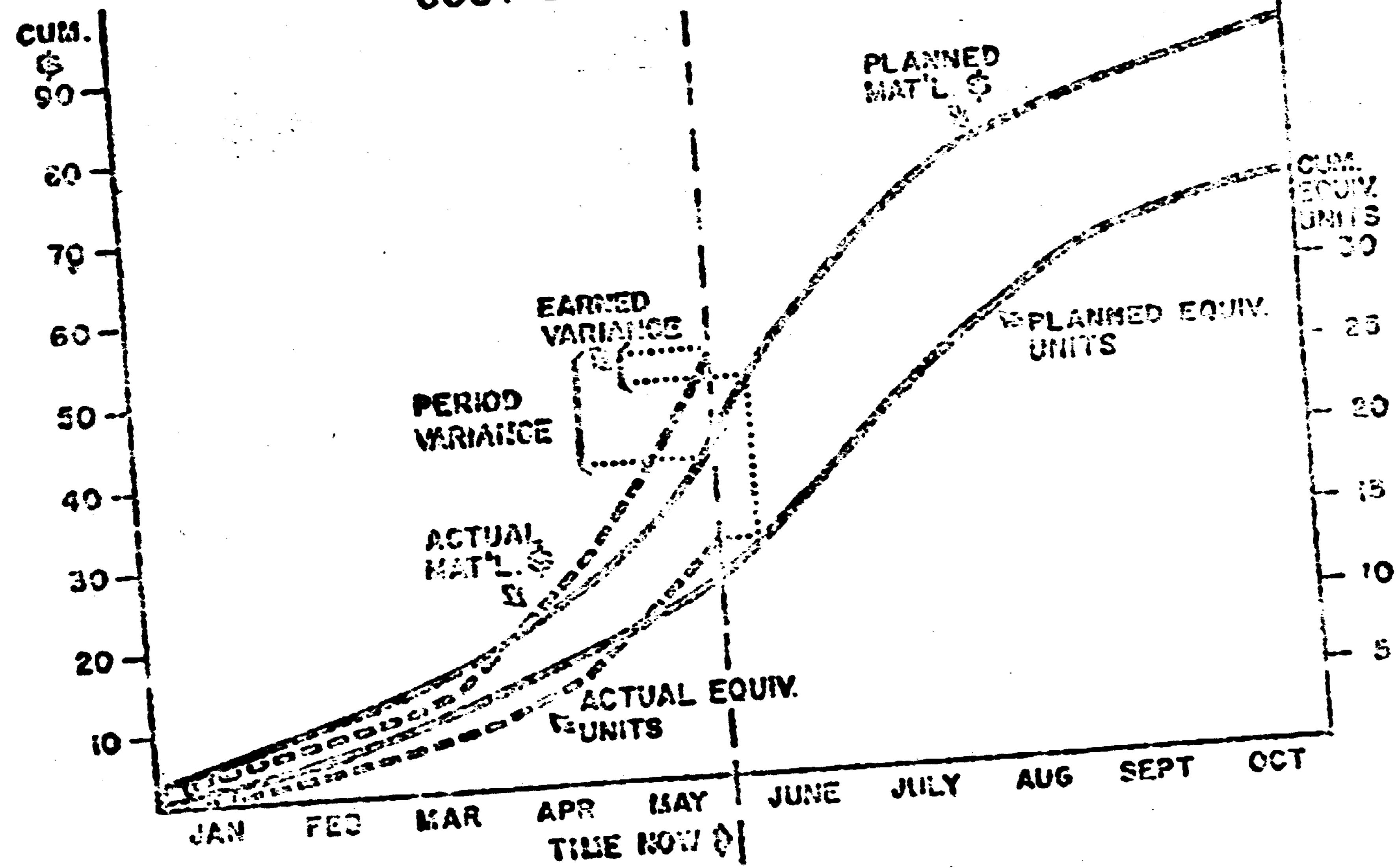


Figure 36.

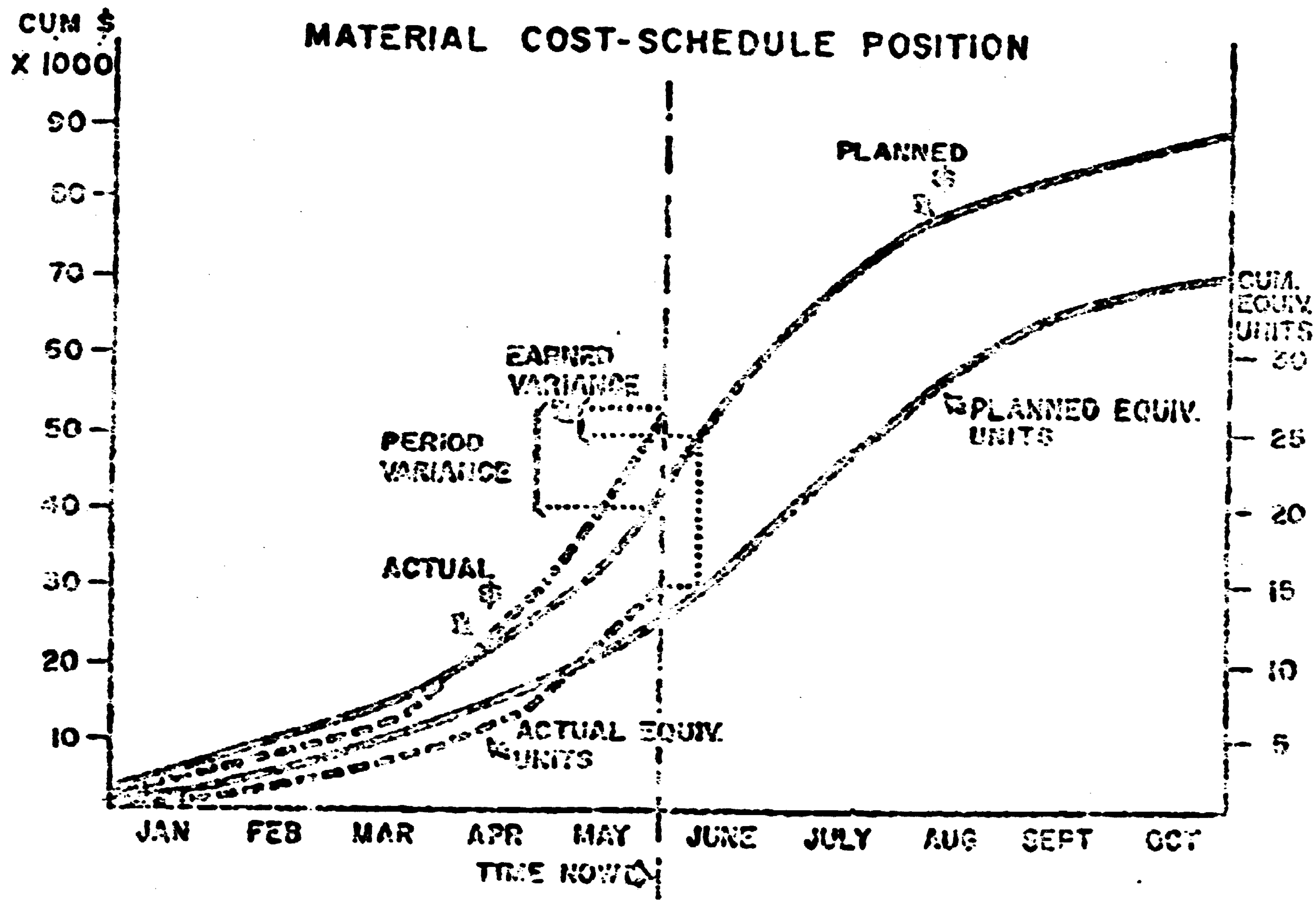

MATERIAL COST-SCHEDULE POSITION
CUM $ X 1000
90
80
70
60
50
40
30
20
10
CUM. EQUIV. UNITS
30
25
20
15
10
5
PLANNED $
PLANNED EQUIV. UNITS
EARNED VARIANCE
PERIOD VARIANCE
ACTUAL $
ACTUAL EQUIV. UNITS
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
TIME NOW

Figure 37.

6. Cost Information

General Electric Company has developed a Companion Cost Information System for application on some of its projects. The system is tied very closely to the traditional PERT Value of Work Performed, wherein the difference between the value of work performed to date and the actual cost is added to or subtracted from the total customer base line to arrive at a cost of completion; or, in the case of a trend, the percentage over/under to date is extrapolated over the entire subtask, as shown in Figure 38.

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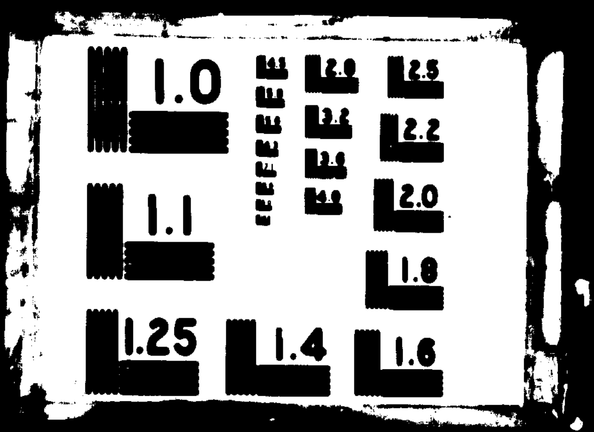
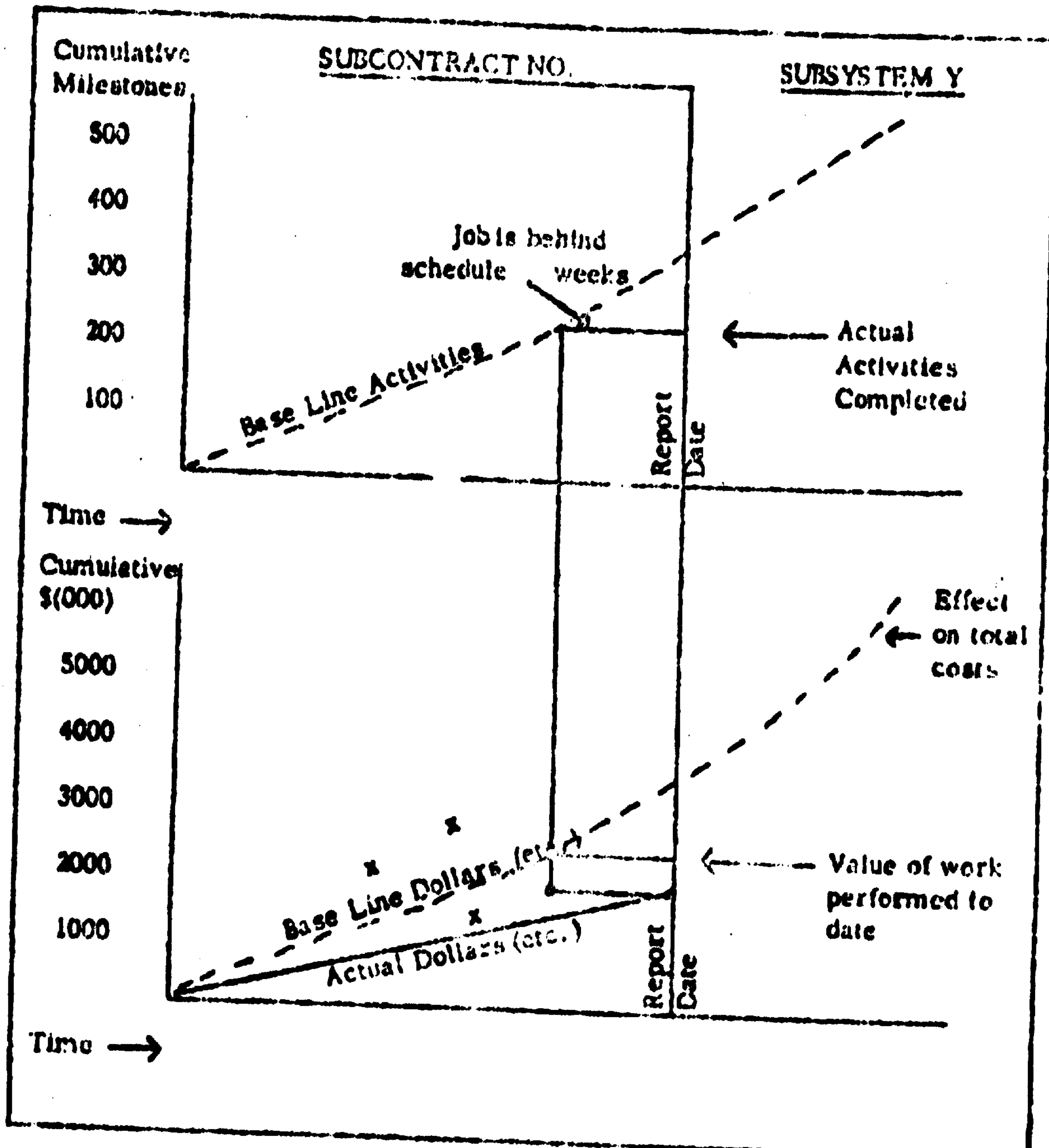




x Prior month's estimates of value of work performed to date

Figure 38. Value Calculation

7. Planned Output

This system has been utilised by Collins Radio. Like the Status Index, it compares input (planned and incurred expenditures and commitments) with output (planned and actual performance indices). Its expressed purpose is to establish visibility necessary to implement timely corrective actions. Schedule performance is measured against a series of pre-selected milestones. These form the basis for the "planned output" curve. The input curve is spread at the projected commitment rate, at both the project summary and task levels. A target line represents total estimated cost, through general and administrative costs, but exclusive of fixed fee. This line is adjusted as a step function when and as purchase change orders are received.

Further applications of this system include:

1) Forecast curves: New estimates of complete prior to formal contractual revision of a purchase order showing:
   a) Target cost in contract;
   b) Pending contractual costs to be negotiated;
   c) Planned variance (O/R or U/R).
2) Current status summary: Shows total planned input and is up-dated monthly;
3) Percentage of completion: Represents and highlights planned versus actual output. It is derived by dividing cumulative attained output by total anticipated output;
4) Effectiveness factor:

$$\frac{\text{Planned Input} \times \text{Actual Output}}{\text{Actual Input} \times \text{Planned Output}} \times 100\% = \text{Factor.}$$

8. Line of Balance

The line of balance technique is used to monitor production and proved demonstrably successful in breaking bottlenecks which restricted the flow of material. Studies and applications clearly demonstrated the utility of the technique as a controlling device in any operation involving the consideration and integration of a number of elements.

For example, the following description represents a hypothetical situation on production of an antiaircraft gun by X Company. To show the basic theory of graphic co-ordination, this is set forth in four separate phases, each illustrated by a chart.

8.1 Production Plan

Figure 39 presents a sample flow chart of the respective lead times for all homogeneous groupings of materials, components and major assembly operations required to manufacture an antiaircraft gun by X Company. Each of the homogeneous groups is known as a "control point". These control points are numbered in sequence from left to right and top to bottom. Beginning at the right with the acceptance of the gun, the lead times for these groupings are shown graphically against a time scale at the bottom of the chart. All time relationships are expressed as planned lead time prior to final acceptance of the gun, and machined parts made from these are required 2½ months prior to the final acceptance. Remote control units are required two months prior to final acceptance. Final assembly starts two weeks previous to acceptance and is completed in one week, leaving one week for test and acceptance.

Management can include in this type of chart as much detailed information as is desired.

GUN, ANTIAIRCRAFT, PRODUCTION AND MATERIAL STATUS

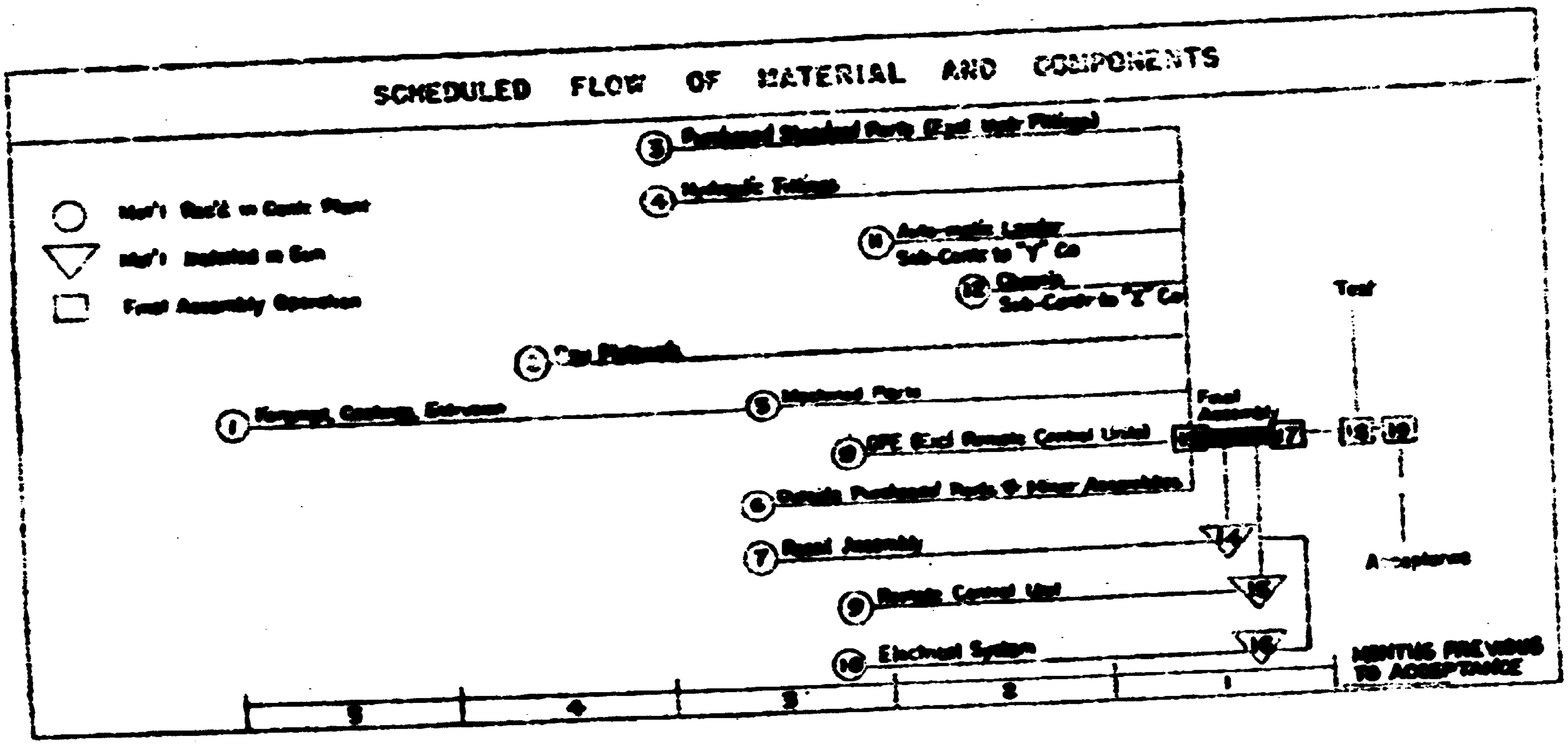


Figure 39.

8.2 Cumulative Acceptance Versus Schedule

The next step is to prepare a line chart (see Figure 40) showing on a time scale the cumulative production schedule. Cumulative gun acceptances are plotted against this schedule. This line chart shows there was a scheduled production, as of 1 March, of fifteen guns. This has been exceeded by eight guns, and thus the manufacturer has gained approximately a week's time in his scheduled production.

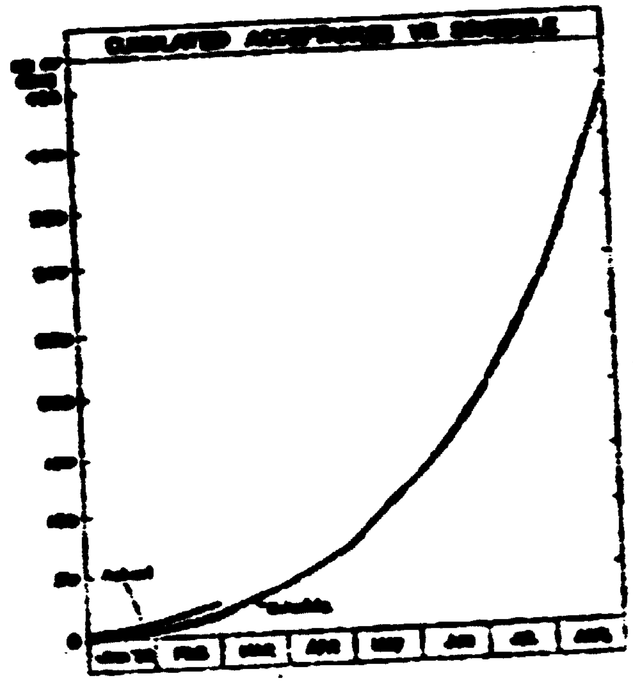
8.3 Determination of Balance

Before proceeding to Figure 41, a basic premise must be noted. Throughout this technique all figures are expressed in terms of end-item sets. For example, if ten bearings of a specific type are required to produce one end item, 1,000 units represent 100 end-item sets of these bearings.

The third and final part of the graphic technique is a bar chart on the same vertical scale as is used for the cumulative schedule. This bar chart has provision for as many bars as there are control points in the flow chart below. These bars are keyed consecutively by number and colour to the control points.

The first step in determining how the company stands with reference to its planned production schedule is to establish a "line of balance" (see Figure 42). This line of balance shows the desired status for each of the control points as of the date of observation. For example, as Figure 41 reveals, gun sets of forgings, castings and extrusions (Control Point No. 1) are required five months ahead of final acceptance. Therefore, starting on the cumulative acceptances versus schedule chart at the point of observation, which is 1 March, we count to the right five months, or in other words, to the first of August. An imaginary line is drawn from this point vertically to the cumulative schedule; next, this point of intersection is projected horizontally to Bar No. 1 on the bar chart. Thus, as of 1 March, 315 gun sets of forgings, castings and extrusions should have been produced. Applying the

GUN, ANTIAIRCRAFT, PRODUCTION AND MATERIAL STATUS



Scheduled Flow of Material and Components

(see Figure 39)

Figure 40.

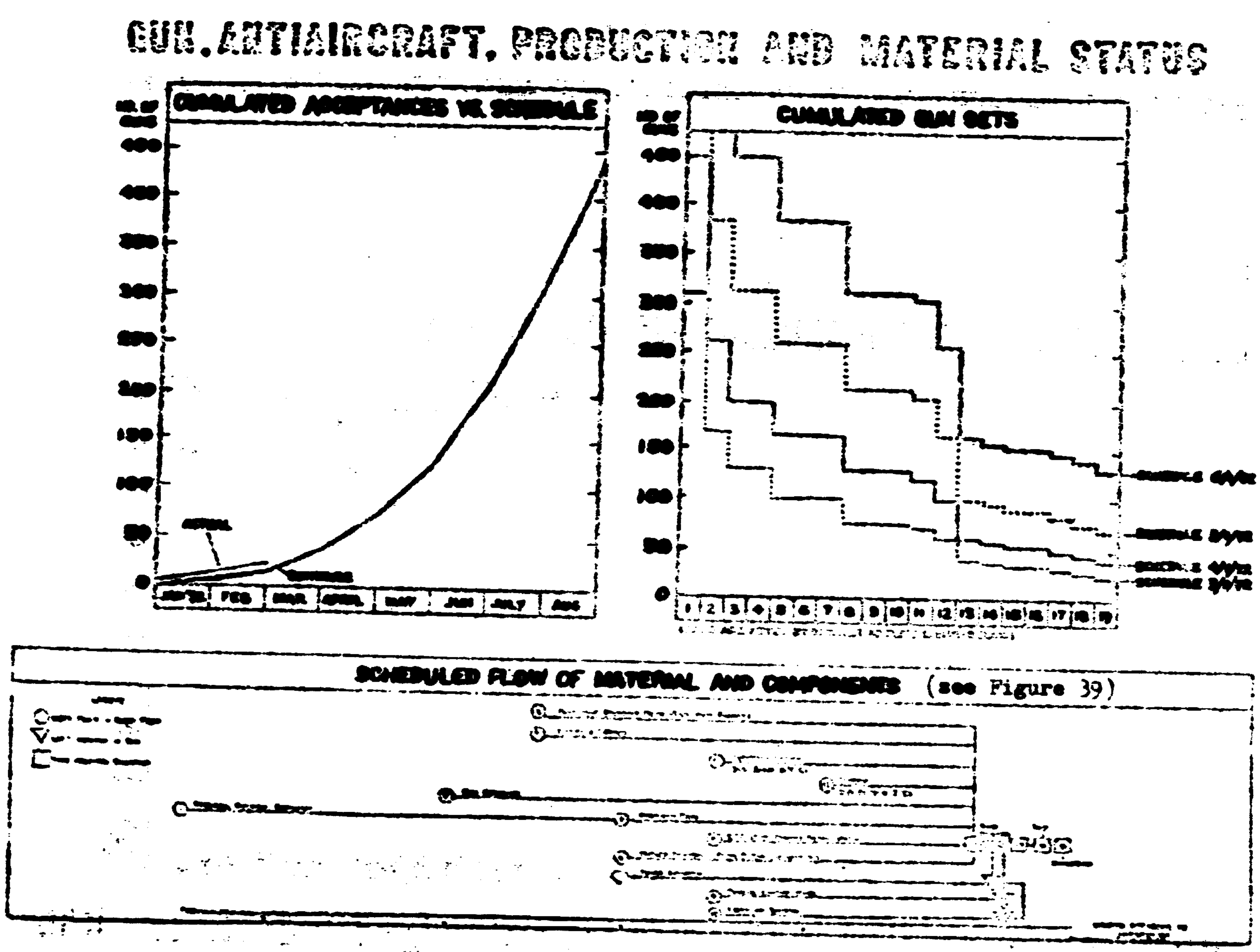

GUN, ANTIAIRCRAFT, PRODUCTION AND MATERIAL STATUS
CUMULATED ACCEPTANCES VS. SCHEDULE
ACTUAL
FEB.
MAR.
APRIL
MAY
JUNE
JULY
AUG.
CUMULATED GUN SETS
SCHEDULED FLOW OF MATERIAL AND COMPONENTS (see Figure 39)

Figure 41.

GUN, ANTIAIRCRAFT PRODUCTION AND MATERIAL STATUS

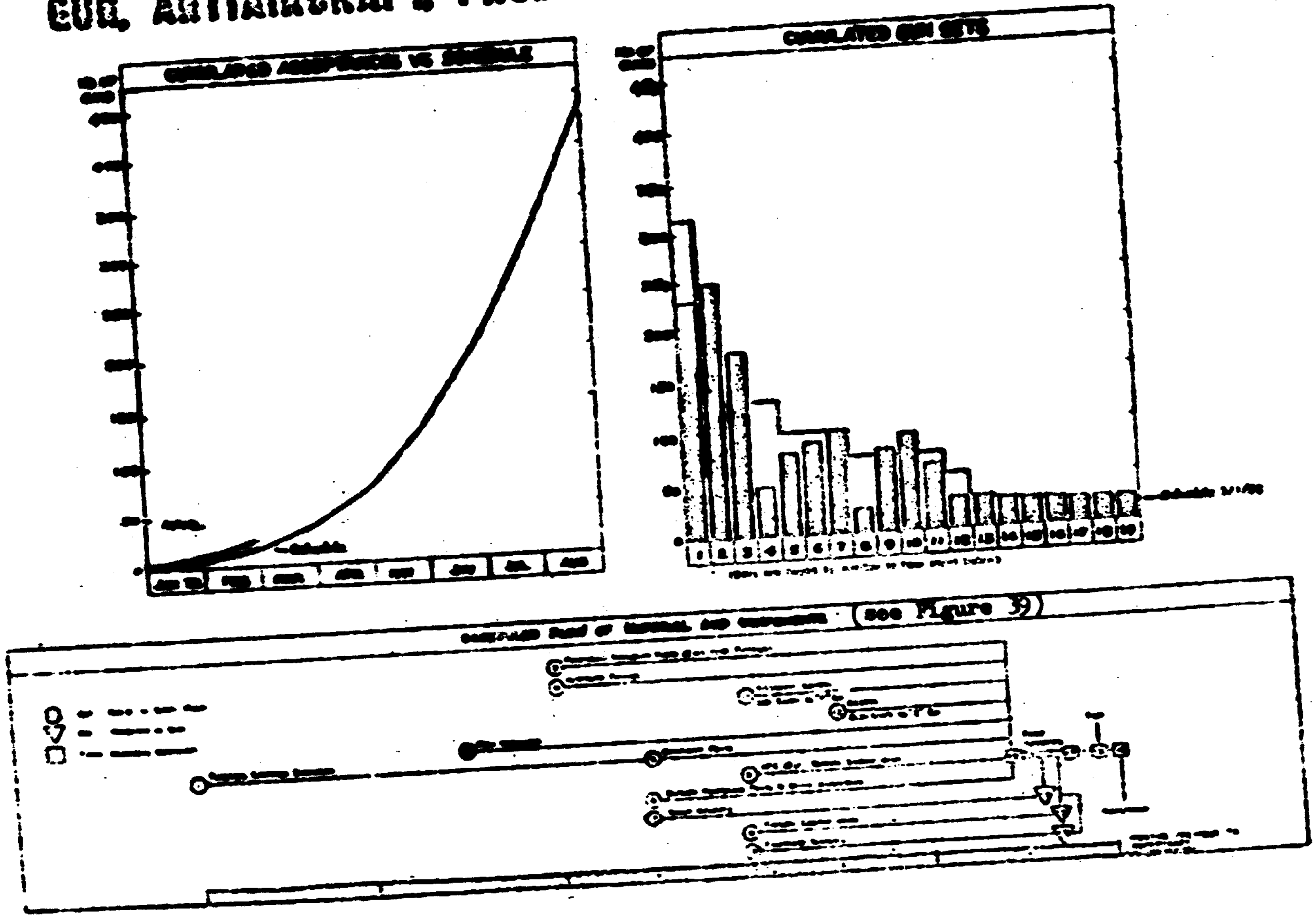


Figure 42.

same technique to raw materials (No. 2), we find from the flow chart that they are required $3\frac{1}{2}$ months before acceptance of the gun. Therefore, we should have received by today sufficient raw materials for the cumulative number of guns which are planned for acceptance by the middle of June. In the same manner, this is projected across to Bar No. 2.

This is continued until we have achieved a somewhat irregular set of "stair steps" leading downward to the right across the face of the bar chart. This line is the line of balance for the various components under observation as of 1 March. This same technique also can be applied to ascertain what the line of balance should be as of 1 April, 1 May, and so forth. These lines are also shown on Figure 41. Note that during the build-up period, the procurement function accelerates at a much greater rate than does final acceptance.

8.4 Status Versus Line of Balance

After the line of balance has been established, it follows logically that the actual status of each control point should be plotted. Figure 42 presents these data.

As mentioned above, all materials, components and major assembly operations are grouped in homogeneous categories. Therefore, the procurement status of every individual part in the end item is not considered. Rather the height of the bar for each control point is determined by the cumulative receipts (less rejections) of the least available item within each homogeneous group as of the date of observation. This cumulative quantity is always expressed in cumulative end-item sets. The basis for this control by least available items is the fact that production of end items is conditioned by the least available part received. For example, no more complete guns can be built than recoil mechanisms received. Thus, by this method the co-ordination levels of management are given only the information on those things which will limit production. This permits management to measure the deviations from plan and avoids unnecessary detail.

8.5 Analysis

In analysing the situation in X Company, it is apparent that although guns have been produced ahead of schedule, forgings, castings and extrusions have been produced in insufficient quantity to provide for scheduled production. It is evident that if this situation is not corrected, the scheduled production for July has been lost. Management, therefore, has four months in which to take corrective action such as bringing in extra capacity, operating additional shifts or seeking outside assistance.

Raw materials and purchased standard parts, Bar Nos. 2 and 3, respectively, show an excess of receipts in terms of lead-time requirements. Bar No. 4, gun sets of hydraulic fittings, is behind schedule and badly out of balance. Bar No. 5, machined parts, is also below the required balance figure. This probably a result of the already observed insufficient production of forgings, castings and extrusions from which they are made. Outside purchased parts and minor assemblies, Bar No. 6, are ten guns short of required balance and should receive attention Bar No. 7 shows that the recoil assembly is in balance. Bar No. 8 representing government-furnished equipment (excluding remote control units), is in trouble. Some items of government-furnished equipment are being installed as fast as they are received. This calls for a detailed study of the individual items to determine which of them constitutes the bottleneck and what is causing this short supply. Bar No. 9, remote control units, and Bar No. 10, electrical system, are both in balance. Bar No. 11, the automatic loader subcontracted to Y Company, has not been received in accordance with the planned programme. Steps should be taken to find out the difficulty of this company before the greater demands of scheduled build-up in production cause the situation to become an acute problem. Bar No. 12, representing the sets of chassis subcontracted to Z Company, shows very poor performance on the part of that company.

All other factors are in balance with the possible exception of the beginning of final assembly, which shows that although X Company is ahead of schedule on complete guns, it is failing to start gun units in final assembly on scheduled time. This will result in a failure to maintain its present rate of production.

To summarise the findings, although X Company has been exceeding its schedule to date, it is not going to be able to continue this status for long. Several indications are shown of failure to build up to schedule monthly production within the desired time limits. Action should be taken to accelerate the procurement programme.

8.6 Submission of Narrative Summary and Analysis

When data are submitted to keep a chart current, particularly to military echelons, a brief narrative summary and analysis should accompany the information. The purpose of this summary is to:

1) Identify the low item in a homogeneous group;
2) State briefly what difficulty is being encountered on the low item;
3) State what corrective action is being taken and when results may be forthcoming. If the problem is outside the control of the contractor, specify briefly what assistance is needed from higher echelons;
4) Submit any other pertinent information or problems which the manufacturer or a military echelon desires to bring to the attention of the next level of management

The analysis should not be restricted to problems shown in the charts It should include anything that may have an adverse effect on end-item output. In addition, the latest production forecast for at least the succeeding two months should be submitted. Finally, the analysis should contain only information of value to the receiver. If no information in addition to the data is necessary, none should be submitted.

9. Strengths and Limitations of Control Systems

Many strengths and limitations are associated with computerized management information systems and derivative systems - far too numerous to attempt to catalogue here. Relevant experience, however, has been summarised recently by using, and this experience can be itemized in a few brief comments on PERT/Cost. The following have as their theme that the total project management can be achieved only if the three interdependent variables, time, resources and performance, are managed on a common framework which classifies all work elements of the project beginning from the top and breaking down to successive tiers representing systems, subsystems, and so forth, which make up the total project. This pyramidal management framework is the project work breakdown structure. The system requires the establishment of project master plans for resources and schedules directly related to the work breakdown structure.

The nature of most NASA projects is such that the total project effort is represented by a combination of the efforts of several major contractors, as well as a significant amount of NASA in-house effort. A primary responsibility of the NASA project manager is to integrate these efforts into a co-ordinated total project plan, monitor and guide the execution of this plan and provide redirection as required. Consequently, the NASA PERT networking philosophy is that there will be "one overall network" which includes all efforts, in-house and contractor. In large projects, it becomes physically impractical to show the total NASA project on one piece of paper, and it is broken down into smaller portions called "fragnets" which are derived from the work breakdown structure. These fragnets are interconnected in such a way that data can be processed separately for each fragnet, for groups of fragnets representing a particular contractor's efforts, or as a total project network. The structuring of the fragnets in accordance with the work breakdown structure will result in systems or end-item-oriented networks.

Cost and financial planning and reporting against "sub-divisions of work" and "elements of cost" for the total project effort include both contractors and NASA in-house work on the project. Both types of cost data are related to the common project work breakdown structure. It is noted that the companion cost system is not limited to use with PERT but can be used by itself or in conjunction with any other NASA time-oriented system, such as milestone reporting, line of balance and so forth.

The minimum acceptable level of time/cost correlation for any project is to establish fragnets and subdivision of work cost accounts at the subsystem level (that is, structure subsystem, telemetry subsystem, and so forth). Using the work breakdown structure, a separate fragnet and a corresponding subdivision of work cost account is established for each subsystem. In this way, all the effort associated with a particular subsystem, as reflected by activities on the subsystem fragnet, is charged to its corresponding subdivision of work cost account. Interface activities between fragnets must be identified as being charged to one of the two corresponding subdivisions of work cost accounts.

Examples of the master schedule, master financial plan and management summary reports of the NASA PERT and Companion Cost System are presented in Figures 43, 44 and 45 respectively.

The NASA PERT and Companion Cost System does not attempt to unduly influence a contractor's internal management system. Rather, both NASA and the contractor use the bilaterally established work breakdown structure as the framework for structuring the PERT fragnets and corresponding cost reporting categories. The work breakdown structure level of indenture for reporting is established (for example, subsystem) and this becomes the interface level between NASA and the contractor for routine reporting and progress evaluation. However, the contractor's lower level time and cost details which he uses for his own management prupose must validate the information reported to NASA. On large programmes in which the contractor has one

PERT AND COMPANION COST SYSTEM

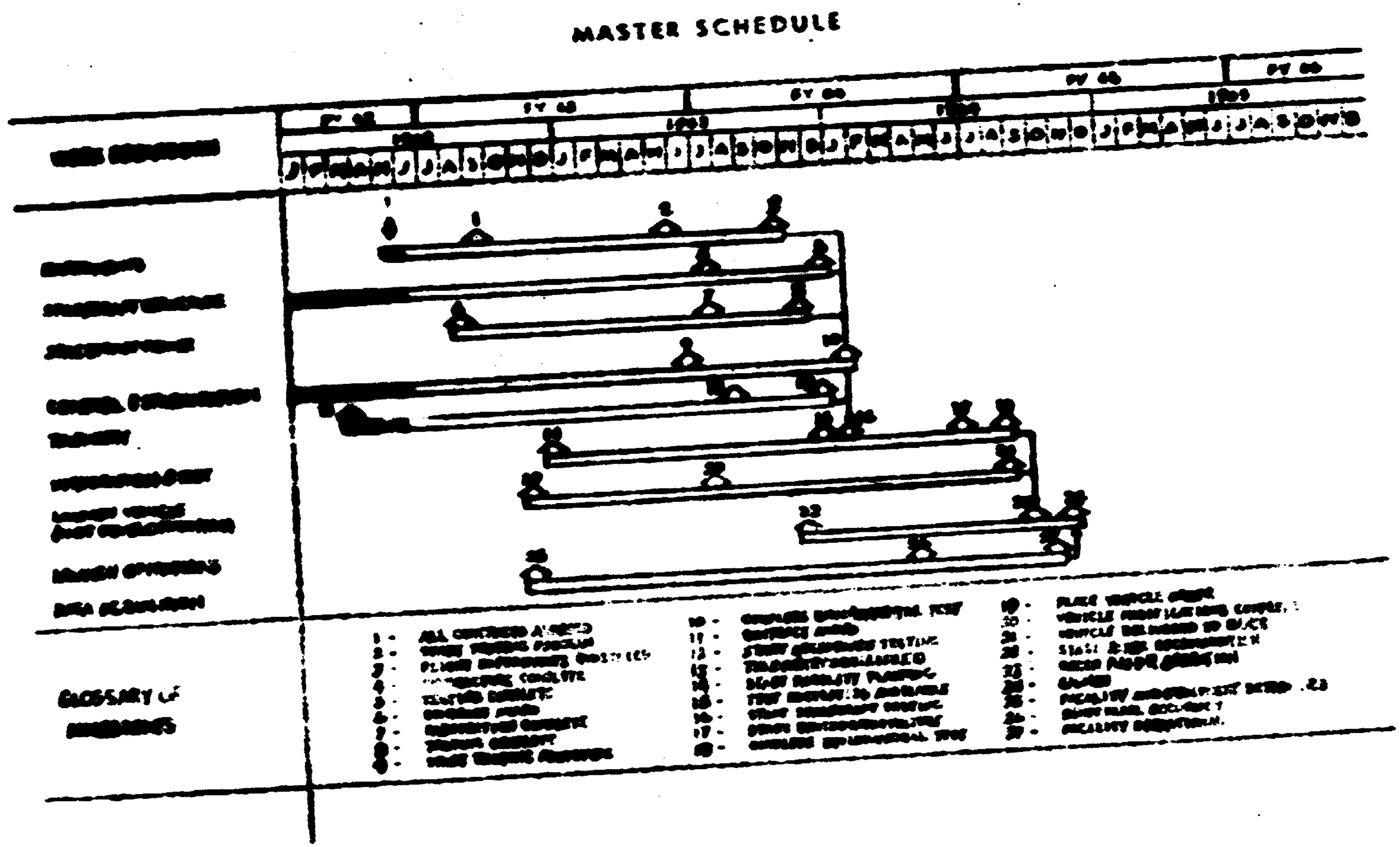


Figure 43.

PERT AND COMPANION COST SYSTEM

MASTER FINANCIAL PLAN

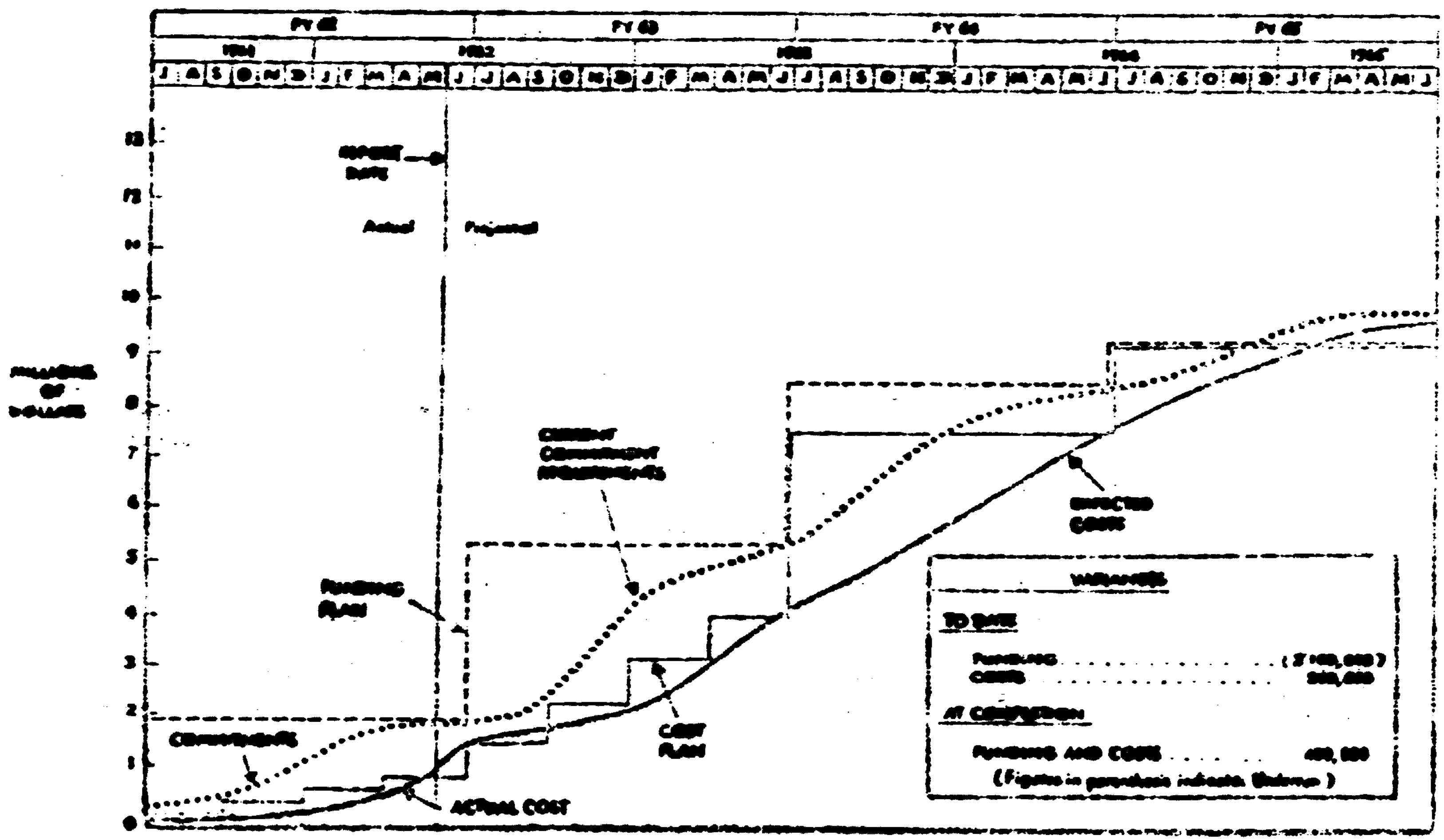
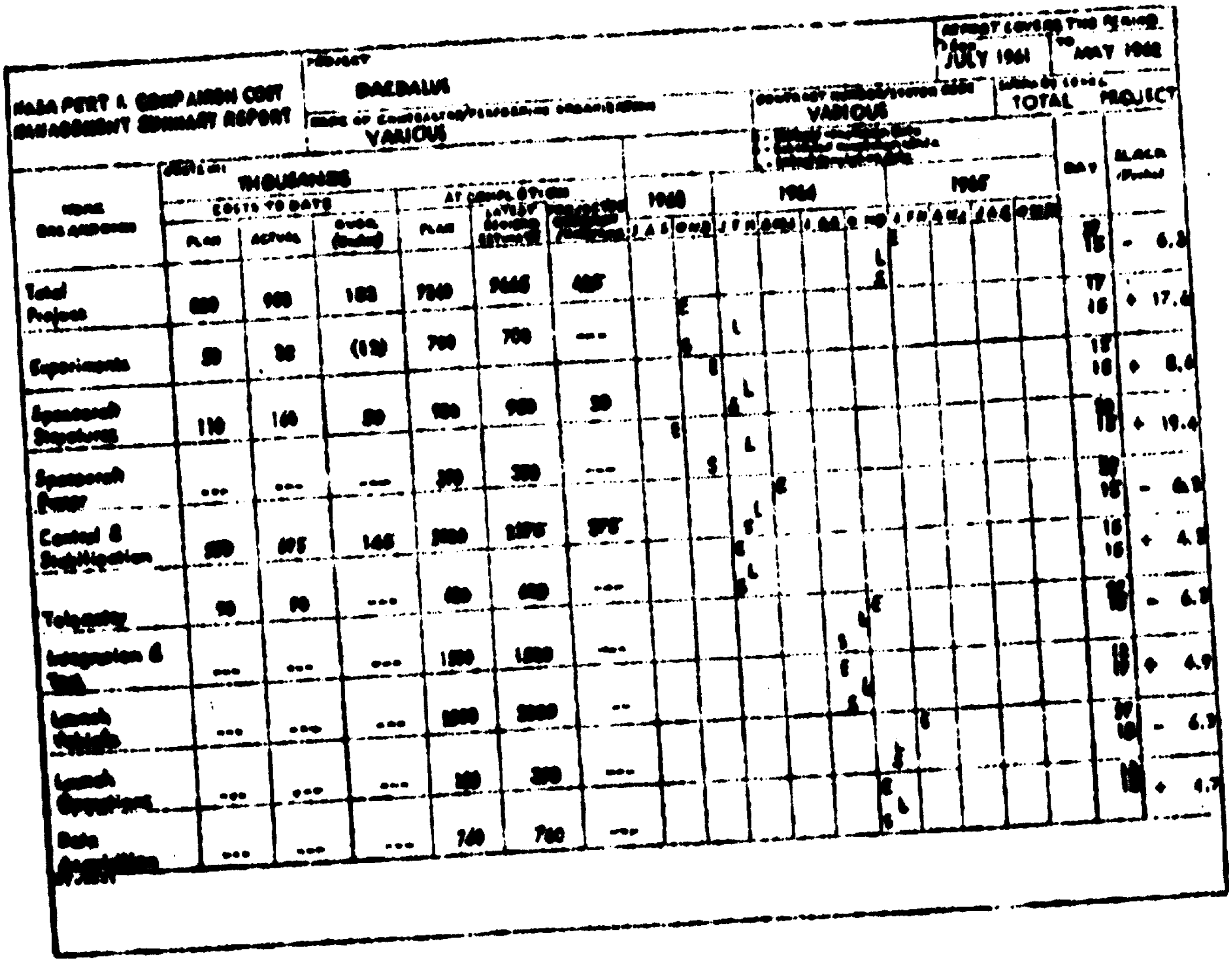


Figure 41.

PERT AND COMPANION COST SYSTEM
MANAGEMENT SUMMARY REPORT



NASA PERT & COMPANION COST MANAGEMENT SUMMARY REPORT — Project: DAEDALUS — Contractor/Performing Organization: VARIOUS — Report covers the period: from JULY 1961 to MAY 1962 — Summary level: TOTAL PROJECT

Work Breakdown	Costs to Date: Plan	Costs to Date: Actual	Costs to Date: Over (Under)	At Completion: Plan	At Completion: Latest Revised Estimate	At Completion: Projected Overrun (Underrun)
Total Project	[illegible]	[illegible]	188	7[illegible]	9646	4[illegible]
Experiments	[illegible]	[illegible]	(12)	700	700	---
Spacecraft Structure	110	160	[illegible]	[illegible]	[illegible]	[illegible]
Spacecraft Power	---	---	---	[illegible]	[illegible]	---
Control & Stabilization	[illegible]	[illegible]	145	[illegible]	[illegible]	[illegible]
Telemetry	[illegible]	[illegible]	---	[illegible]	[illegible]	---
Integration & Test	---	---	---	1500	1500	---
Launch Vehicle	---	---	---	[illegible]	[illegible]	--
Launch Operations	---	---	---	[illegible]	[illegible]	---
Data Acquisition	---	---	---	760	760	---

Slack (weeks), in printed order: - 6.3; + 17.6; + 8.6; + 19.4; - 6.9; + 4.8; - 6.9; + 4.9; - 6.3; + 4.7

Figure 45.

or more major subcontractors, NASA often requires the contractor to exert his best efforts to ensure meaningful participation of his subcontractors in the implementation and operation of the NASA PERT and Companion Cost System.

APPENDIX B

Computer Use in PMIS

Beyond a certain number of activities in a project, the use of the computer becomes necessary. There are several factors to consider 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 up-dating 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 programme to satisfy one's needs. These programmes range from the very simple to the highly complex such as PERT/Cost package. The choice of a computer programme depends on the need for information required for decision-making, such as:

- Statistical analysis;
- Graphical output;
- Resource allocation;
- Cost allocation, etc.

The following list of programmes available for project management relates the programme to the computer needed to run it. The capacity of the programme is specified by the number of activities or events that can be accommodated by the programme.

Computor Programmes

Computer	Programme Name	Capacity
Burroughs B200/B306	PERT/Time	900 Events
Burroughs B5500	Time-PERT in Algol 60	524,288 Events
Control Data 1604	PERT	3000 Activities
GE-115	Critical Path Method Programme	350 to 3000 Events
GE-215/225/235	Project Monitor and Control Method (CPM/PROMOCOM)	999 Events
GE-400/600	Critical Path Method Programme and CPM/Monitor	3000 Events
Honeywell 400/1400 or 800/1800	PERT	3000 Activities
IBM 1401 and Sys. 360	Management Control System	4,600 Nodes
IBM System/360	Project Control System/360	5000 Activities
IBM 1130	1130 Project Control System	2000 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	5000 Activities
RCA 501	PERT	2000 Activities
UNIVAC 1107	PERT/Cost	Not given

More specific comparisons are given related to the Project Management System (PMS) utilizing IBM System/360 and the less-complicated Project Control System (PCS) utilizing IBM 1130 computer.

Comparison

PMS/360:

- High number of activities
- 64 K minimum
- Three disks or four tapes
- Printer
- O.S./360
- Various processors (versatile)
    - Network
    - Cost
    - Report-any format
    - Resource

1130 PCS:

- Smaller number of activities
- 8 K minimum
- One disk
- Printer
- 1130 O.X.
- Basic reports
    - Critical
    - Cost control
    - Bargraphs

APPENDIX C

Strength and Limitations of Computerized Project Information Systems

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

- It permits work breakdown structure.
- It permits effective integration of cost and time.
- It permits management by major significant exception rather than by exception only.
- It permits effective quantification of uncertainties.
- It is eminently visible.
- It lends itself to the management cycling process.
- 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 the limitations cited are:

- PERT is diagnostic; it deals only with effects, not causes; therefore, it is not consistent with entrepreneurial objectives of buying cheap and selling dear.
- PERT supports the fiction of resource flexibility.
- 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 although the

project manager can plan his project through the elapsed-time phase, he does not own the resources he will need to complete the project successfully. He is dependent upon a pooled work unit.

- Project managers are frequently distracted by the slack-time fiction, so they are managing residual time, not the work.
- PERT never converted information to knowledge. Parenthetically, we might ask if it ever could be expected to do so.
- 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 project control is the failure to get enough information to the right people in time for them to take corrective 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 organisational relationships that the PERT/Cost system utilises 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 considerable 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 of 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 material usage 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. As a matter of 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 operating results 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 insure 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 work load, but he does not own the resources he will need to successfully implement the programme 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 form 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.

APPENDIX D

Comments Expressed by Participants from Developing Countries

1. Successful utilization of project management requires well-trained personnel in the new techniques as well as well-trained decision-makers. The most important consideration to assure success of the implementation is to ensure top management support. Seminars or round table discussions will be instrumental in acquainting them with the concepts of project management. Detailed training programmes will follow for the project management level and the task or operational level. In countries with central planning economies, a further type of training may be required.

2. On the educational level, there is a need for specific up-dated courses in the universities for project management techniques. This, however, should be supplemented by on-the-job training programmes.

3. There is a need for scientific approach in handling project management. This can be accomplished through more meaningful information related to available institutions and courses of instruction in the area of project management. In addition, information should be provided in the recent literature and applications in this subject.

4. The reporting system needed for project implementation should be clarified. Specific formats should be designed to suit the reporting needs of the different levels of management.

5. The executing organization or contractor should be encouraged to present the required network. The manual handling of network analysis should be emphasized at the early stage of the project. In case of big projects, the possibilities of using a computer should be studied.

6. The project management main functions, namely planning, scheduling and control should be understood and the reponsibilities involved should be assigned. The following are some specific recommendations in this respect:

Planning

Management should assign clearly the responsibility and authority for project implementation. It is recommended that a task team should be established whose leader reports to the programme manager. This team is responsible for developing implementation plans which are approved and monitored by management. One of the most important top management responsibilities is to assure the integration of the planning of the project with related projects.

Scheduling

Time estimating for project tasks should be assigned to personnel who are familiar with the work to be performed. Inadequate networking is a serious problem. Project breakdown structure should be used as a basis for network development. The work package should be well-defined and should be related to the internal organization and responsibilities. All performing organizations involved in a work package should understand and agree to its scope and timing, i.e. identifying the precise start and completion events or milestones for each total work package.

Control

Programme manager should establish appropriate level of detail for programme control. Excessively detailed reports for top management should be avoided.

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