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ABSTRACT

Network-based management procedures serve as valuable aids in organizational management, achievement of objectives, problem solving, and decisionmaking. Network techniques especially applicable to educational management systems are the program evaluation and review technique (PERT) and the critical path method (CPM). Other network charting techniques are (1) line of balance charts, (2) Gantt bar charts, (3) milestone charts, and (4) flowcharts. Research for this project was provided by an ESEA Title III grant. (Author/RA)

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NETWORK-BASED MANAGEMENT PROCEDURES

by

Allen L. Buckner

Produced by

OPERATION PEP: A State-Wide Project
to Prepare Educational Planners for California

EA 003 501

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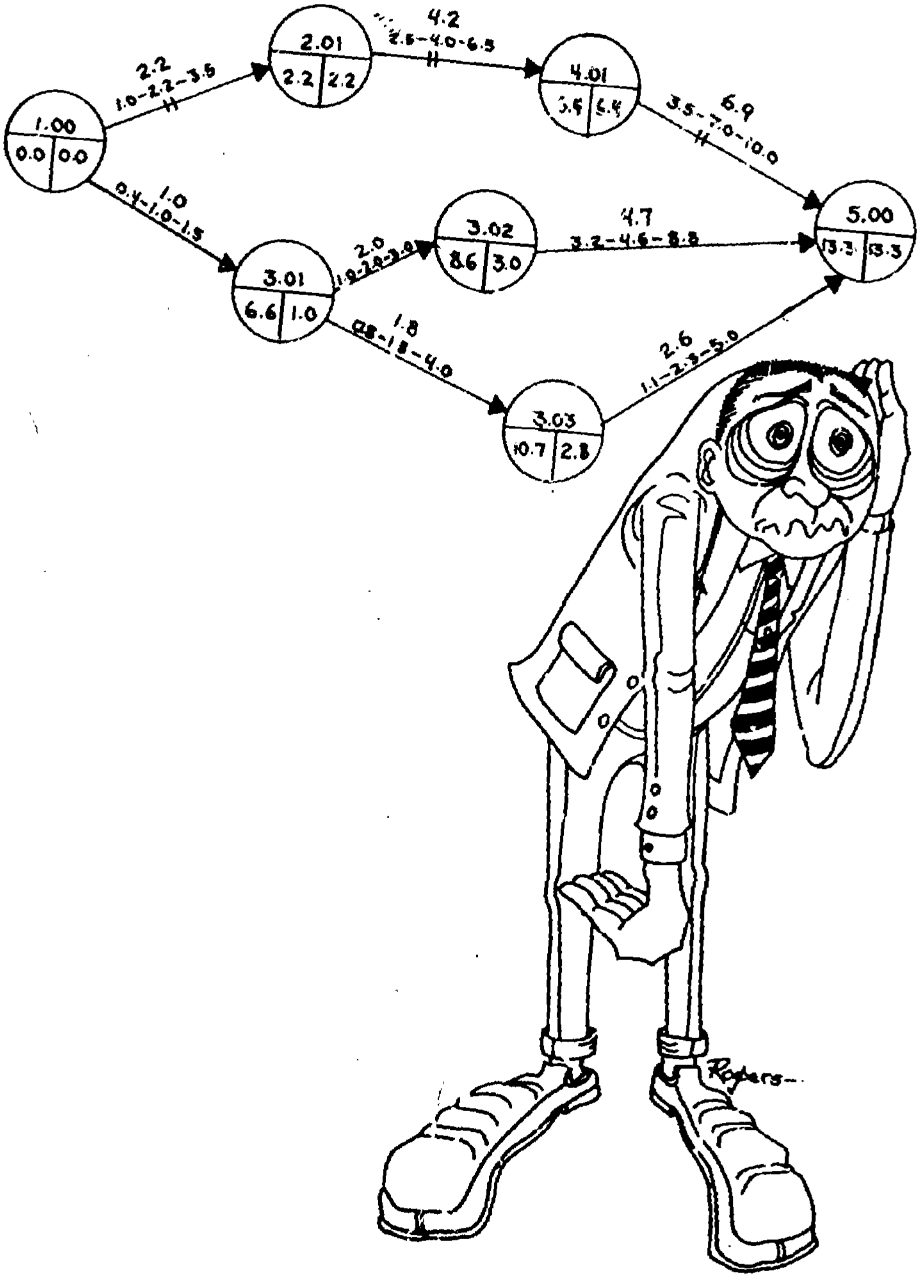
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PREFACE

In the continual change-demand environment of public school education, many management problems can be avoided through the use of systematic planning, evaluation and review procedures. The benefits to be derived through their use are illustrated by the following anecdote:

> Early in his career, Henry Ford, in granting a subcontract for engine parts, specified that these parts were to be delivered in wooden boxes of a certain size, held together by screws, not nails. He even indicated the exact size and location of the screws.
>
> In order to receive this lucrative order the subcontractors willingly accepted the conditions, although they privately agreed that "this guy Ford is slightly batty." Many of his own employees felt that the "old man" was being unnecessarily dogmatic about the shipping cases, too, but they chalked it up to erratic genius.
>
> Came delivery day--and revelation. Henry Ford's "whimsy" had been the work of genius all right, but hardly erratic. The sides of those precisely measured wooden shipping boxes were exactly the size of the floorboards of Henry's Fords. With each screw hole correctly placed and drilled, the boards were ready to be slipped into place.[1]

This monograph presents the "why's," "when's," "what's," "where's" and "how's" of network-based management procedures. It is designed to serve as a training and management referent. As a training referent, it provides an integrated treatment of network-based management concepts and principles. It provides operating definitions for relevant terms, discussions of five network-based management procedures and their respective

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[1]George Relf, quoted by Helen Houston Boilear, Reader's Digest Treasury of Wit and Humor (Pleasantville, New York: The Reader's Digest Association, Inc., 1958), p. 302.

values and limitations and practicum exercises for skill development.

As a management referent, it provides a systematic perspective and guidelines for program management, procedures for utilizing available inputs for effective and efficient achievement of objectives, and other managerial procedures that can be used to plan, implement, control and evaluate proposed and/or actual performance toward the achievement of valued benefits.

Network-based management procedures can be used at all levels of organization in an educational system. Significant demands on the time of educational managers are generated by increasing problem complexity and the criticality of time, cost and technical requirements. The resolution of most educational problems requires establishment and maintenance of multiple human relations. Systematic procedures, operations and processes must be developed across the interfaces between and among individuals and groups in the educational system. Establishment of effective and efficient working relations and interactions across these interfaces requires both time and coordinated effort on the part of management.

Time expended in planning, evaluating and reviewing performance efforts and related achievements too often is minimal because of routine operational demands on management. Operational crises frequently require management decisions in a stringently limited "real time" period.[2] Sufficient time often is not available for thorough appraisal of alternative choice-consequence relations, nor for evaluation of the on-going course of performance. As a result, management frequently is forced to act without

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[2]Real time is that period of time between the decision event and the deadline for completion of desired actions.

sufficient information for decision making.

When network-based management procedures are used in planning specific programs; mission, function, task and methods-means analyses must be performed for each operational level of the program. Mission analysis results in a priority-arranged hierarchy of goals and objectives. Function analysis is performed to assess essential organizational activities in relation to the purposes established in mission analysis. Task analysis results in the definition of individual or group activities in terms of essential organizational functions and established purposes. Methods-means analyses are performed with due respect for and in relation to the products of mission, function and task analyses.

The results of these analyses are graphically displaced in a time-phased management plan which reveals organizational, managerial and operational relations, interfaces and interactions. These analytical products provide managers with tools that are useful in controlling work and progress more efficiently and effectively in terms of verifiable performance objectives. Further, these tools provide visual communication referents and guides for action in managing complex programs, in solving critical problems and in making program-related decisions relevant to purposes, priorities and policies.

The writer expresses his appreciation to authorities listed in the bibliography. Much of the content presented is based on concepts designed and developed in these sources. Thanks are extended to Helen and Luther Smeltzer who edited this monograph. Further, the author acknowledges the time and energies of Donald R. Miller, Director of OPERATION PEP, and Ted M. Rogers, Lynne Svenning, Sheldon Varney, Virginia Carroll, Richard Wehe and others on the OPERATION PEP staff who offered many helpful

suggestions. Responsibility for information presented, however, rests with the author. Suggestions for improvement and/or revision will be gratefully appreciated by the author.

Allen L. Buckner

Burlingame, California
February 1970

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AN INTRODUCTION TO NETWORK-BASED MANAGEMENT PROCEDURES

Network-based management procedures can be used as tools in educational management. Promising network-based procedures for education include:

1. Planning, Evaluation and Review Technique (PERT)
2. Critical Path Method (CPM)
3. Line of Balance (LOB)
4. Gantt Bar Charts
5. Milestone Charts
6. Flow Charts.

Definitions of Network-Based Management Procedures

Network-based management procedures are visual communication referents and guides to action for managers at multi-levels in educational organizations. They are synthesis tools which aid in planning and managing time, cost and technical considerations in complex and/or critical programs of planned change. All personnel involved in programs using such tools can see the relations between individual responsibilities and program activities as a whole.

A Participative Management Perspective

Interaction among managers with varied experiential backgrounds, training, capacities and capabilities is required for analyses and development of network designs. Participation in organizational planning serves as a catalyst for improving organizational morale and communication. Teamwork will result in a more acceptable plan of action than individualistic efforts. Eckman emphasized the need and value of teamwork by stating:

> The system analyst is not a know-all, see-all, hear-all omnipotent but rather a legitimate expert in the methodology and techniques applicable to the study of complex systems. Hence it is concluded that every worthwhile and purposeful systems analysis must be accomplished by more than one person. Call this group a team if you like, but regardless of whether the team interplay is formalized or not, the interchange is a necessary activity.[3]

In an organizational climate of participative management, people representing all levels of operation will be involved in deriving, specifying and integrating statements of organizational purpose and plans for their achievement. Individuals involved in specific operations will participate in the definition of verifiable performance objectives and in the analysis of relevant functions and tasks required for successful achievement. The primary benefit to be realized through participative management is the definition of valid, relevant, feasible, acceptable and reliable alternatives which are consistent with the strategic plans of the organization. Interaction and communication during these objective-setting processes also facilitate development of activity-oriented and event-oriented networks, workflow plans and work analysis structures.

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[3]Donald P. Eckman (ed.), Systems: Research and Design (New York: John Wiley and Sons, Inc., 1961), p. x.

Planning, Evaluation and Review Technique (PERT)

Definitions and Aspects

The acronym PERT stands for Planning, Evaluation and Review Technique. It is a time- and cost-phased graphic display of objectives, functions and tasks and their prerequisite occurrences arranged logically in sequence and parallel.

PERT/TIME is a management technique to determine, plan for and manage time necessary to the achievement of prespecified objectives.

PERT/COST is a management technique for equating planned program performance and planned resources utilization to actual accomplishments and expended resources.

Planning is the conscious determination of alternative courses and/or methods of action for accomplishing a valued target in light of relevant situations and conditions, future probabilities and perceptions of consequences to be experienced. It includes assessment, integration, time-phasing, cost estimates, evaluation and communication in relation to the target. Products of planning are clearly and cogently stated objectives and strategies for action. These products are developed by:

1. Analyzing, evaluating and interpreting relevant data in relation to objectives to be achieved
2. Systematically appraising choice-consequence relations
3. Selecting preferred alternatives for the achievement of objectives
4. Simulating and graphically portraying the functions and tasks (work) required to achieve each objective
5. Determining probability factors for successful and effective achievement.

Planning and its products must be related to and internally consistent with relevant organizational philosophies, purposes, priorities, policies and programs.

Evaluation is the process of fixing the value of relevant decision and action alternatives. Evaluation is performed to determine cause and effect relations among alternatives. The evaluation process includes:

1. Simulating the choice-consequence relations for priority alternatives

2. Comparing planned with actual performance achievements in terms of time, cost and technical requirements

3. Determining the effectiveness of actual performance in relation to organizational purposes, priorities, policies and programs.

The product of evaluation is complete, accurate, relevant and timely information for decision making.

Review is the process of continuously and judiciously examining the planned course and/or method of performance in light of actual achievements. It entails the continuous re-examination of the on-going course of performance using the products of planning and evaluation.

As in the case of planning and evaluation, review procedures must be internally consistent and compatible with organizational purposes, priorities, policies and programs.

Aspects of PERT include:

1. Prescriptive planning to determine definitive courses and/or methods of action through time

2. Continuous review and evaluation of temporal, monetary and technical considerations during the on-going course of performance to determine status of actual performance related to plan

3. Flexible adaptation as replanning may be desired and/or required.

Critical Path Method (CPM)

Definitions and Aspects

The Critical Path Method (CPM) is a management technique to determine the Critical Path(s) (CP) throughout the planned course of performance. The Critical Path is the most time consuming sequence of activities leading to achievement of the program objective(s).

Aspects of the CPM include:

1. Definition of the most time consuming path(s) leading to objective(s) achievement
2. Delineation of information that is compatible to the problem finding problem solving and decision-making requirements of management.

Description of PERT and CPM as Network-Based Management Procedures

As management tools, PERT and CPM must incorporate these selected descriptive terms:

1. Analysis--Determination of relations of organizational functions and/or individual tasks to each other and to the whole is inherent in the analytic process. An objective of analysis is the clarification of required functions and/or tasks and is achieved by separating a complex whole into manageable parts and by examining the relations among functions which produce desired input-output transformations.
2. Planning--Functions and/or tasks must provide for definitive determination of courses and/or methods of action to achieve prespecified objectives. Planning involves assessment, evaluation, organization and communication of program objectives as they relate to strategic plans of the organization.
3. Control--Functions and/or tasks must be managed to achieve continuous review and evaluation of planned courses and/or methods of action on the bases of established standards. PERT is designed to provide for initiation of corrective action when actual performance deviates from plan. Control procedures are required to make

continuous self-correction and revision of objectives, plans, strategies, procedures and methods-means employed in performance.

4. Evaluation--The process determines or judges the value of performance and/or assigns qualitative and quantitative values to planned performance outputs. Complete, accurate, relevant, timely and valid evidence of achievement is a vital output of evaluation processes.

5. Feasibility--A measure of organizational capability and capacity to perform required work for each function and/or task specified in the program plan. Inter, intra and extra-organizational needs and requirements must be specified and considered.

6. Probability--A measure of chance and expectancy relative to the performance of organizational activities (functions) and/or individual activities (tasks) within estimated time, cost and technical limits. Determining probability for the achievement of innovative educational program objectives within an estimated time period is a major benefit of PERT.

7. Interrelation--Functions and/or tasks must be clearly related to each other and to relevant organizational purposes, priorities and policies.

8. Integration--Functions and/or tasks must be systematically interrelated to achieve a desired performance outcome and/or state and must bring the parts within the whole. The actions, patterns and structures of the whole must be planned, organized, directed and controlled toward the achievement of program objectives.

9. Interdependencies--Functions and/or tasks may be dependent on each other. These relations must be assessed and managed to achieve effectiveness and efficiency in working toward common program objectives. Management of interdependencies requires a closed-loop communication network to stimulate free exchange of information.

10. Reporting--Feedback control channels establish closed-loop patterns for regulatory or managerial action that focus upon the execution, evaluation and revision of performance factors and the organization. Reporting is a managerial control action that feeds information regarding the demonstrated performance outputs of functions and/or tasks back to the managerial level of organization where it can be compared with information regarding inputs, operational plans and activities and prespecified objectives.

In summary, PERT and CPM are management tools which:

1. Are based on detailed appraisal and specification of desired objectives

2. Focus on the management processes of planning, implementing, controlling and evaluating

3. Encompass human interrelations, interfaces and interactions in performance

4. Treat time, cost and technical considerations

5. Facilitate determination of probability factors for success.

Comparison of PERT and CPM

Within the last decade, PERT and CPM have become valuable tools for managing complex programs in industry, government and education.

PERT and CPM differed in their original conceptual design in these ways:

1. PERT used a method based on probability (i.e., three time estimates) for predicting duration of an activity. CPM originally used the deterministic method which includes only one time estimate for an activity.

2. PERT was designed as a program control tool. CPM was initially conceived of as a program planning tool.

3. PERT was designed to be either manually or computer operated. CPM was designed as a computer-oriented management tool.

4. PERT was initially designed as an activity-oriented management tool. CPM was conceived as an event-oriented management tool.

Today, each technique:

1. May use one or three activity time estimates

2. Is equally applicable both to planning and control

3. May be either computer or manually operated

4. May be either activity oriented or event oriented.

Options that relate to one also apply to the other. Both network procedures are equally applicable to planning and to controlling programs of educational change and both relate to the informational requirements of decision making.

Managerial Uses of PERT and CPM

If PERT/CPM networks are applied to situations where many performance factors are uncertain and/or unknown, then they can serve as valued techniques for determining program time, cost and technical requirements in terms of prespecified purposes and alternative plans for their achievement. Critical and/or complex educational programs of planned change require that management be able to respond to unexpected performance deviations. The use of network-based procedures enables management to develop an effective and timely response to deviations by identifying them at points of departure from plans.

Line of Balance (LOB) Charts

Definition and Aspects

Line of Balance Charts are output-oriented management techniques. They are visual representations of plans for action. They are tools that enable management to make systematic performance comparisons of key milestones leading to recurring objective(s) achievement.

Aspects of LOB Charts include:

1. Systematic appraisal of temporal relations among activities
2. Continuous evaluation of performance and early identification of performance deficiencies at specific control points
3. Early assessment of interdependency, interrelation, interaction and interface requirements.

Description of LCB Charts as Network-Based Management Procedures

LOB is a management tool which:

1. Permits comparison between planned activities and actual achievements
2. Displays the interrelations, interfaces and interactions in a work flow sequence
3. Serves as a referent in assessing performance deviations from plan at points of departure from plan.

Managerial Uses of LOB Charts

Line of Balance is used in planning and controlling time, cost, schedule and performance requirements of recurring programs.

Gantt Bar Charts

Definition and Aspects

Gantt Bar Charts are process-oriented network tools used to plan and manage performance tasks through time. They represent a planned course of action and provide a means for comparing actual performance with planned performance.

Aspects of Gantt Bar Charts include:

1. Planning a course and/or method of action leading to objective achievement when multiple interfaces and/or interactions are not required
2. Continuous review and evaluation of performance tasks
3. Simplicity and clarity in design.

Description of Gantt Bar Charts as Network-Based Management Procedures

Gantt Bar Charts are management tools which:

1. Permit comparison between planned activities and actual achievements

2. Are simple to construct, read and interpret

3. Serve as communication referents.

Managerial Uses of Gantt Bar Charts

Gantt Bar Charts are process-oriented and are useful in planning and managing educational programs when multiple interfaces and/or interactions are not required.

Milestone Charts

Definition and Aspects

Milestone Charts are product-oriented network techniques that aid the planning and managing of performance functions through time. Milestones represent planned event occurrence and provide a means for comparing actual achievements with planned outputs at specific control points.

Aspects of Milestone Charts include:

1. Planning the occurrence of performance events through a time-oriented framework

2. Evaluation of performance outputs during the on-going course of performance

3. Simplicity and clarity in design.

Description of Milestone Charts as Network-Based Management Procedures

Milestone Charts are management tools which:

1. Are simple to construct, read and interpret
2. Serve as communication referents
3. Define target start and completion events for displayed functions.

Managerial Uses of Milestone Charts

Uses of Milestone Charts as planning and managing tools are similar to Gantt Bar Charts but, by definition, Milestone Charts are product oriented rather than process oriented. Also, Milestone Charts are better applied to organizational activities (functions). Gantt Bar Charts are better applied to task-level activities.

Flow Charts

Definitions and Aspects

Flow Charts are visual techniques to plan and display the logic sequencing of activities through time. Interrelations between activities are defined and visually depicted on Flow Charts. Management then has a referent for control and evaluation during the on-going course of performance.

Aspects of Flow Charts include:

1. Planning definitive courses and/or methods of action through time
2. Continuous evaluation of temporal and technical considerations during performance to determine planned-actual comparisons

3. Early identification of potential performance deviations

4. Performance visibility of activities to be performed and of interaction requirements.

Description of Flow Charts as Network-Based Management Procedures

Flow Charts are management tools which:

1. Enable continuous evaluation of actual performance results

2. Visually depict interaction, interrelation and interface requirements in work flow sequences

3. Serve as communication referents

4. Assist management in making replanning decisions on expedited bases through early identification of performance deviations.

Managerial Uses of Flow Charts

Flow Charts are planning and control tools. By definition, functionally-oriented and/or task-oriented interrelation, interaction and interface requirements can be depicted. Flow Charts can be used in recurring programs where temporal requirements for performance of activities are based on past experience.

Summary

As tools help the carpenter achieve his objectives in construction, so Network-Based Management Procedures serve as valuable aids in organizational management, achievement, problem solving and decision making. Management decisions to adopt networks as tools generally have resulted in more effective achievement of objectives and more efficient utilization of organizational inputs.

Network techniques for educational managers include:

1. PERT and/or CPM Charts
2. Line of Balance Charts
3. Gantt Bar Charts
4. Milestone Charts
5. Flow Charts.

CHAPTER II

DEVELOPING PERT MANAGEMENT PROCEDURES

Pert Network Planning and Development Considerations

PERT is a relatively new, adaptable tool for planning and managing complex and/or critical programs. ". . . because of its reported application to widely diverse activities (e.g., house construction, missile development, Broadway plays), its potential usefulness to the management of educational . . . activities has been recognized."[4]

PERT is a network-based management procedure that can be applied to non-repetitive developmental programs that vary in time, cost, size, criticality and complexity. Programs with inherently critical schedule problems particularly benefit from the application of PERT procedures. PERT networks are not decision-making instruments in themselves. Rather, they are graphic patterns within which criteria and priorities can be considered. They assist the decision maker in simulating choice-consequence relations, in selecting effective alternatives and in assigning responsibilities for activities necessary to achieve prespecified objective(s).

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[4]Desmond L. Cook, PERT Applications in Education, Bureau of Research, U.S. Department of Health, Education and Welfare, Cooperative Research Monograph No. 17 (Washington, D.C.: Government Printing Office, 1966), p. 2.

PERT Network Planning Considerations

The conceptual design for PERT presented in this monograph is based upon the analysis strengths of a system approach to educational management and the synthesis strengths of network-based management procedures. Analysis is performed by classification: i.e., mission, function, task and methods-means. It results in a Work Breakdown Structure (WBS). The WBS represents an assessment of organizational and individual activities required to achieve a prespecified objective. Following the development of a WBS, the logical sequencing and relations of the activities are determined. Function Flow Block Diagrams (FFBD) are the analytical techniques applied to determination of sequencing and logical relations.[5]

The analysis strengths of the WBS and FFBD are used as visual communication referents for management action. Translating the FFBD into a network flow offers technical advantages in the synthesis aspects. Logic relations, dependencies, interfaces and interaction junctions can more easily be maintained.

PERT Network Development Considerations

To be a valid management tool, PERT must be "a logical rather than a substantive system."[6] The PERT network is based upon analysis. Logical relations must be assessed and maintained in network construction. Logic

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[5]The Work Breakdown Structure (WBS) is primarily associated with PERT Analysis. The system approach includes the Function Flow Block Diagram (FFBD) as an extension of the traditional approach in order to provide a check for logic relations and for internal consistency.

[6]PERT Coordinating Group, PERT Guide for Management Use, June 1963, (Washington, D.C.: Government Printing Office, 1963), p. 3.

is defined as discrimination plus reason. For meaningful application to program management and requirements, PERT must include:

1. A project-oriented work breakdown structure, beginning with prime objectives subdivided into successively smaller end items
2. A flow plan consisting of all the activities and events that must be completed or accomplished to meet the program objectives, showing their planned sequence of accomplishment, interdependencies and interrelationships
3. Elapsed time estimates and identification of critical paths in the networks
4. A schedule with attempts to balance the objectives, the network flow plan and resource availability
5. Analysis of the interrelated networks, schedules and slack values as a basis for continuous evaluation of program status, forecast of overruns and the identification of problem areas in time for management to take corrective action.[7]

Mission, function, task and methods-means analyses result in definitions of program objectives and related functions and tasks that must be performed to achieve the objectives. The resulting functions and tasks form a point outline or Work Breakdown Structure.

Mission Analysis and First Level N 'work Flow Diagram Considerations

Mission analysis is performed to .b-set the broad mission statement into more specific segments. It results in a priority-arranged hierarchy of goals and objectives.

<u>First-Level Work Breakdown Structure (WBS)</u>

An example of a first-level WBS resulting from mission analysis of the certificated services of a school district is presented in Figure 1.

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[7] Ibid., p. 3.

- (0.0) Administer School District Personnel Services
  - 1.0 Appraise School District Requirements
  - 2.0 Assess Certificated Staffing Requirements and Predict Staffing Needs
  - 3.0 Develop, Install and Operate Recruitment Program
  - 4.0 Develop, Install and Operate Selection Program
  - 5.0 Develop, Install and Operate Assignment Program
  - 6.0 Determine Effectiveness of Assessment, Recruitment, Selection and Assignment Programs

Fig. 1.--First-Level Work Breakdown Structure

The first-level WBS represents a possible mission profile.

First-Level Function Flow Block Diagram

Developing logical interrelations and sequencing of the six (6) statements is the next step in analysis. FFBD's are developed and the resultant diagrams provide a check for internal consistency.

Such diagrams are developed using information secured in analysis and are based upon logical relations, simulation of alternatives and selection of priorities. System objectives and related functions and tasks (activities) are standard guidelines for diagram development. The diagrams aid in defining relations, interactions and interfaces[8] vital to work flow activities

[8] "Interfaces are defined as events which signal the transfer of responsibility and items or information from one part of the plan to another" (Ibid, p. 15).

and successful achievement of the mission.

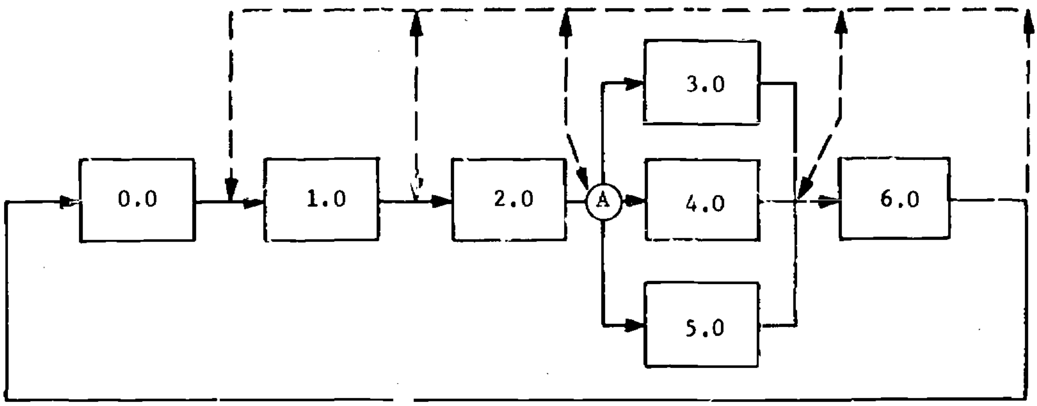


Fig. 2.--First-Level Function Flow Block Diagram

Designing Network Flow Diagrams

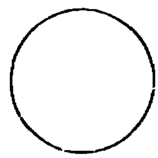
Design Fundamentals

Basic ingredients of a network are events and activities.

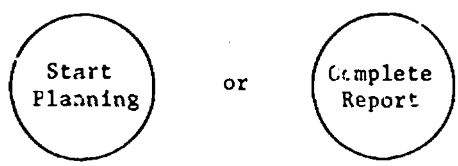
Events. Events are points in time when specific achievements are realized. Events consume neither resources nor energy. They are recognized "happenings" at a definable, specific point in time. "Precise event identification and definition are necessary to properly determine event occurrence which indicates the actual progress made in a program."[9]

[9]PERT Orientation and Training Center, PERT Fundamentals, Vol. 1, (Washington, D.C.: Government Printing Office, 1963), p. 22.

Events are represented by circles (nodes):



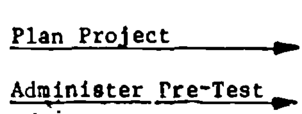
In constructing an event-oriented network, the terms <u>start</u> or <u>complete</u> precede the event description. Examples of event designators are:



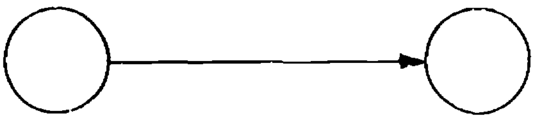
<u>Activities</u>. An activity is a task that must be performed. It utilizes information, energy and resources. The work in an activity may not begin until its related preceding event occurs. An event cannot occur until all work involved in the preceding related activity has been performed.

Activities are represented by lines fitted with arrowheads:

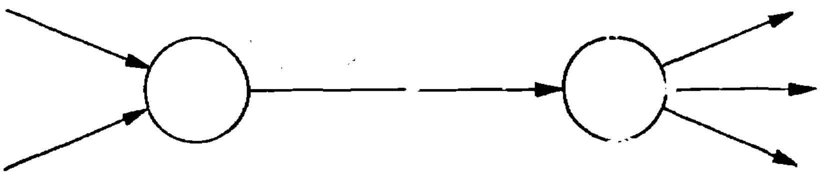
As terms representative of required functions and/or tasks, activities are always described in action and object terms (verbs and nouns) that enable the activity to be observed, demonstrated and/or measured. Examples of activity designators are:



Event-Activity-Event Relation. An event-activity-event relation appears:



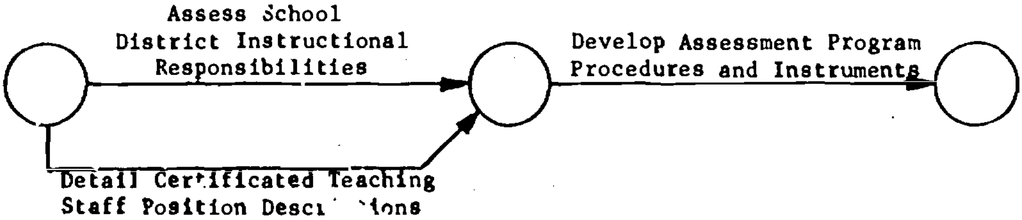
Two or more activities may precede and/or follow an event occurrence. Each activity must have a separate event-code reference.



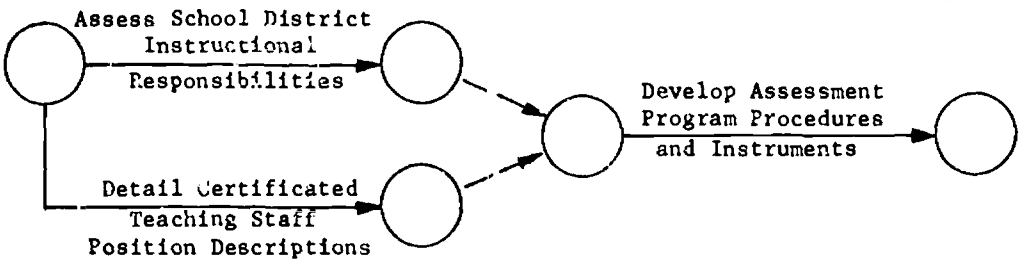
Dummy Activities. Separate event-code references necessitate the use of "dummies." A dummy activity is one that utilizes neither energy nor resources. It is represented by a broken line. It is used for clarity of communication and/or as a means to depict activity dependencies.

The requirement for and the use of "dummies" appear:

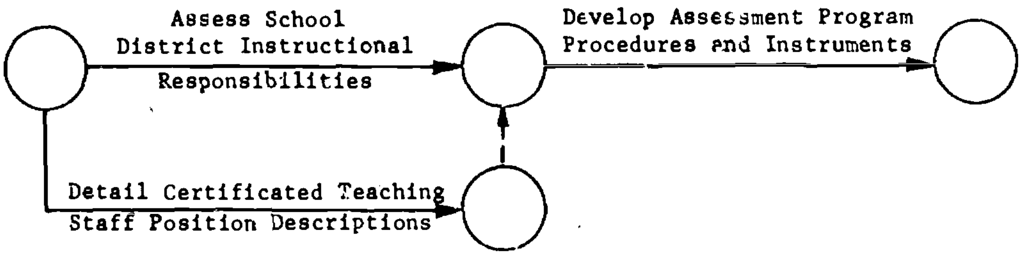
Incorrect



Correct (Clarity of Communications)



Correct (Dependencies)



First-Level Network Flow Diagram. A related network flow diagram for Certificated Personnel Services in a school district, based on the FFBD in Figure 2, is depicted in Figure 3. The network flow diagram is based on the following mission profile:

1.0 Appraise school district requirements

2.0 Assess certificated staffing requirements and predict staffing needs

3.0 Develop, install and operate recruitment program

4.0 Develop, install and operate selection program

5.0 Develop, install and operate assignment program

6.0 Determine effectiveness of assessment, recruitment, selection and assignment programs.

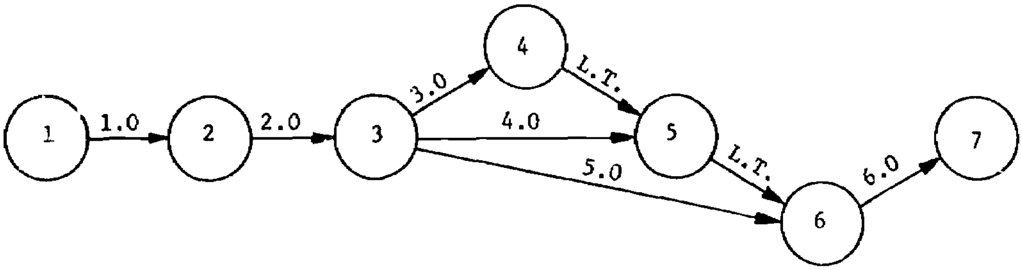


Fig. 3.--First-Level Network Flow Diagram

Lead Time Activities. Activities 4-5 and 5-6 are lead time. Lead time designation denotes that time estimates must be made for these activities. They are not "dummies" since they require time allowances. Responsible managers are required to estimate, for example, how much time is required after the occurrence of event 4 before event 5 can occur. Lead time allowances are used if two or more activities are performed concurrently but performance of one or more of these activities must be completed some time before other(s).

As Figure 3 shows, work required to perform the activities, develop, install and operate the recruitment, selection and assignment programs (3.0, 4.0, 5.0) can be started concurrently. The recruitment program must be completed prior to the selection program since certain tasks delegated to the selection program cannot be performed until the recruitment program tasks are performed. Similarly, lead time must be provided after the selection program work is performed and before the assignment program work can be completed.

Function Analysis and Second-Level Network Flow Diagram Considerations

Following mission analysis, analysis techniques lead to delineation of functions. Function analysis is performed to assess essential organizational activities in relation to the purposes established in mission analysis. A function analysis of Certificated Personnel Services in a school district requires a Work Breakdown Structure, Function Flow Block Diagram and related Network Flow Diagram.

Second-Level Work Breakdown Structure (WBS)

The "back-to-front" technique is a useful method for developing a WBS. As an example, in structuring the organizational function 1.0, Appraise School District Requirements, the analyst looks for the final function to achieve the appraisal. He then works back through successive steps to a controllable function and/or task.

The analysis process proceeds by level. Functions are deline[illegible] [illegible]t. Sub-functions related to each function are determined next. Indiv[illegible] tasks are then delineated. The process is continued until suffic[illegible] [illegible]tail has been considered. Work Breakdown Structure schema are read fro[illegible] simple to the complex and indenture lines detail the level of analy[illegible]

The analysis-synthesis process is instrumented in developing a [illegible] the Work Breakdown Structure. Caution must be exercised to mainta[illegible] activity sub-setting principle in developing the Work Breakdown Stru[illegible]re.

Determination of serial and concurrent operations among the su[illegible]inate activities of a function is made after identity relations between t[illegible] [illegible]-set and the function have been proved. Failure to prove the identi[illegible] [illegible]f the sub-set will produce incomplete sets of subordinate activities.[10] A[illegible]ysis

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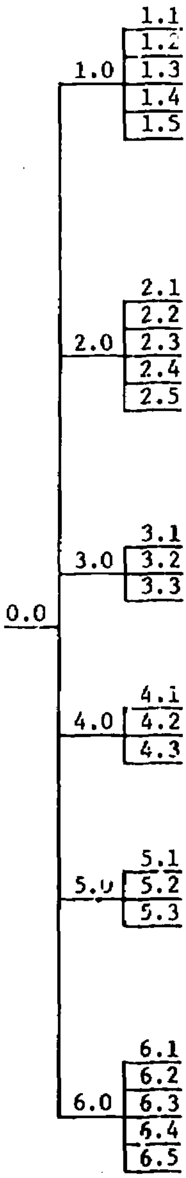
[10]The principle of identity can be expressed as: x = (f)y. I[illegible] [illegible] not equal the (f)y, then further analysis is required. If x does [illegible] the (f)y, then the sub-set (f)y analysis is complete.



1.0 Appraise School District Requirements
- 1.1 Assess School District Purposes, Priorities, Policies and Programs
- 1.2 Appraise Performance Context
- 1.3 Appraise Performance Controls
- 1.4 Appraise Demonstrated Performance
- 1.5 Define School District Requirements

2.0 Assess Certificated Staffing Requirements and Predict Staffing Needs
- 2.1 Assess School District Instructional Responsibilities
- 2.2 Detail Certificated Teaching Staff Position Description
- 2.3 Develop Assessment Programs, Procedures and Instruments
- 2.4 Install Continuous Assessment Program
- 2.5 Operate Assessment Programs

3.0 Develop, Install and Operate Recruitment Program
- 3.1 Develop Recruitment Program Procedures and Instruments
- 3.2 Install Continuous Recruitment Program
- 3.3 Operate Recruitment Program

4.0 Develop, Install and Operate Selection Program
- 4.1 Develop Selection Program Procedures and Instruments
- 4.2 Install Continuous Selection Program
- 4.3 Operate Selection Program

5.0 Develop, Install and Operate Assignment Program
- 5.1 Develop Assignment Program Procedures and Instruments
- 5.2 Install Continuous Assignment Program
- 5.3 Operate Assignment Program

6.0 Determine Effectiveness of Assessment, Recruitment, Selection and Assignment Programs
- 6.1 Review School District Purposes, Priorities, Policies and Programs
- 6.2 Review School District Performance Requirements
- 6.3 Review Assessment, Recruitment, Selection and Assignment Objectives, Plans, Strategies and Procedures
- 6.4 Appraise Outputs of Assessment, Recruitment, Selection and Assignment Programs
- 6.5 Determine Assessment, Recruitment, Selection and Assignment Programs Effectiveness

Fig. 4.--Second-Level Work Breakdown Structure

of function 1.0 (Figure 4) will reveal that activity 1.1 must be performed first. Activities 1.2, 1.3 and 1.4 can be performed concurrently after activity 1.1 has been performed. Upon performance of activities 1.2, 1.3 and 1.4, activity 1.5 can be performed.

Second-Level Function Flow Block Diagram (FFBD)

Each major function and its related sub-functions, tasks and sub-tasks can be examined for internal and logical consistency by using the Function Flow Block Diagram technique. A diagrammatic presentation of the second-level FFBD (related to the WBS in Figure 4) of functions required to perform first-level sub-missions and to check for internal consistency with relevant objectives appears in Figure 5.

After a consistency check has been made and subsequent appraisals of alternative choice-consequence relations indicate that results are expected to be satisfactory, the FFBD can be integrated into a network flow diagram.

Second-Level Network Flow Diagram

Compiling the FFBD segments into a rational network provides management with a visual representation of organizational functions and other related activities that must be performed to achieve prespecified objective(s). "Once the objectives have been identified by the work breakdown structure, the means of attaining the objectives should be graphically portrayed in the form of a network(s)."[11] Development of a network flow diagram is

[11] U.S. Army Management Engineering Training Agency, PERT/COST and Control (Rock Island, Illinois), p. 12-16.

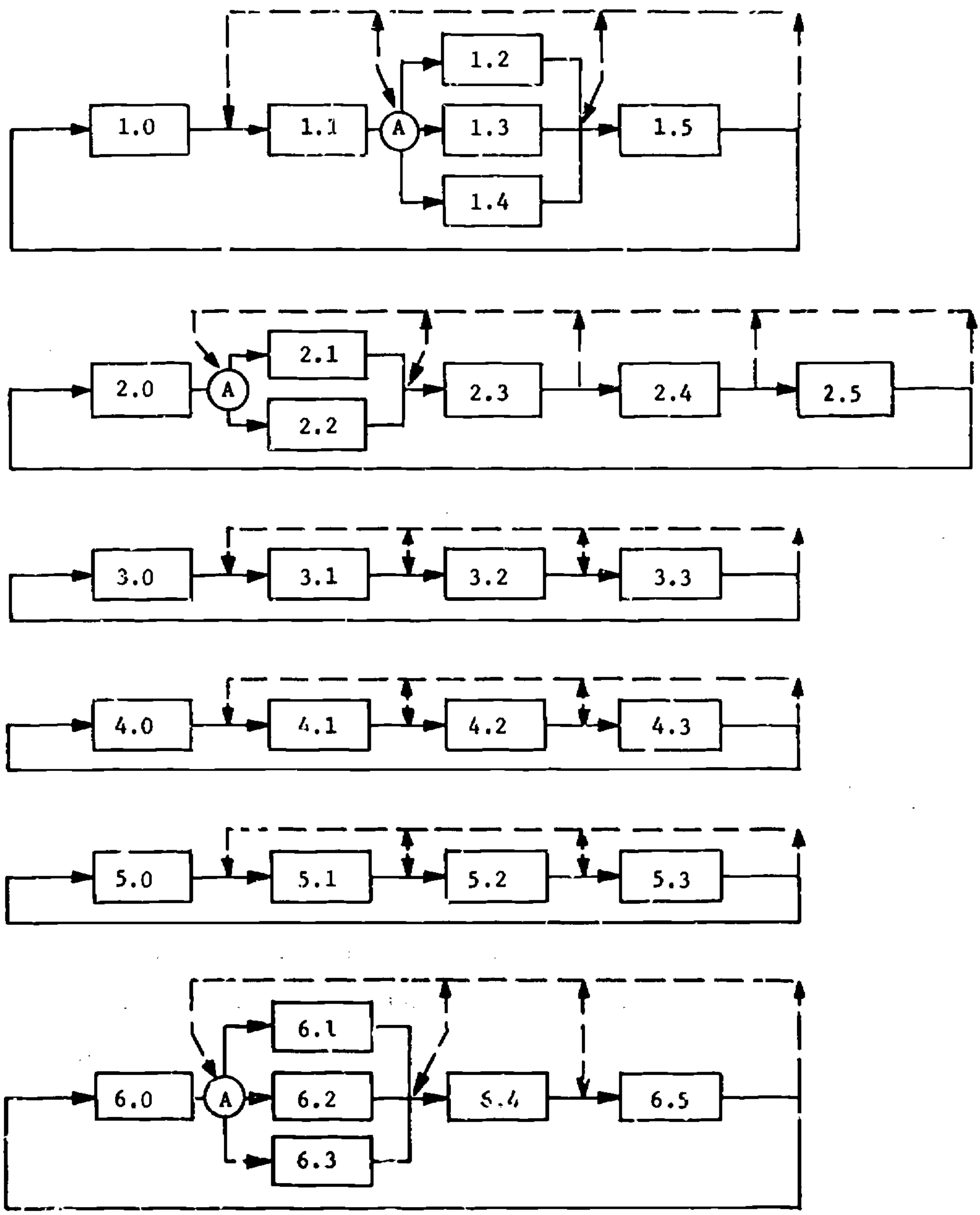


Fig. 5--Second Level Function Flow Block Diagram

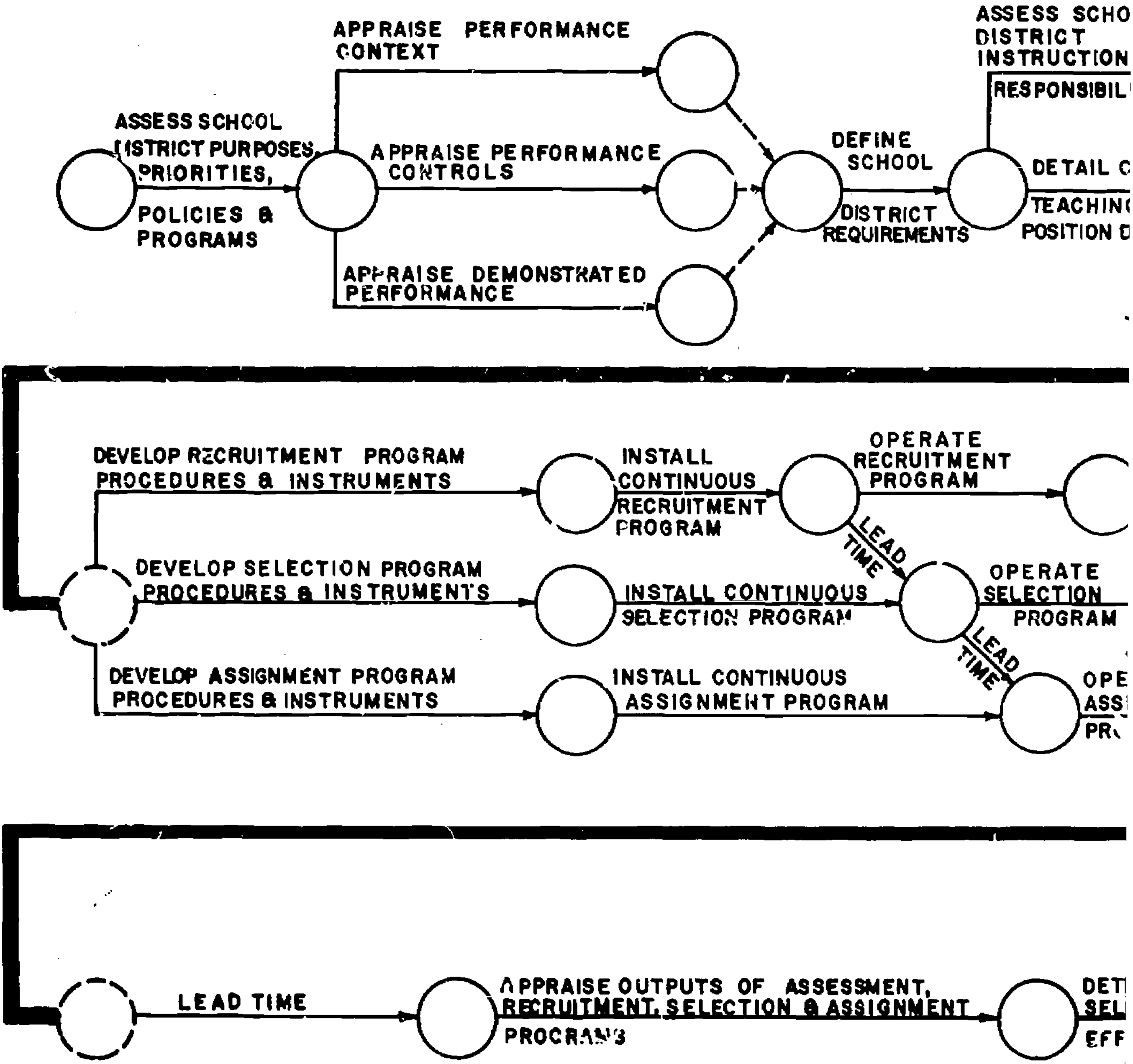


FIGURE 6

MANAGEMENT NETWORK FOR THE ASSESSMENT, RECRUITMENT, SELECTION, A

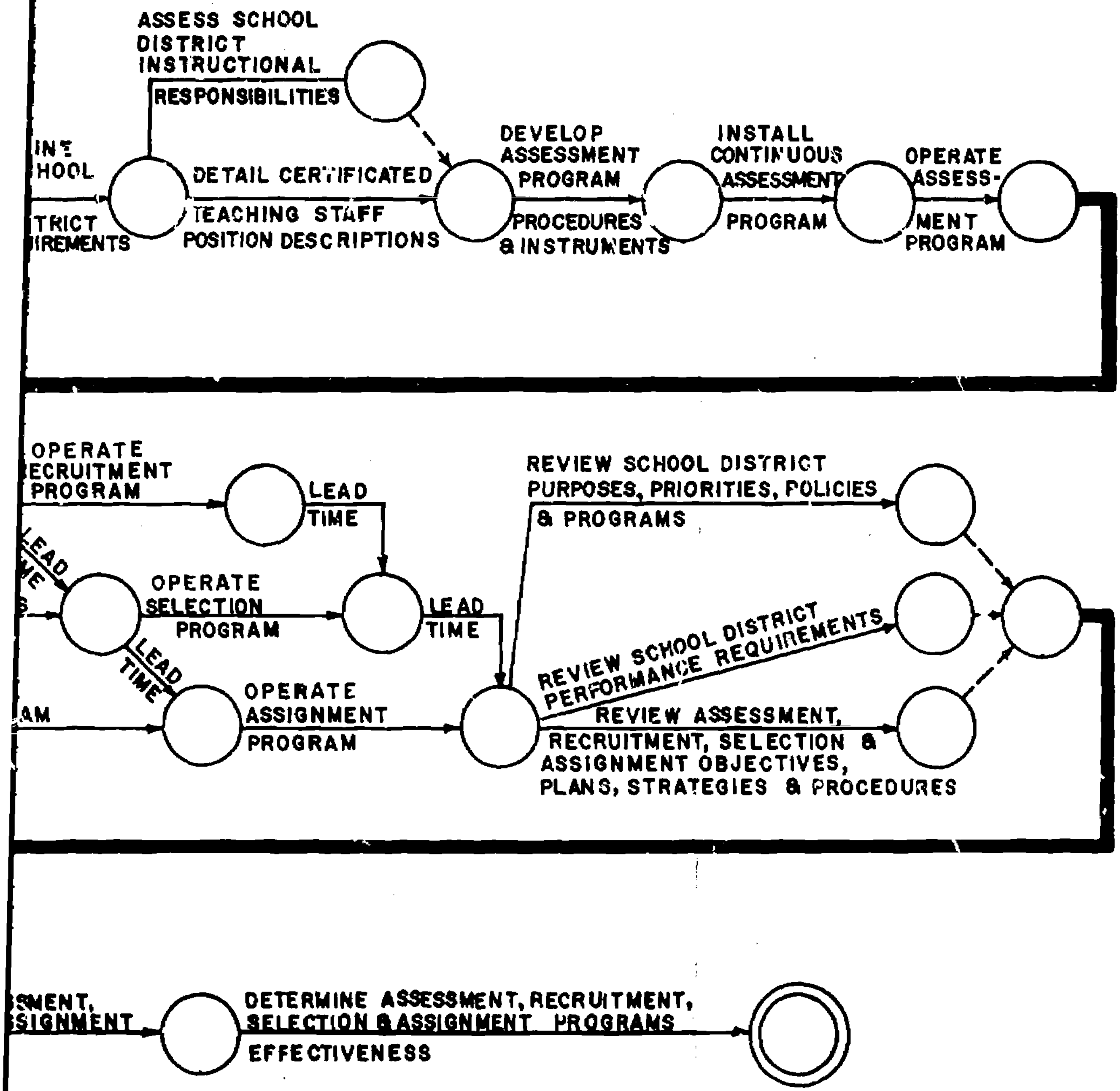


FIGURE 6

MENT, SELECTION, AND ASSIGNMENT OF CERTIFICATED TEACHING PERSONNEL

CHAPTER III

PERT TIME CALCULATIONS AND CONSIDERATIONS (SCHEDULING)

"Scheduling is the bridge from the planning stage to coordinated, effective implementation."[12] Network scheduling, using time calculations and considerations of probability, facilitate planned to actual performance comparisons.

PERT and CPM cost and/or schedule (time) networks are developed using the WBS and FFBD as design frameworks. PERT and CPM networks are time-phased and cost-phased graphic displays of functions and tasks and related prerequisite occurrences (events) which are arranged logically as serial and/or concurrent operations. Network development is based on analyses of group and/or individual tasks, organizational functions and objectives.

There are five (5) temporal calculations necessary to make PERT an operational tool. They are:

1. Determining activity-oriented expected elapsed time (t_e)
2. Determining event-oriented earliest expected time (T_E)
3. Determining event-oriented latest allowable time (T_L)
4. Determining event-oriented slack time
5. Determining activity-oriented float time.

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[12] *Ibid.*, p. 1-6.

Determining Activity-Oriented Expected Elapsed Time (t_e)

Scheduling a program plan (network) requires activity-time estimates in order to predict expected elapsed time for each of the activities represented in the network. Time estimates, to be valid approximations, must be determined by the operational personnel assigned responsibility for performing the activity and must be made using deliberate "reasonableness."

PERT networks can be developed using one or three activity-oriented time estimates. If three estimates are used, a single expected elapsed time and probability factor can be derived using the following formula:

$$t_e = \frac{a + 4m + b}{6}$$

In the foregoing formula for calculation of expected elapsed time (t_e), the optimistic time estimate (a) indicates one chance in one hundred for success if everything "goes right." The most likely time (m) indicates a 50% chance for success and represents a reasonable best guess. The pessimistic time estimate (b) indicates one chance in one hundred for successful completion of the activity and it assumes that everything will "go wrong." The formula produces a time estimate in units and tenths of units on a selected time scale--usually weeks and tenths of weeks. Using weeks as scalar units, time estimates are based on a 5-day, 8-hour-per-day work week. If extended hours are to be used in making estimates, a notation is required.

If, for example, time estimates for activity 1.00-1.01[13] (TABLE 1) are

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[13] The event code designators have been expanded for possible computerization and more efficient cost control.

TABLE 1

t_e MATRIX

ACTIVITY DESCRIPTION	REFERENCE EVENTS	MOST LIKELY (m)	OPTIMISTIC (a)	PESSIMISTIC (b)	t_e
Assess School District Purposes, Priorities, Policies and Programs	1.00-1.01	1.4	0.8	4.0	1.7
Appraise Performance Context	1.01-1.02	0.4	0.2	1.0	0.5
Appraise Performance Controls	1.01-1.03	0.8	0.4	2.0	0.9
Appraise Demonstrated Performance	1.01-1.04	1.5	0.8	4.0	1.8
Dummy	1.02-1.05	0.0	0.0	0.0	0.0
Dummy	1.03-1.05	0.0	0.0	0.0	0.0
Dummy	1.04-1.05	0.0	0.0	0.0	0.0
Define School District Requirements	1.05-2.00	0.8	0.4	2.0	0.9
Assess School District Instructional Responsibilities	2.00-2.01	1.0	0.6	3.0	1.3
Detail Certificated Teaching Staff Position Descriptions	2.00-2.02	4.0	2.4	6.0	4.1
Dummy	2.01-2.02	0.0	0.0	0.0	0.0
Develop Assessment Program	2.02-2.03	1.0	0.4	2.0	1.1
Install Continuous Assessment Program	2.03-2.04	0.4	0.2	2.0	0.6

TABLE 1--Continued

ACTIVITY DESCRIPTION	REFERENCE EVENTS	MOST LIKELY (m)	OPTIMISTIC (a)	PESSIMISTIC (b)	t_e
Manage and Operate Assessment Program	2.04-2.05	3.0	2.0	4.0	3.0
Develop Recruitment Program Procedures and Instruments	2.05-3.01	1.0	0.4	2.0	1.1
Develop Selection Program Procedures and Instruments	2.05-4.01	1.0	0.2	2.0	1.0
Develop Assignment Program Procedures and Instruments	2.05-5.01	1.0	0.6	2.0	1.1
Install Continuous Recruitment Program	3.01-3.02	2.0	1.0	4.6	2.3
Install Continuous Selection Program	4.01-4.02	1.0	0.6	2.0	1.1
Install Continuous Assignment Program	5.01-5.02	1.0	0.6	2.0	1.1
Lead Time	3.02-4.02	2.0	1.4	4.0	2.2
Lead Time	4.02-5.02	4.0	1.2	8.0	4.2
Manage and Operate Recruitment Program	3.02-3.03	12.0	6.0	20.0	12.3
Manage and Operate Selection Program	4.02-4.03	12.0	1.0	19.0	11.3
Manage and Operate Assignment Program	5.02-5.03	8.0	4.0	15.0	8.5
Lead Time	3.03-4.03	2.0	1.4	4.0	2.2
Lead Time	4.03-5.03	4.0	1.2	8.0	4.2

TABLE 1--Continued

ACTIVITY DESCRIPTION	REFERENCE EVENTS	MOST LIKELY (m)	OPTIMISTIC (a)	PESSIMISTIC (b)	t_e
Review School District Purposes, Priorities, Policies and Programs	5.03-6.01	2.0	1.2	4.0	2.2
Review School District Performance Requirements	5.03-6.02	2.0	1.0	4.0	2.2
Assessment, Recruitment, Selection and Assignment Objectives, Plan, Strategies and Procedures	5.03-6.03	2.0	0.4	4.0	2.1
Dummy	6.01-6.04	0.0	0.0	0.0	0.0
Dummy	6.02-6.04	0.0	0.0	0.0	0.0
Dummy	6.03-6.04	0.0	0.0	0.0	0.0
Lead Time	6.04-6.05	12.0	8.0	17.0	12.2
Appraise Outputs of Assessment, Recruitment, Selection and Assignment Programs	6.05-6.06	14.0	3.0	6.0	4.2
Determine Assessment, Recruitment, Selection and Assignment Programs Effectiveness	6.06-6.07	1.4	0 2	3.0	1.5

used to calculate expected elapsed time by substituting them into the formula, a t_e value of 1.7 weeks results. The activity time estimates are: a = 0.8 weeks, m = 1.4 weeks and b [illegible]eks. Calculating t_e using the formula can be represented as:

$$t_e = \frac{0.8 + 4(1.4) + 4.0}{6}$$

$$t_e = \frac{0.8 + 5.6 + 4.0}{6}$$

$$t_e = \frac{10.4}{6} = 1.7 \text{ weeks.}$$

Thus, activity 1.00-1.01 (Assess school district purposes, priorities, policies and programs) is expected to consume 1.7 units (weeks) of time.

When the probabilistic method is employed in time estimating, remember that three estimates are considered. A matrix, such as the one presented in TABLE 1, may be used to record expected elapsed time data for activities in a network. It can be used as a basis for comparing probable performance time estimates to expected elapsed time calculations (TABLE 1).

Probability and Standard Deviation

The t_e determined using the $t_e = \frac{a + 4m + b}{6}$ formula has, by definition, a 50% probability for success. Management may be required to forecast the probability of achieving work within a specific time period. Determination of the standard deviation values enables management to predict time-oriented probability factors. By PERT definition:

1. There is a 67% probability for performing an activity within ± one standard deviation.

2. There is a 95% probability for performing an activity within $\pm$ two standard deviations.

3. There is a 99% probability for performing an activity within $\pm$ three standard deviations.

The standard deviation (σ) for an activity is determined using the formula:

$$\sigma = \frac{b - a}{6}$$

For example, the t_e for activity 1.00-1.01 is 1.7 weeks. The standard deviation for activity 1.00-1.01 (TABLE 2) is:

$$\sigma = \frac{4.0 - 0.8}{6} = \frac{3.2}{6} = 0.5 \text{ weeks}$$

There is a 67% probability of performing the activity in $t_e \pm .5$ of a week. There is a 95% probability of performing the activity in $t_e \pm 1.0$ week and a 99% probability in $t_e \pm 1.5$ weeks.

A matrix for determining standard deviation values is presented in TABLE 2.

Determining probabilities and σ ranges gives management valuable information for decision making. Depending on organizational philosophies, purposes, priorities, policies and programs, management may be required to make "trade-offs" between available inputs. Trade-offs are made to reduce known risks and to increase the probability of success. Uncertainties must be assessed and difficulties must be appraised to determine necessary trade-offs. For some programs, high probability values may be desirable, others will have more latitude. Time estimates can help management plan

Table 2

STANDARD DEVIATION MATRIX

$$\sigma = \frac{b-a}{6}$$

Activity Sequence	t_e = 50%	b	a	σ	67% 1 Range	95% 2 Range	99% 3 Range
1.00-1.01	1.7	4.0	0.8	0.5	1.2-2.2	0.7-2.7	0.2-3.2
1.01-1.02	0.5	1.0	0.2	0.1	0.4-0.6	0.3-0.7	0.2-0.8
1.01-1.03	0.9	2.0	0.4	0.3	0.6-1.2	0.3-1.5	0.1-1.8
1.01-1.04	1.8	4.0	0.8	0.5	1.3-2.3	0.7-2.8	0.2-3.3
1.02-1.05	0.0	0.0	0.0	0.0	0.0-0.0	0.0-0.0	0.0-0.0
1.03-1.05	0.0	0.0	0.0	0.0	0.0-0.0	0.0-0.0	0.0-0.0
1.04-1.05	0.0	0.0	0.0	0.0	0.0-0.0	0.0-0.0	0.0-0.0
1.05-2.00	0.9	2.0	0.4	0.3	0.6-1.2	0.3-1.5	0.1-1.8
2.00-2.01	1.3	3.0	0.6	0.4	0.9-1.7	0.5-2.1	0.1-2.5
2.00-2.02	4.1	6.0	2.4	0.6	3.5-4.7	2.9-5.3	2.3-5.9
2.01-2.02	0.0	0.0	0.0	0.0	0.0-0.0	0.0-0.0	0.0-0.0
2.02-2.03	1.1	2.0	0.4	0.3	0.8-1.4	0.5-1.7	0.2-2.0
2.03-2.04	0.6	2.0	0.2	0.3	1.7-2.3	1.4-2.6	1.1-2.9
2.04-2.05	3.0	4.0	2.0	0.3	2.7-3.3	2.4-3.6	2.1-3.9
2.05-3.01	1.1	2.0	0.4	0.4	0.7-1.5	0.3-1.9	0.1-2.3
2.05-4.01	1.0	2.0	0.2	0.3	0.7-1.3	0.4-1.6	0.1-1.9
2.05-5.01	1.1	2.0	0.6	0.2	0.9-1.3	0.7-1.5	0.5-1.7
3.01-3.02	2.3	4.6	1.0	0.6	1.7-2.9	1.1-3.5	0.5-4.1
4.01-4.02	1.1	2.0	0.6	0.2	0.9-1.3	0.7-1.5	0.5-1.7
5.01-5.02	1.1	2.0	0.6	0.2	0.9-1.3	0.7-1.5	0.5-1.7
3.02-4.02	2.2	4.0	1.4	0.4	1.8-2.6	1.4-3.0	1.0-3.4
4.02-5.02	4.2	8.0	1.2	1.1	3.1-5.3	2.0-6.4	0.9-7.5
3.02-3.03	12.3	20.0	6.0	2.3	10.0-14.6	7.7-16.9	5.4-19.2
4.02-4.03	11.3	19.0	1.0	3.0	8.3-14.3	5.3-17.3	2.3-20.3
5.02-5.03	8.5	15.0	4.0	1.8	6.7-10.3	4.9-12.1	3.1-13.9
3.03-4.03	2.2	4.0	1.4	0.4	1.8-2.6	1.4-3.0	1.0-3.4
4.03-5.03	4.2	8.0	1.2	1.1	3.1-5.3	2.0-6.4	0.9-7.5
5.03-6.01	2.2	4.0	1.2	0.5	1.7-2.7	1.2-3.2	0.7-3.7
5.03-6.02	2.2	4.0	1.0	0.5	1.7-2.7	1.2-3.2	0.7-3.7
5.03-6.03	2.1	4.0	0.4	0.6	1.5-2.7	0.9-3.3	0.3-3.9
6.01-6.04	0.0	0.0	0.0	0.0	0.0-0.0	0.0-0.0	0.0-0.0
6.02-6.04	0.0	0.0	0.0	0.0	0.0-0.0	0.0-0.0	0.0-0.0
6.03-6.04	0.0	0.0	0.0	0.0	0.0-0.0	0.0-0.0	0.0-0.0
6.04-6.05	12.2	17.0	8.0	1.5	10.7-13.7	9.2-15.2	7.7-16.7
6.05-6.06	4.2	6.0	3.0	0.5	3.7-4.7	3.2-5.2	2.7-5.7
6.06-6.07	1.5	3.0	0.2	0.5	1.0-2.0	0.5-2.5	0.1-3.0

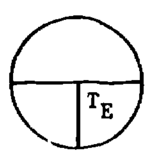
the utilization of available inputs in relation to desired probability values.

Without time estimates and calculations a network is referred to as a flow diagram. When activity-oriented time estimates are added to the flow diagram, the network is transformed into a work performance measure ment tool (see Figure 7).

After determining the activity time estimate (t_e) for required functions and/or tasks, managers can derive Earliest Expected (T_E) and Latest Allowable (T_L) times for events.[14] Event-oriented time determinations will reveal the estimated total elapsed time required for achievement of program objectives.

Determining Event-Oriented Earliest Expected Time (T_E)

Earliest Expected Time (T_E) for an event to occur is expressed as a unit-decimal indicator that is entered in the lower right hand quadrant of the event node:



Point-in-time determinations for events are calculated using a two-step process. The first step establishes the earliest point-in-time that each

[14] Note that activity-oriented expected elapsed time is symbolized using lower case letters (t_e). Event-oriented earliest expected time (T_E) and latest allowable time (T_L) are symbolized using upper case letters.

event can occur. Starting with the beginning event of the network, earliest expected times (T_E) of successive events are found by adding the activity's <u>expected elapsed time</u> (t_e) to the earliest expected time (T_E) for the preceding event.

To clarify this concept, a model network having four (4) events will be used (Figure 7). The event code references of the model network are single unit numbers as no computer applications would be applied to a network of such minimal size. Event 1 is always time now (0.0).

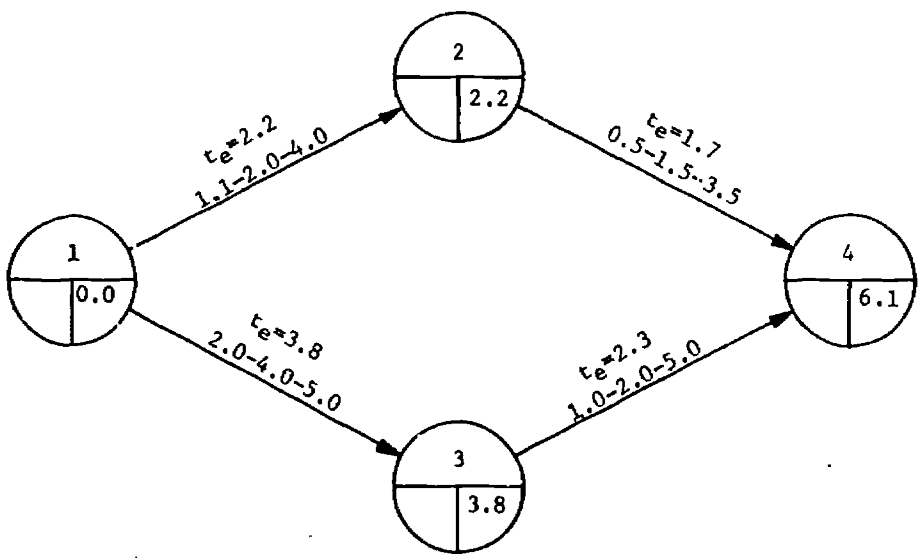


Fig. 7.--Determining T_E of Model Network Events

The three time-unit references above each activity are the optimistic (a), most likely (m) and pessimistic (b) activity time estimates. The derived

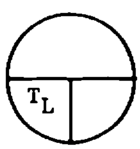
t_e is placed above the three estimates.

Event 1 is always time zero (0.0). Activity 1-2 is expected to consume 2.2 weeks of elapsed time. The earliest expected time for event 2 to occur is, therefore, 2.2 weeks. The t_e for activity 2-4 is 1.7. Adding the 1.7 (t_e for activity 2-4) to the 2.2 (T_E) of event 2, the T_E value for event 4 is determined as 3.9 weeks. Activities 1-2 and 2-4, however, are not the only requirements for the realization of event 4. The work required in activities 1-3 and 3-4 must also be accomplished. The t_e for activity 1-3 is 3.8 weeks. Added to the time zero of event 1, earliest expected time (T_E) for event 3 is 3.8 weeks. Effort required to achieve the desired results of activity 3-4 is expected to consume 2.3 weeks. Adding the t_e of activity 3-4 to the 3.8 weeks (T_E of event 3), the T_E for the occurrence of event 4 is 6.1 weeks.

The most time-consuming activity sequence that is directly related to the occurrence of any given event is the earliest point-in-time that the designated event can occur. The earliest expected time values for realization of events in the example problem (Certificated Personnel Services) are presented in Figure 12 (p. 49).

Determining Event-Oriented Latest Allowable Time (T_L)

Following computation of earliest expected time (T_E) values, the second step of determining latest allowable time (T_L) values for events can be initiated. Latest Allowable Time (T_L) is a unit decimal indicator that is entered in the lower left hand quadrant of the event node:



In contrast to the method used for T_E computations (beginning event forward), T_L values are calculated by working from the ending event in a reverse direction to the network flow (back-to-front technique). The T_L of the end event will be identical to the T_E unless a different T_L is assigned or contractually dictated. The T_L represents the latest allowable time an event can occur without jeopardizing the expected elapsed time (t_e) required to complete succeeding network activities. The T_L may be significantly different (positive or negative) or identical to the T_E. If the T_L is a larger number than the T_E, the event has temporal latitude. The event may occur as early as the T_E or as late as the T_L and not jeopardize time estimates for succeeding activities.

If the T_L is a smaller number than the T_E, the event is limiting. Slack will be a negative value. The earliest expected time for the event to occur is greater than the latest allowable time. Management is required to make trade-offs to reduce known temporal risks.

Using the model network presented in Figure 7 and assuming that T_L and T_E values for event 4 are identical, event T_L values can be calculated as detailed in Figure 8.

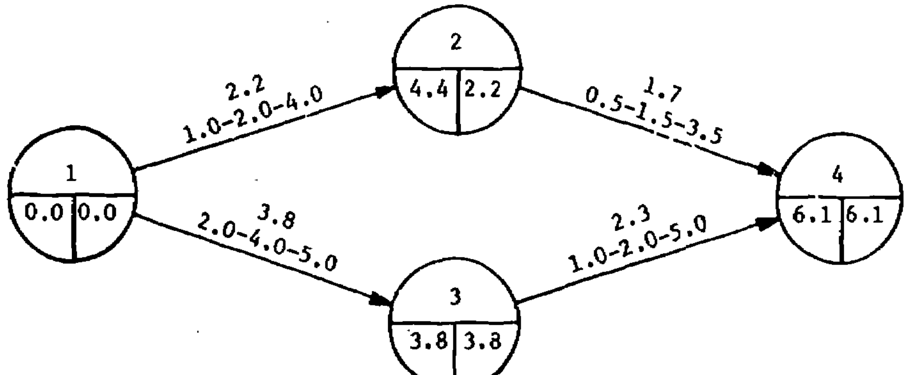


Fig. 8.--Determining T_L of Model Network Events

Event 2 can occur as early as 2.2 weeks after event 1 occurs or as late as 4.4 weeks and not affect the 6.1 week time value of end event 4. Event 3 must occur 3.8 weeks after event 1 to meet the 6.1 week value (T_E/T_L) of end event 4.

Determining Event-Oriented Slack Time

Slack values are indicative of an event's criticality. They relate only to events. Criticality is related to temporal requirements. Slack is calculated by subtracting the earliest expected time (T_E) value for its occurrence from its latest allowable time (T_L) value. Thus, slack is determined using the equation, $S = T_L - T_E$. The value of slack for event 2 in the model network (Figure 9) is 2.2 weeks ($S = 4.4 - 2.2 = 2.2$ weeks). Every event in a network has a slack value. The value may be positive, negative or zero.

Positive slack values indicate probable time tolerances that may allow flexibility in resource management. By reappraising resource requirements for activities along the network path, it may be possible to re-allocate surplus inputs to more critical paths. Thereby, managers may reduce expected elapsed time. In this way, an entire program network can be developed using more reliable values for time and/or costs.

Managers must exercise caution in allocating additional resources to reduce the expected time for activities along a critical path. Often, paths that initially were "non-critical" become critical when managers transfer resources from one path to another.

Negative slack values are indicators of potential disaster. The quantity of real time available is less than the anticipated time need.

Negative slack is recognizable when T_E is greater than T_L. If negative slack exists, the responsible manager must examine and consider possible changes which would produce positive slack values. Negative slack may result from special program requirements. It may indicate that variance exists or that there is insufficient time available to complete activities. If negative slack values are detected, replanning may be required.

Zero slack occurs if T_E is equal to T_L. Network paths with either zero or negative slack are potential critical paths. Criticality, however, is dependent on allocation of available resources and determination of a program schedule. Slack values for the model network (Figure 7 and 8) are presented above each event in Figure 9.

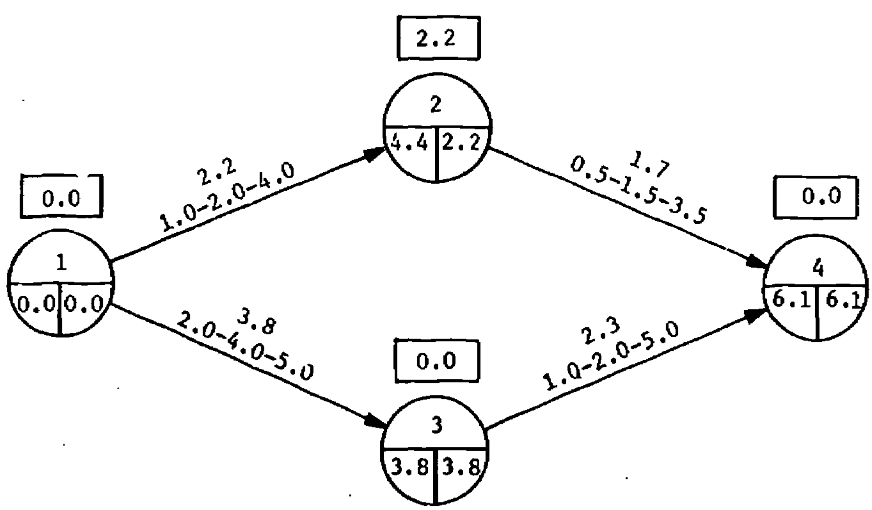


Fig. 9.--Slack Determinations in a Model Network

A matrix for slack values is useful in performing arithmetical calculations. A matrix for the example problem presented in Figure 9 is depicted in TABLE 3.

TABLE 3

SLACK MATRIX

Event	T_L	T_E	Slack
1	0.0	0.0	0.0
2	4.4	2.2	2.2
3	3.8	3.8	0.0
4	6.1	6.1	0.0

Because event 1 is always "time now," no slack is possible since there will be no difference between the T_E and T_L unless a directed time (less than T_E) is used for the end event's T_L. In this case the slack for event 1 is negative.

In the example given, slack for event 2 is 2.2 weeks. Events 3 and 4 each have zero slack. By definition, the activities 1-3 and 3-4 appear to be along the critical path.

If, in the model network (Figure 10), management is directed to complete all activities required for the occurrence of event 4 in 5.0 weeks, then one possible way to reduce the expected elapsed time (t_e) of activities 1-3 and 3-4 is to assign additional resources. Another possibility is to re-allocate available resources within the network from activities 1-2 and

2-4 to activities 1-3 and 3-4. The same work is required, but the T_E and T_L of the end event can be reduced. Such a solution could be reached by making personnel "trade-offs."

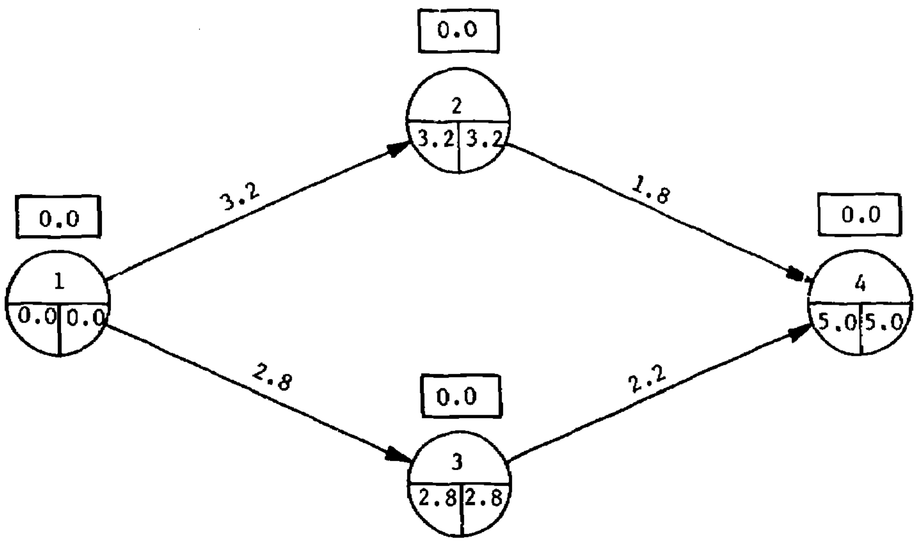


Fig. 10.--Slack Determination in a Model Network

The related slack matrix is presented as TABLE 4. By reallocating the resources, all paths are now critical and possibly will require close management attention . The directed completion time of five (5.0) weeks is possible.

Analysis of slack events on the example problem network (Figure 12) indicates that events 1.02, 1.03, 2.01, 4.01, 5.01, 4.02, 5.02 and 6.03 are non-critical in schedule orientation.

TABLE 4

SLACK MATRIX

Event	T_L	T_E	Slack
1	0.0	0.0	0.0
2	3.2	3.2	0.0
3	2.8	2.8	0.0
4	5.0	5.0	0.0

Determining Activity-Oriented Float Time

Just as every event in a network has slack time, every activity has float time which can be expressed as a positive, negative or zero value. Float time values can be used by management in the scheduling of resources to activities in a network.

The formula used to determine float time is:

$$f = T_L - T_E - t_e$$

The T_E of the preceding event and the t_e of the referenced activity are subtracted from the T_L of the succeeding event. Float values are presented above the t_e values for each activity in the model network (Figure 11). The value of the end event T_L and T_E is 6.1.

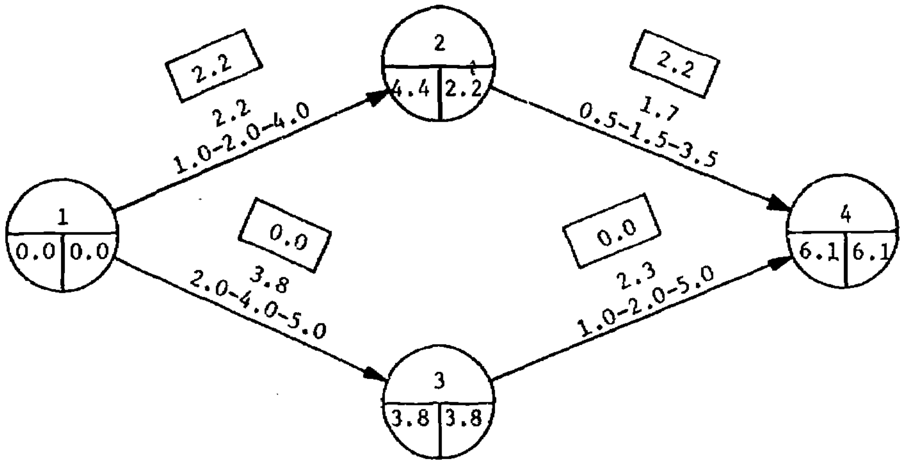


Fig.11.--Float Determinations in a Model Network

Referring to activity 2-4, the float value is 2.2 weeks. The 2.2 value is derived by subtracting 2.2 (T_E of event 3) and 1.7 (t_e of activity 2-4) from 6.1 (T_L of event 4).

Values and calculations in TABLE 5 (Float Matrix) indicate the amount of float time available within specific activities in the example problem presented in Figure 12.

Float values can be used to achieve management flexibility in resource allocation and schedule control for those activities in a program network.

Determining Critical Path(s)

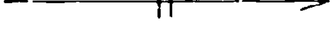
If the T_L is identical to T_E, it is an indication of what network theorists refer to as "critical path." Determination of critical path(s) affords managers a visual referent that can be used in allocating the available resources (men, money, materiel, machines and time) to priority activities that lead to the effective and efficient achievement of valued results. By determining earliest expected and latest allowable time for events, the first indication of the critical path (CP) will be identical values for T_E and T_L or T_E values that are larger than T_L values.

The calculation of float time is the final determinant in identifying critical path(s). Two conditions must be appraised. If one is missing, then the path may not be designated as critical. The two indicators or conditions of critical path are:

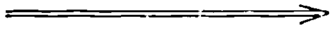
1. Event T_E value is equal to, or smaller than, the T_L value (zero or negative slack)
2. The float time value is zero or negative.

A further distinction may be made relative to critical path. If there is zero slack and zero float, the path is designated as critical. If there is negative slack and/or negative float, a limiting designation is given the path.

It is useful and desirable to mark the critical path(s) in some distinctive manner so that it (they) can be distinguished from the non-critical paths. Two alternative symbols for distinctive marking used in network construction are:



or



The example problem presented in Figure 12 is depicted complete with t_e, T_E, T_L and critical path values and symbols.

TABLE 5

FLOAT MATRIX

Job Sequence	Duration	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Total Float
Activity	t_e	T_E	$T_E + t_e$	$T_L - t_e$	T_L	$T_L - T_E - t_e$
1.00-1.01	1.7	0.0	1.7	0.0	1.7	0.0
1.01-1.02	0.5	1.7	2.2	3.0	3.5	1.3
1.01-1.03	0.9	1.7	2.6	2.6	3.5	0.9
1.01-1.04	1.8	1.7	3.5	1.7	3.5	0.0
1.02-1.05	0.0	2.2	2.2	3.5	3.5	1.3
1.03-1.05	0.0	2.6	2.6	3.5	3.5	0.9
1.04-1.05	0.0	3.5	3.5	3.5	3.5	0.0
1.05-2.00	0.9	3.5	4.4	3.5	4.4	0.0
2.00-2.01	1.3	4.4	5.7	7.2	8.5	2.8
2.00-2.02	4.1	4.4	8.5	4.4	8.5	0.0
2.01-2.02	0.0	5.7	5.7	8.5	8.5	2.8
2.02-2.03	1.1	8.5	9.6	8.5	9.6	0.0
2.03-2.04	0.6	9.6	10.2	9.6	10.2	0.0
2.04-2.05	3.0	10.2	13.2	10.2	13.2	0.0
2.05-3.01	1.1	13.2	14.3	13.2	14.3	0.0
2.05-4.01	1.0	13.2	14.2	17.7	18.7	4.5
2.05-5.01	1.1	13.2	14.4	24.5	25.7	11.4
3.01-3.02	2.3	14.3	16.6	14.3	16.6	0.0
4.01-4.02	1.1	14.2	15.3	18.7	19.8	4.5
5.01-5.02	1.1	14.3	15.4	25.7	26.8	11.4
3.02-4.02	2.2	16.6	18.8	17.6	19.8	1.0
4.02-5.02	4.2	18.8	23.0	22.6	26.8	3.8
3.02-3.03	12.3	16.6	28.9	16.6	28.9	0.0
4.02-4.03	11.3	18.8	30.1	19.8	31.1	0.0
5.02-5.03	8.5	23.0	31.5	26.8	35.3	3.8
3.03-4.03	2.2	28.9	31.1	28.9	31.1	0.0
4.03-5.03	4.2	31.1	35.3	31.1	35.3	0.0
5.03-6.01	2.2	35.3	37.5	35.3	37.5	0.0
5.03-6.02	2.2	35.3	37.5	35.3	37.5	0.0
5.03-6.03	2.1	35.3	37.4	35.4	37.5	0.1
6.01-6.04	0.0	37.5	37.5	37.5	37.5	0.0
6.02-6.04	0.0	37.5	37.5	37.5	37.5	0.0
6.03-6.04	0.0	37.4	37.4	37.5	37.5	0.1
6.04-6.05	12.2	37.5	49.7	37.5	49.7	0.0
6.05-6.06	4.2	49.7	53.9	49.7	53.9	0.0
6.06-6.07	1.5	53.9	55.4	53.9	55.4	0.0

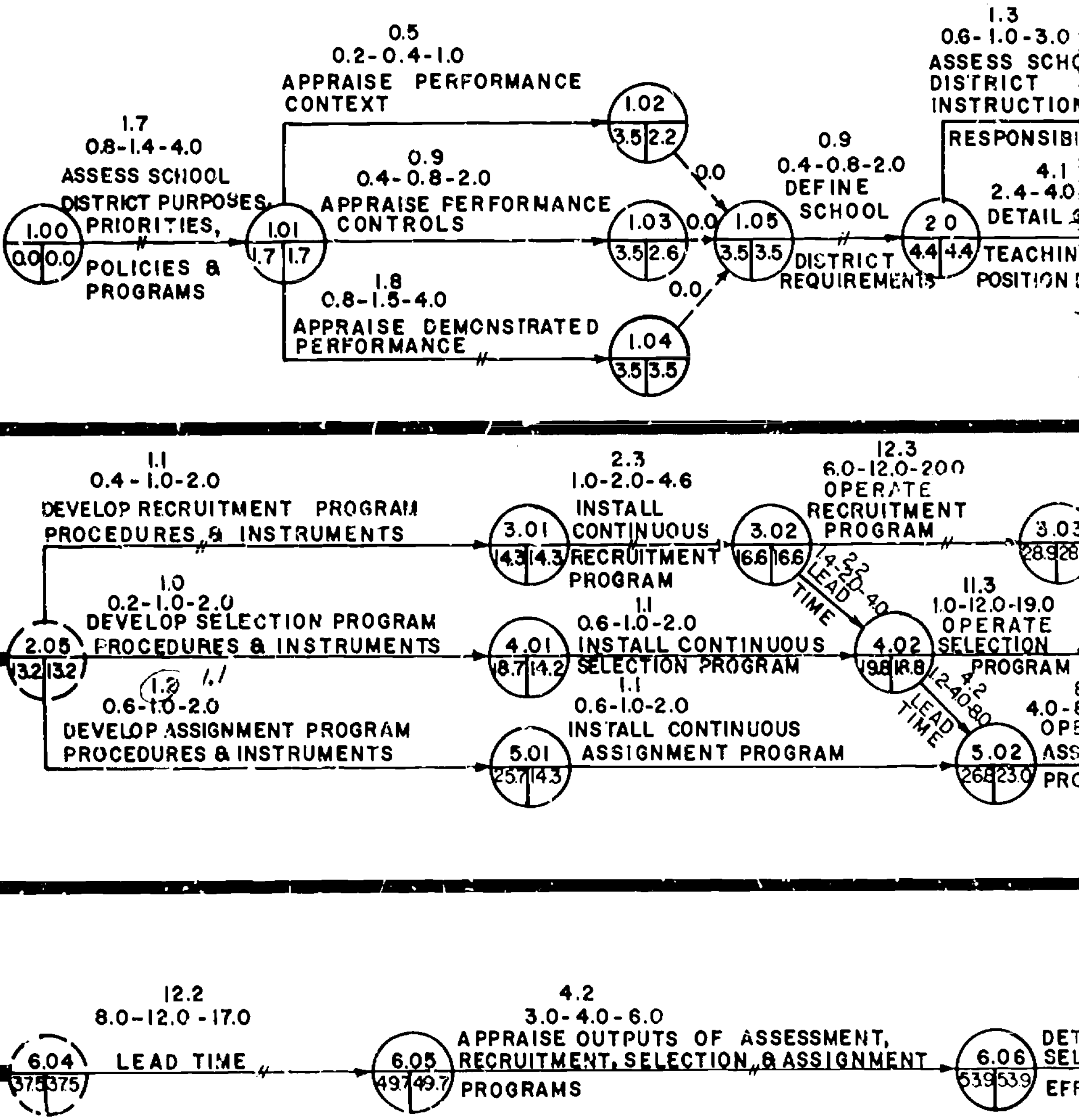


FIGURE 12

MANAGEMENT NETWORK FOR THE ASSESSMENT, RECRUITMENT, SELECTION,

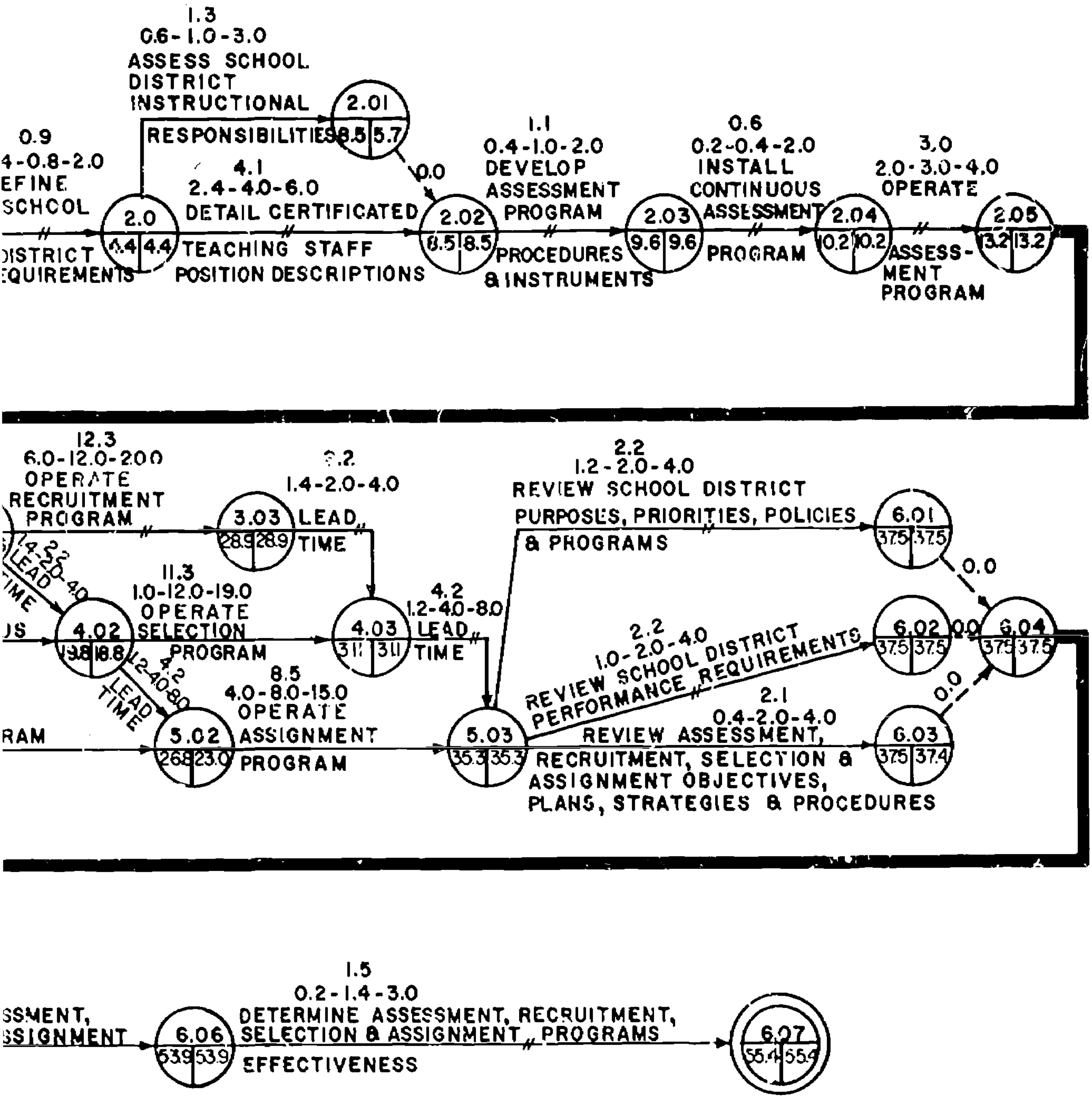


FIGURE 12

RMENT, SELECTION, AND ASSIGNMENT OF CERTIFICATED TEACHING PERSONNEL

CHAPTER IV

INPUT ALLOCATION AND WORK PACKAGE CONSIDERATIONS

Among the important program considerations in the allocation of organizational inputs (information, energy and resources) are: (1) appraising temporal requirements, (2) determining program priorities and (3) leveling the variable, fixed and combined categories of resources available to the organization. Each of these considerations can be investigated using PERT and/or CPM program networks.

Appraising Temporal Requirements

The scheduling of resources to network activities must be based upon a thorough knowledge of program objectives and the requisite conditions that must be met, managed and/or maintained for their achievement. These requisite conditions (requirements) may originate outside as well as inside the program context. They are important influences on network flow and the scheduling of inputs.

In scheduling, managers must be especially conscious of the availability of resources as a prime consideration in determining the feasibility of program objective achievement. The goal is to appraise the time, cost and technical requirements involved in priority objective achievement and schedule available inputs to achieve maximum effectiveness.

Three scheduling steps can be closely associated with the appraisal of program time requirements. The first step involves the calculation of network t_e values. The second step includes computation of T_E and T_L values. The third step entails calculation of slack and float network values. Obviously, each step provides information about program time requirements that can be used in the judicious allocation of available inputs toward the achievement of prespecified program objectives.

Determining Program Priorities

The availability of resources must be considered when making activity expected elapsed time estimates. Resulting schedules provide a means by which needs can be weighed against the availability of resources. Realistic rather than idealistic beginning events and/or completion times must be derived and specified. To allocate resources judiciously, management must assess and evaluate the capabilities and capacities of personnel and make assignments on the results of this appraisal. Activity scheduling must also be consistent with the availability of inputs. By scheduling available inputs within high-priority programs, managers can often provide resources needed to develop, install and operate lower-level activities within the priority program.

Specification of performance priorities within a program is aided by determination of:

1. Negative or zero slack activities
2. Precedence needs for total resources
3. Event sequencing codes.

Criticality is the prime consideration in assigning priorities within a program network flow. By using networks and considering alternative patterns for the most efficient and effective utilization of resources, educational management can establish operational controls for the successful achievement of priority-rated ends.

Planning and scheduling the utilization of available inputs in complex and/or critical programs often requires that managers perform "trade-offs" between time, money, personnel, machinery and materials. Leveling assists management in planning and controlling these inputs in order to achieve efficiency and effectiveness in performance.

Leveling Available Resources

Leveling is the process of planning and managing fixed, variable and/or combined resources and their related energy and information requirements in order to develop, install and operate priority-selected educational programs to achieve prespecified objectives. Resources to be leveled "can be considered under three separate categories: variable, fixed and combined."[15]

Fixed resources within an educational organization are contracted personnel who are employed annually and those machines, materials, land, facilities and time which are a fixed part of the annual operating program. Other fixed resources include administrators and/or teachers who, on a part-time basis, are employed to participate in developing educational programs of planned change.

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[15] R.L. Martino, Applied Operational Planning--Project Management and Control, Vol. I, American Management Association (New York: Comet Press), 1964, p. 110.

Variable resources are consultants, research and/or administrative assistants and leased or contracted machines, facilities, land, materials and services which may be required to achieve program objectives.

Combined resources are a combination of fixed and variable resources assigned to an educational program.

Work Packages

Definition

A basic objective of planning and management is the development of qualitative and/or quantitative criteria which can be used to compare the actual work performed and actual costs expended with the program plan. Work packages are sets of related tasks that are detailed in analysis of low-level activities in a Work Breakdown Structure or in a Function Flow Block Diagram. They detail the work required to accomplish specific tasks and can be used as references in planning and controlling actions. Work packages can be prepared for each performance unit involved in a particular operation.

Establishing Cost-Account Reference Codes

Work packages consist of incremental task-level activities that are identified in Work Breakdown Structures and Function Flow Block Diagrams. Programs are assigned cost-account reference code numbers that relate directly to organizational cost-account reference code numbers assigned to the WBS and the FFBD. The activity of one and only one department may be specified using a cost-account reference code number. If two or more performance units interface or interact to perform an activity, each unit must be assigned separate and distinct reference code numbers. For example, if the central administrative staff and selected teachers work cooperatively in structuring curricular objectives, then separate reference code numbers for the administrative unit and instructional units must be assigned. Separate code numbers permit costs to be allocated to the objective-writing activity in terms of existing performance units using cost-account reference code numbers.

Responsibility for performing the activities specified in a work package rests with operational managers. They must manage the resources within their jurisdictions and control achievements toward the accomplishment of prespecified objectives for the work package.

Work Package Task Plan Sample Format

A work package plan is presented as Figure 13. Use of the plan requires thorough familiarity with the following symbols and their corresponding definitions:

Program: Title of Program

Date: Completion date of work package plan

Responsibility: Functional Manager's signature to designate his acknowledgement of assigned responsibility

Work Package Title: Same

Task Description: Specific task description

Job Account Code: Program cost-account reference code number

Task Number: Number assigned to account code number

Revision Date: Latest date of changes to plan caused by recycling

WORK PACKAGE PLAN

Program ______________________

Date ______________________

Responsibility ______________________

Work Package Title	Task Description	Job Account Code	Task Number	Revision Date

Statement of Work:

Task Descriptions		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	PWS													
	PWA													
	AC													
	PWS													
	PWA													
	AC													
	PWS													
	PWA													
	AC													
	PWS													
	PWA													
	AC													
	PWS													
	PWA													
	AC													
Monthly PVWS														
Monthly PVWA														
Monthly Actual Cost														
Actual	1st Week													
	2nd Week													
	3rd Week													
	4th Week													
	5th Week													
	Monthly Variance ($)													
	Program Variance ($)													
	Man-Hours Variance													

Fig. 13.--Work Package Plan

Statement of Work: Narration of succinctly defined objective(s) including "who," "what," "how," "where," "when," and "why"

Task Descriptions: Descriptions of work required to achieve work package objective(s)

PWS = Planned Work Schedule: Estimates of time to accomplish task description

PWA = Planned Work Accomplished: Objective judgment of achievement at specific points in time

Actual Costs: Actual expended energy and/or resources related to specified tasks (measured in dollars or hours)

Monthly PVWS: Monthly planned value of work scheduled = monthly estimate of cost required for work scheduled

Monthly PVWA: Monthly planned value of work accomplished = objectively derived judgment of work accomplished in terms of cost

Monthly Actual Cost: Total dollar expenditures directly relating to all tasks on work package

First Week: Actual costs expended for tasks

Second Week: Actual weekly costs expended for tasks

Third Week: Actual weekly cost expended for tasks

Fourth Week: Actual weekly costs expended for tasks

Fifth Week: Actual weekly costs expended for tasks

Monthly Variance in Costs: Actual costs equal to, lower than or higher than related planned costs

Program Variance: Difference between planned information, energy and resources expended to achieve work package tasks (expressed in dollars or hours)

Man-hours variance: Difference between planned hours and actual hours expended

Managerial Uses of Work Packages

The work package is the cost-account element upon which PERT/COST systems are based. Operational managers are assigned responsibilities for planning, integrating, managing and conserving the utilization of resources and controlling performance toward the achievement of prespecified objectives. They are required to account for all program costs and maintain records that can be used to develop cost-based progress reports. Costs of incremental task-level activities can be collected and related to summary code numbers and in turn summarized at progressively higher levels until they relate directly to a specific program.

Work Packages - PERT Relations

Work package activities are incorporated into a PERT network, as required, to identify, to plan and to control efforts toward the achievement of objectives. Work packages detail essential functions and tasks that must be performed by operational units.

> The program is first defined and then broken down into end item subdivisions and then into work packages to be assigned to first-line supervisors. These work packages are then represented by activities (one or more) on a conventional . . . network to identify the interdependencies in the program and the sequence in which the work will be performed.[16]

Cost estimates, based on work package and related network activities, can be accumulated upward to the Work Breakdown Structure and/or to the Function Flow Block Diagram and, ultimately, they can be used to project total program costs By comparing estimated costs with actual costs and plans with work accomplished at the detail level, management can sense potential problems where the first indicators of variance appear. Decisions may then be made by management to correct negative variances in performance and to preserve internal control.

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[16]PERT Coordinating Group, Guide for Management Use, p. 39.

The development of performance networks create a common visual referent for management decision making. The networks created must be complete and responsive to objectives.

> Networks can readily be constructed without the use of a work breakdown structure, but quite possible such networks will be incomplete or inconsistent with program objectives.[17]

Similarly, networks can be designed without developing work packages, but it will be more difficult to produce a responsive framework for action. The need for detailed networks that are sensitive to objectives, performance and costs and which can be used as management aids in developing, installing and operating educational programs of planned change cannot be overemphasized. Work package development and use leads to more efficient and effective management action in complex operations. Work packages can be used as essential references for cost-accounting and budgeting procedures in planning-programming-budgeting systems (PPBS).

Summary

Activity time estimating, event time determinations and related slack and float calculations provide management with a tool to plan unknown time considerations. Input allocation when activity time estimates are made precludes temporal reliability. Leveling includes a categorization of fixed, variable and combined resources.

Work packages detail performance activities. The level of detail is related to needs of the program and/or management. Work packages can be used as references in planning and managing performance.

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[17] AMETA, PERT/Cost and Control, p. 7-2.

CHAPTER V

PROGRAM CONTROL CONSIDERATIONS

> Sir Winston Churchill was once asked what qualifications he thought the most essential for a politician. Without hesitation he answered, "It's the ability to foretell what will happen tomorrow, next month and next year--and to explain afterward why it did not happen.[18]

Control is a management function designed to assure that performance proceeds according to plan. Management control procedures must include provisions for:

1. Establishing standards for performance and outputs,
2. Executing plans in a timely manner,
3. Directing and coordinating actions toward the achievement of objectives,
4. Supervising and monitoring the actions of people,
5. Reporting progress,
6. Comparing progress to plans and objectives,
7. Estimating variance in performance and outputs,
8. Adjusting performance through corrective action,
9. Revising plans, strategies and procedures. and
10. Appraising, clarifying and refining statements of purpose.[19]

Control may be designed in terms of the "management by exception" principle. Management by exception involves concentrating upper-level management attention on major performance deviations from plan. If the course of performance is proceeding to plan, higher-level management attention is not required except for knowledge of progress and achievement.

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[18] Reader's Digest Treasury of Wit and Humor, Reader's Digest Assn., p. 265.

[19] D.R. Miller, "Assessing Relevant Change and/or Renewal Factors in Achievement," (Burlingame, California: OPERATION PEP) (in press).

Adoption and use of network-based management procedures and the principle of management by exception facilitate horizontal and vertical coordination of performance within the organization. The focus is on results. Causes of deviations are related to objectives and plans. Clearly and cogently stated objectives and explicitly detailed plans enable management personnel at all levels to visualize the need for recycling and to recognize whether or not higher-level management decisions are required. Decentralization of decision making can increase the availability of higher-level management time and promote staff development and growth.

Reports Implications for Management

Reports are managerial control instruments which are designed to provide information that can be used to relate actual performance to pre-specified plans and objectives. In regard to a reporting system, Jones and Trentin state that:

> The reporting system is designed as a tool for all levels of supervision in controlling their operations and their costs. It emphasizes information which is useful to the individual supervisor and deemphasizes the bookkeeping aspects of reporting.[20]

Network-based reporting techniques can be used to improve all aspects of educational management. Certainly, reports "should facilitate control and replanning."[21] Management achieves "dynamic" program control through

[20]Reginald L. Jones and H. George Trentin, Budgeting: Key to Planning and Control: Practical Guidelines for Managers, American Management Association (Brattleboro, Vermont: The Book Press, Inc., 1966), p. 20.

[21]Ibid., p. 61.

analyses of variances at points of departure from plan. These analyses utilize the information contained in systematic program status reports which are based on evaluation and comparisons of PVWS, PVWA and actual costs expended.

Jones and Trentin also emphasize that basic considerations for budget-related reports include:

> 1. Only those items of cost which are actually incurred by the individual charged with the responsibility for a particular department should be included in the budget report of that department. . .
> 2. Only that information which is meaningful and necessary should be included in the report.
> 3. Only the minimum amount of detail appropriate for the organizational level for which the report is intended should be included.
> 4. Accounting and reporting of expenditures should be in accordance with the principles of responsibility.[22]

Reports should be sufficiently detailed to provide enough information for logic and clarity and should not be so succinct that they allow misinterpretation.

Network-based reporting techniques in organizations facilitate the achievement of:

1. More effective communication to involved personnel at responsible levels

2. Clarification of responsibility through delegation of authority

3. Reliable information regarding program status and real and/or potential problem areas

4. Effective decision making using complete, accurate, relevant and timely information that is based on appraisals of relevant choice-consequence relations

5. Efficient allocation of resources to minimize non-productivity

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[22] Ibid, p. 180.

6. Cost credibility

7. Schedule and performance reliability.

Reported data are accumulated to justify and legitimate actual cost and schedule performance in relation to prespecified plans. If performance schedule slippage is indicated in reports, cause(s) may include:

1. Inadequate task breakdown on which time estimates were projected

2. Unidentified interrelations

3. Delays in receiving funding allocations

4. Unavailable inputs.

Reasons for cost increases may include:

1. Insufficient identification of program objectives

2. Incomplete task descriptions

3. Lack of clarity in specifications

4. Inadequate control of expenditures.

Managing program performance is improved by:

1. Specifying desired and/or required outcome(s)

2. Identifying and communicating requirements

3. Specifying standards of measurement

4. Defining work flows succinctly (i.e., descriptions of plans and/or strategies for action)

5. Specifying and communicating motivational rationale

6. Clarifying assigned responsibilities and related areas of authority

7. Evaluating actual performance and comparing planned performance with actual achievements

8. Initiating action to correct variances.

Reports Considerations

Many network-based reporting techniques are available that can be used in obtaining and maintaining complete, accurate, relevant, timely and valid performance data. These techniques are aids for improving both schedule and cost control.

Performance factors that influence the number and types of reports include: program direction, cost of application, available facilities and/or resources, criticality and complexity of the program. Meaningful and dynamically-utilized reports are valuable aids in determining performance alternatives and in appraising relevant choice-consequence relations.

Reports should be designed in terms of the following considerations:

1. Are cost and schedule commitments being met, and, if not, why?
2. Are schedule and cost estimate outlooks improving, and, if not, why?
3. What is the degree of progress per plan?
4. Are resource allocations being realistically and effectively planned to achieve maximum results for costs expended?
5. What problems are being encountered? Has corrective action been initiated and, if so, what is the effect of the corrective action on time and cost?
6. Can manpower and resource elements be manipulated to expedite accomplishment of critical activities?
7. What are recommendations for actions at the next higher level of authority? Is management attention really required, or has the responsible functional manager for the task already devised and instituted a work around plan?[23]

Reports are vital management instruments. They provide:

1. A means whereby network slack values and network flow can be appraised
2. Feedback for continuous evaluation of program objectives
3. A basis for identification of problem areas.

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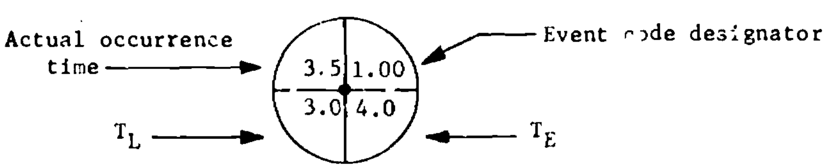
[23]National Aeronautics and Space Administration, PERT and Companion Cost System Handbook (Washington, D.C.: Government Printing Office, 1962), p. IX-8.

4. Information regarding potential long-range forecasts of monetary over-runs.

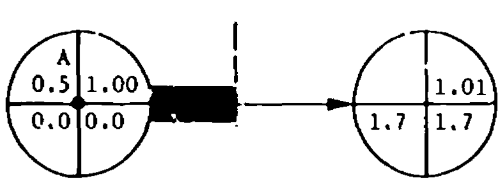
Statistical reports must be designed to avoid misrepresentation of data and/or incomplete information.

If, within a program span, schedule and/or cost estimates seem excessive, concise reports will indicate the degree of improvement from one reporting period to the next. Potential and/or real "slippage areas" may require more frequent reports. Reports can visually display problem areas by use of colors, symbols or other graphic methods.

Progress in relation to network schedules can be shown using many techniques. One simple and effective technique emphasizes only events that have occurred. The event node, complete with an actual achievement date is blackened at its center to denote completion. This can be represented as:



Greater sophistication results if activity lines are blackened to denote achievement. The use of black adhesive line tape enables easy revision of progress estimates. Tape, slightly wider than activity lines, is clearly visible and serves as an effective communication referent:



If plans are to be executed to achieve highest returns for costs expended, management requires complete, accurate, relevant and timely information inputs. Reports provide essential data concerning work progress relative to plan, status of the plan and program validity. These reports compare value of work planned with value of work accomplished and with actual costs expended. TABLE 6 illustrates specific management implications and the possible utility of these reporting techniques.

Use of the matrix presented in TABLE 6 requires pre-established criteria. Qualitative and quantitative criteria for work planned must be established for use as standards of comparison. The matrix can be used as a basis for variance analysis.[24] However, in its present form it is instructive of a range of cost and schedule relations that can be used in management decision making.

Networks and related reports provide management with an operational means of evaluating status of work in process, work completed and real problem areas. They also can be used to forecast probable and/or potential problem areas. The value of reporting is emphasized by Justus as:

> Get regular reports, once the project is underway and evaluate the project continuously. Keep a close watch to match progress against schedule. When your critical path is in danger, your whole project is in danger. Recycle as necessary. At some point in the actual project, you may have to refigure everything that remains to be done. Seldom can a project be completed without some change in the original plan or in the original purposes. Study alternative courses to find the one most appropriate course to follow. Simulation--throwing variables (dropping some steps, changing methods, etc.) into a network to produce different possibilities--helps here. Simulation can also tell you which is the most or least costly way of doing a project.[25]

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[24]Lester R. Bittel, Management by Exception: Systematizing and Simplifying the Managerial Job (New York: McGraw-Hill Book Co., 1964), p. 125-162.

[25]John E. Justus, "PERT," School Management, December, 1967, p. 25.

TABLE 6

COST AND SCHEDULE REPORT MATRIX

PVWS	PVWA	ACTUAL COSTS	IMPLICATION
$10	$ 8	$10	Behind Schedule Over Budget
$10	$10	$12	On Schedule Over Budget
$10	$12	$12	Ahead Schedule On Budget
$10	$12	$13	Ahead Schedule Over Budget
$10	$12	$11	Ahead Schedule Under Budget
$10	$ 8	$ 8	Behind Schedule On Budget
$10	$ 8	$ 7	Behind Schedule Under Budget
$10	$10	$10	On Schedule On Budget
$10	$10	$ 9	On Schedule Under Budget

Objectives of Reporting

The Douglas PERT Policy outlines that effective internal reporting procedures are based on these objectives:

Measure accomplishment against schedule and objectives (status)
Assist in identifying realistic time requirements and provide limits for scheduling (schedule)
Fix responsibility and assure continuity of effort despite changes in personnel (responsibility)
Provide total program visibility at required level (coordination and communication)
Locate potential future problem areas in time for corrective action (forecasting)
Apply management by exception techniques for higher levels of management (analysis)

Stimulate outcome of projected changes and parallel approaches.[26]

Benefits of Reports

If reports show that deviations from plan occur within the program process, and that greater benefits can accrue by recycling, network adaptability permits consideration and adoption of alternatives. This process may require alterations to the logic flow of the program. Although replanning requires additional inputs, (information, energy and resources) the effort expended could result in more efficient program cost and schedule control and more effective realization of objectives. Flexibility in adapting to changes in plans permits continuing control over program activities, requirements and outputs.

The type of report required is directly related to the level of organization to which it will be submitted. Data provided in reports submitted to lower levels of organization are more detailed than those designed for the policy-making level. Reports should be designed to provide essential information for decision making at particular levels in an organization.

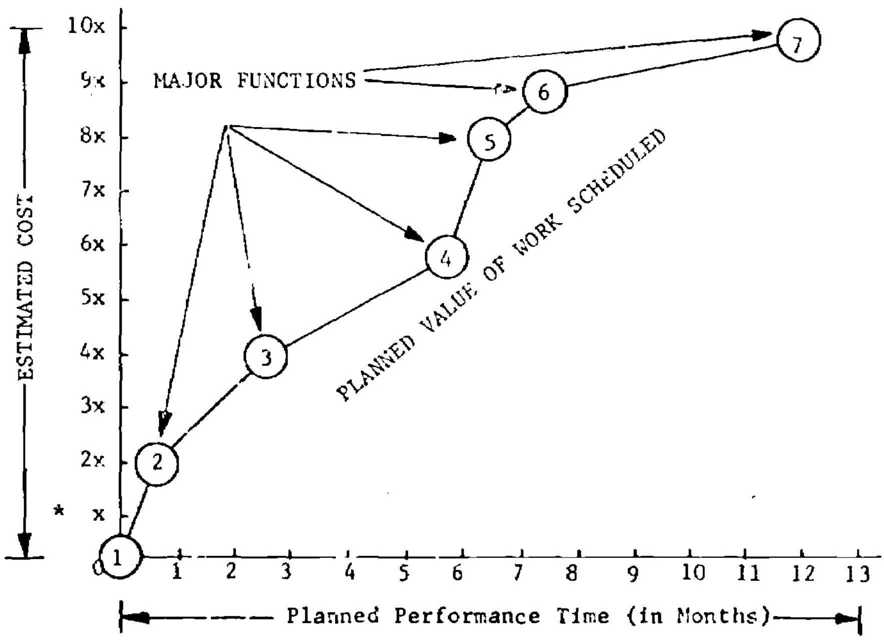
Reporting Techniques for Cost and Schedule Control

Figures 14, 15 and 16 are examples of cost and schedule reporting techniques that can be used to establish high visibility in such areas as program status, program schedule, assigned responsibilities, coordination

[26] Douglas PERT Policy, Corporate PERT Departments, The Douglas Company, Long Beach, California, p. 3-8.

and communication, forecasting, analysis and simulation.

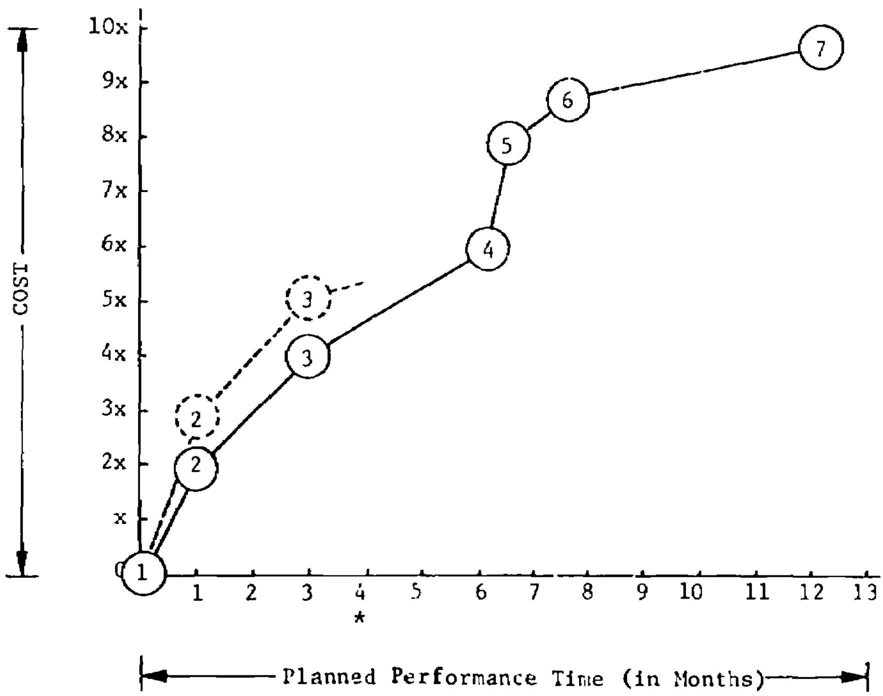
Figure 3 reveals a first level network flow diagram that possesses events 1, 2, 3, 4, 5, 6 and 7 and activities 1.0, 2.0, 3.0, 4.0, 5.0 and 6.0. This network can be used to demonstrate schedule and cost relations between planned value of work scheduled, planned value of work accomplished and actual costs expended in performance. Figure 14 plots the relations between estimated costs and planned performance through time. The relations plotted indicate the planned value of work scheduled.



*Cost here is arbitrarily assigned.

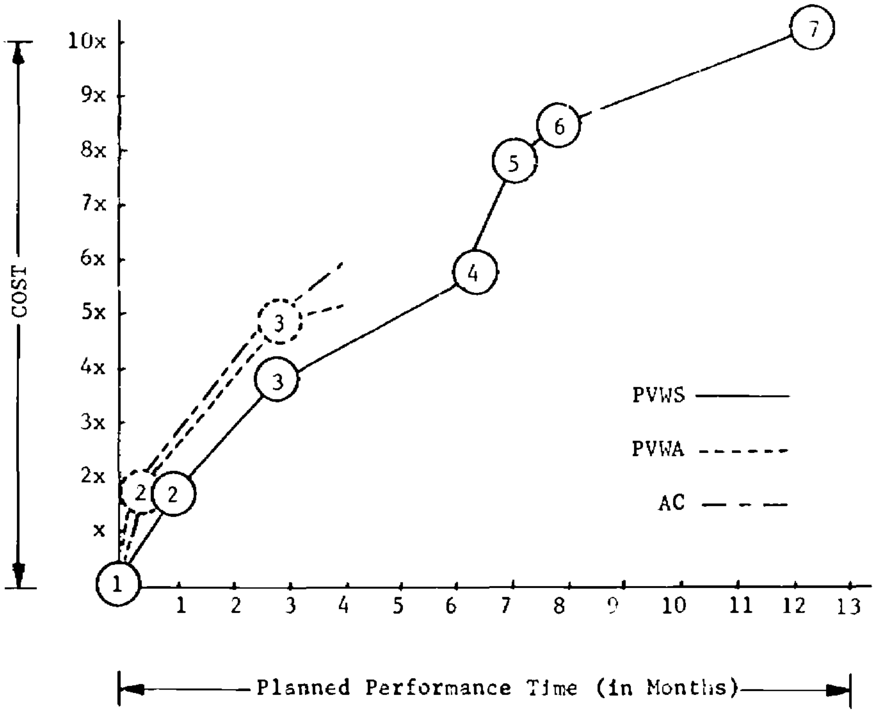
Fig. 14--PVWS Matrix

Using the relations established in Figure 14, it is possible to compare the planned value of work scheduled with the planned value of work accomplished (Figure 15). Note that the PVWA of event 2 is greater than the PVWS. A possible implication of this variance is positive "spill-over" benefits; i.e., the work accomplished is objectively determined (using pre-established criteria) as being of greater value than that which was planned. From the standpoint of information presented, it is evident that the program is progressing approximately on schedule with qualitative productivity higher than expected.



*Assume time of status at end of month four (4)

Fig. 15--PVWS-PVWA Matrix



*Assume time of status at end of month four (4)

Fig. 16--PVWS-PVWA-Actual Cost Matrix

Figure 16 can be used to compare actual costs expended with PVWA to establish current program status. It demonstrates that performance, compared to schedule, is on target and its quality is higher than forecasted. It reveals that actual costs expended are considerably higher than those predicted. Management action may be required to curtail costs, establish performance accountability and maintain end-item cost credibility. Recycling and/or reappraisal of benefits may be necessary to re-establish balanced program cost and schedule relations. Figure 16 extends network schedule and cost relations to include the ingredient of actual costs expended. They must be plotted to evaluate the credibility of cost-to-schedule relations.

Replanning Considerations

A prime benefit to be gained from using PERT as a management tool is the forecasting of potential problem areas. Significant performance deviations may require that replanning functions be performed. The use of PERT affords managers opportunities to visually depict choice-consequence relations. Simulating future outcomes related to preferred replanning alternatives enables management personnel to institute corrective action when variances from plan are first evident.

Replanning alternatives include:

1. Rearranging serial activities into parallel or concurrent configurations
2. Reallocating resources from network paths showing positive slack
3. Decreasing work scope, if feasible, to minimize requirements
4. Eliminating activities.

Planning and Control Cycle in Network-Based Management Procedures

If performance deviations from plan are noted in systematic reporting procedures, regulatory functions must be operable to measure extent of the deviation and to project long-range implications. A planning and control cycle for network-based management procedures is presented in Figure 17. The cycle is based upon specific aspects of network-based management procedures as previously presented.

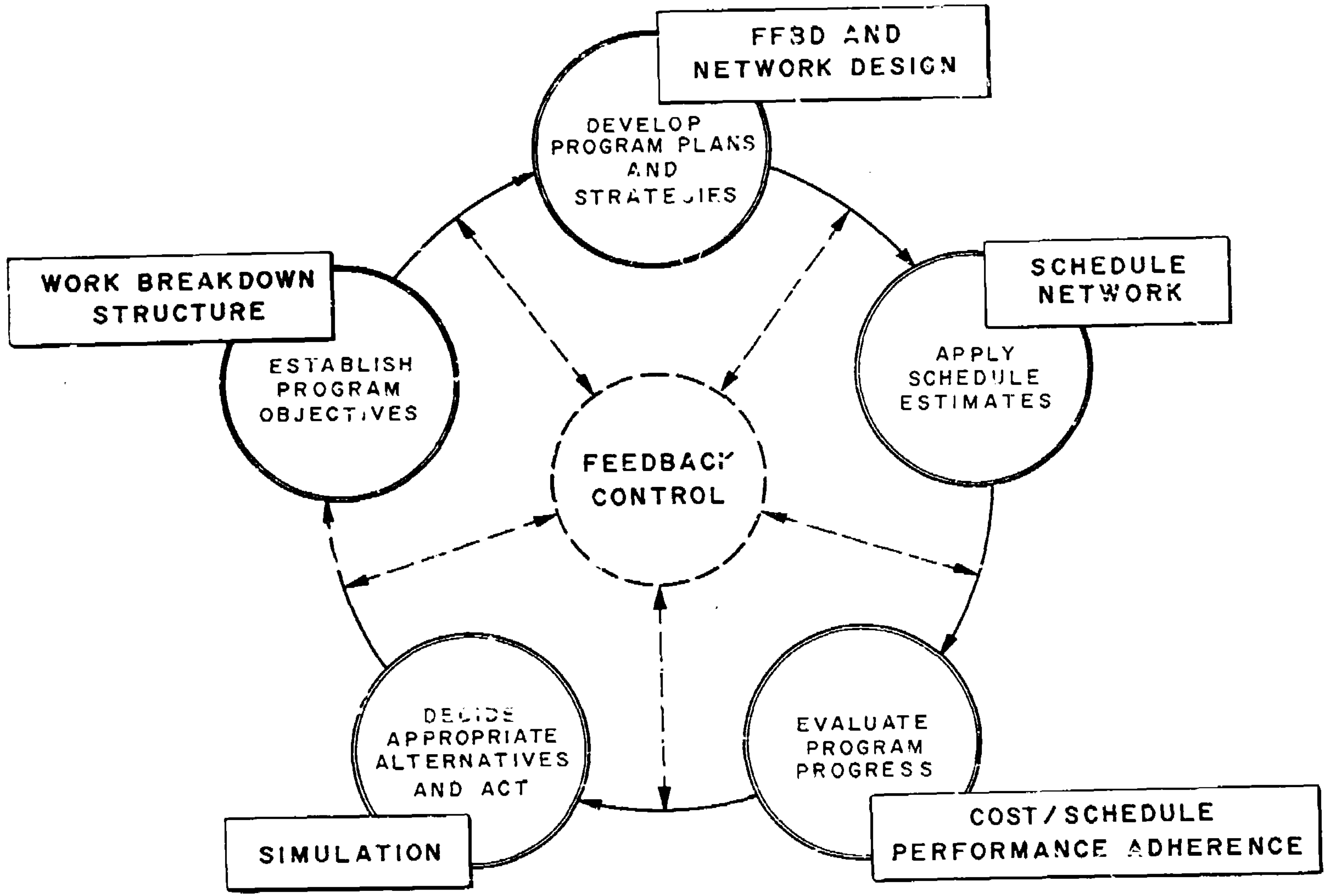


Fig. 17--Planning and Control Cycle for Network-Based Management Procedures

Management Objectives and PERT

Management objectives during planning and control operations that can be achieved through the use of PERT may be summarized as follows:

1. To establish performance comprehension through planning
2. To appraise, select and schedule priorities
3. To manage by exception using prespecified objectives and plans
4. To assess risks, uncertainties and probable difficulties
5. To anticipate problems which may cause schedule slippages, cost over-runs and/or sub-standard performance.

Among the benefits to be achieved by adopting PERT management procedures are improved capabilities and/or effectiveness in:

1. Developing more logical and credible schedules of performance
2. Lateral and vertical communication
3. Defining areas of performance requiring management attention
4. Developing an awareness of, and focusing attention on, interactions and interrelations between performance activities
5. Anticipating probabilities for success
6. Graphically displaying program progress using schedule and cost status network reports.

A PERT/COST system can be implemented to facilitate management actions in such areas as:

1. Developing Work Breakdown Structures and related Function Flow Block Diagrams
2. Making objective, as opposed to subjective, comparisons of PVWS and PVWA against actual costs expended
3. Developing and managing expenditure estimates based on credible time estimates
4. Maintaining compatibility between cost estimating details and existing accounting system procedures
5. Preparing summary reports for higher echelons of management.

PERT can be used as a valuable management aid in assessing performance requirements, justifying and rationalizing needs for technical assistance and developing criteria that can be used to measure performance effectiveness. PERT procedures enable management personnel to:

1. Develop realistic plans for action that focus upon objectives to be achieved

2. Assess performance factors, evaluate achievements and determine performance effectiveness

3. Compare planned value of work scheduled and value of work achieved with actual costs expended.

Problem Analysis Using PERT as a Management Tool

Variances from plans, estimated costs and/or schedule necessitate problem assessment to determine probable causes and effects of such variances. They may require prompt development and initiation of corrective measures. The assessment process may be performed using network-based data to:

1. Determine PVWS and PVWA

2. Compare PVWS and PVWA with relevant actual costs expended

3. Determine cost and schedule variances and their implications for management action

4. Simulate possible alternatives and determine choice-consequence relations for each alternative

5. Select and install preferred alternative for correction of variance.

The installation of preferred alternatives is based upon important management decisions regarding performance requirements, criteria, objectives, plans, strategies and procedures. Management must be cognizant of the need for carefully designed processes that can be used to: (1) derive valid and relevant performance information; (2) determine performance requirements and criteria; (3) specify and negotiate statements of goals and objectives; (4) determine priorities for action; (5) develop plans and strategies based on performance criticalities; and (6) develop realistic management procedures based upon predicted activities and events.

A network-based planning and control model (Figure 18) can be outlined as follows:

1.0 Appraise program decisions and objectives, determine performance requirements and criteria, develop plans and strategies for action

2.0 Define performance activities by developing a WBS and FFBD

3.0 Prepare cost account reference code structure

4.0 Design activity-based PERT and/or CPM network(s)

5.0 Estimate activity time values

6.0 Define significant events and determine activities schedule

7.0 Prepare cost estimates for scheduled activities

8.0 Review plans, schedule and costs

9.0 Secure approval for plans, schedule and cost estimates

10.0 Secure authorization for work to begin

11.0 Accumulate performance achievement and cost expenditure data

12.0 Up-date and revise time and cost estimates as progress milestones are achieved

13.0 Prepare and submit schedule and cost reports

14.0 Analyze progress reports in terms of objectives and plans

15.0 Evaluate program status and identify variances in performance

16.0 Assess and evaluate relevant alternatives and determine probable choice-consequence relations

17.0 Prepare and submit change proposals and recommend new courses and/or methods of action

18.0 Secure necessary approvals

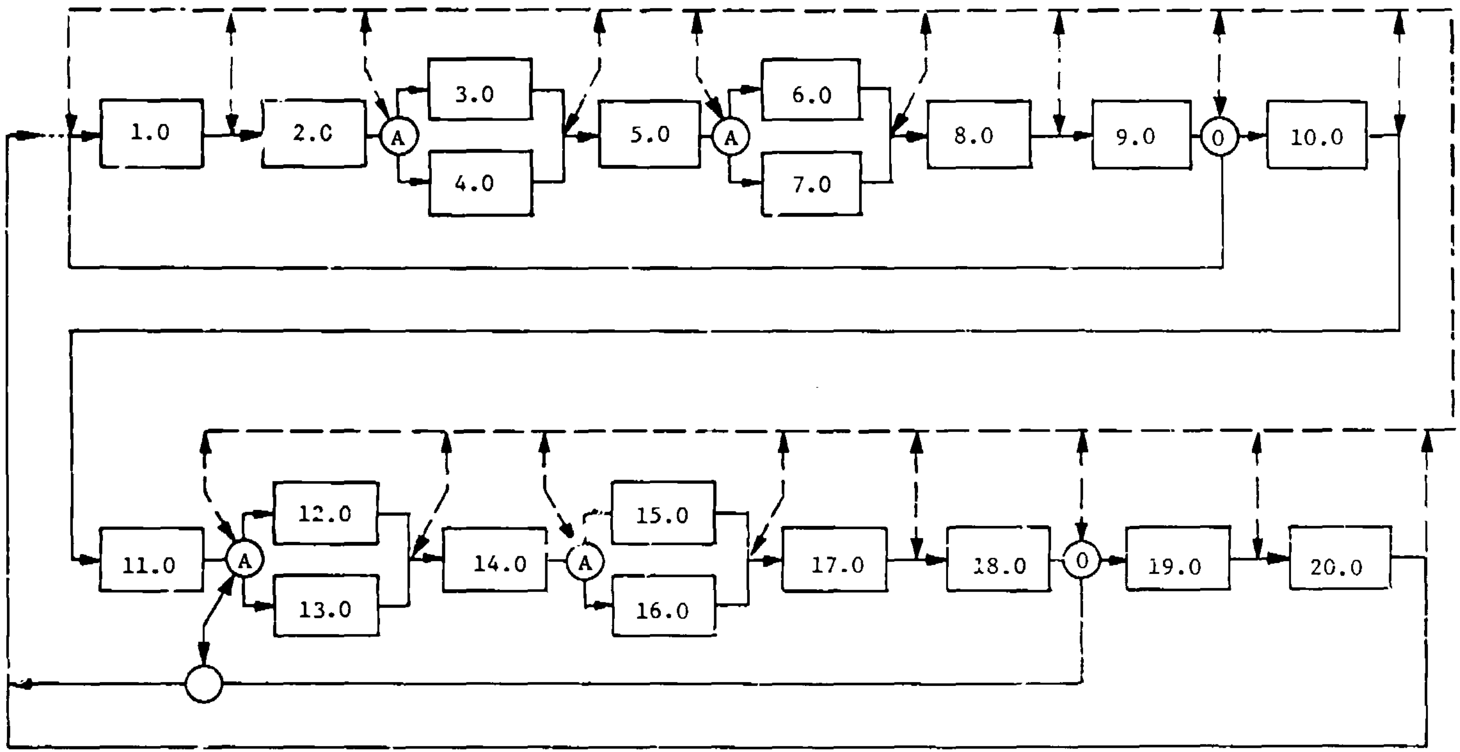


Fig. 18--Planning and Control Model

19.0 Develop and install preferred alternatives

20.0 Manage performance, evaluate achievements and determine effectiveness of performance.

PERT/COST

PERT/COST is concerned with each of the following activities:

1. Estimating the work to be done (planning)
2. Estimating the time required to perform the work (scheduling)
3. Assigning and delegating authority (fixing accountability)
4. Allocating inputs and managing efforts according to schedule (programming and budgeting)
5. Regulating performance and appraising variances (controlling)
6. Assuring quality achievement of outputs (evaluating)
7. Establishing reliability in performance outcomes (achieving credibility).

PERT/COST planning and control systems aid in achieving organizational effectiveness. They serve as management guidelines for improving efficiency in the utilization of inputs.

Relative to the value and benefits to be derived through the use of PERT/COST systems, Douglas PERT policy states:

> PERT Time and PERT/COST comprise an integrated management information system for planning and control over the program variables of time and cost. . . it is a management tool that provides for decision making beforehand, at the point of action.[27]
>
> Through a study made on behalf of the Assistant Secretary of Defense, Douglas has determined that PERT Time was directly responsible for a savings of $6.00 for every dollar spent on the PERT Time function.[28]

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[27]Ibid., p. 1-3

[28]Ibid., p. 1-19.

Networks such as PERT and CPM are best utilized in non-standard situations where uncertainty is prevalent. Model networks must be appraised in relation to program decisions and objectives, desired and/or specified outcomes, requirements and criteria and plans and strategies for action. Such appraisals are required to determine the applicability of network-based procedures to specific organizational problems and/or programs. Cook states that:

> Management specialists in general recognize . . . that PERT is most suitable for research and development activities and not for routine or production-type projects.[29]

Regarding educational applications, Garlock states that:

> Benefits to educational managers from using PERT for such programs as curriculum development and educational research include:
>
> 1. A single network portrayal of the complete system.
> 2. A basis for a unified standard of communication among staff members.
> 3. A procedure that enhances common understanding at all decision-making levels.
> 4. Reports that allow for thorough assessment of the sequence of activities, schedules and costs.
> 5. Reports that assist in analyzing and evaluating the status of completed schedules and costs.
> 6. Reports that assist in forecasting or isolating potential problems and decision making.
> 7. Reports that assist in planning the best possible use of resources to achieve desired goals.
> 8. A means whereby all tasks must be specifically defined.
> 9. A means to determine where resources should be applied to best achieve the desired objectives
> 10. A means to assist in identifying those areas of potential delays.[30]

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[29]Cook, PERT Applications in Education, p. 68.

[30]Jerry C. Garlock, "PERT: A Technique for Education--Research in Review," Educational Leadership, January 1968, p. 353.

Summary

Control is a management function designed to assure that performance proceeds according to plan. Use of PERT as a management tool helps to identify performance deviations at the point of departure from plan.

Reports and reporting procedures must be developed, installed and operated that provide information to management at all levels of the organization. The information must be complete, accurate, relevant, timely and valid to provide management with sound information for effective decision making.

PERT/COST provides a systematic method for planning and controlling program expenditures. It provides information for comparing and evaluating relations between:

1. Planned Value of Work Scheduled (PVWS)
2. Planned Value of Work Accomplished (PVWA)
3. Actual Costs (AC) expended.

CHAPTER VI

OTHER NETWORK-BASED MANAGEMENT PROCEDURES

Other network-based management procedures can be implemented to plan and control "processes" and/or "routine" activities. Network-based procedures typically used for standard or routine tasks include:

1. Line of Balance (LOB)
2. Gantt Bar Charts
3. Milestone Charts
4. Flow Charts

These procedures were developed prior to PERT and CPM. The primary difference between these procedures and PERT or CPM is one of application and utility rather than one of concept and principle.

Line of Balance (LOB)

Line of Balance is a product-oriented networking technique that enables management and subordinates to visualize "where they are" and "where they should be" for any given milestone (event) at any given time. It is best applied to programs where objective achievement recurs systematically, and activities, to achieve the objective (performance cycle), require an extended time span. For example, if the objective is to be achieved on a four-week recurring cycle and five or more weeks are required to perform necessary activities, Line of Balance Charts enable management:

1. To determine where performance should be related to activity overlap requirements

2. To make systematic comparisons of actual performance outputs and planned performance outputs at strategic control points (milestones) throughout the performance cycle

3. To make systematic performance comparisons related not only to the next objective to be achieved (x) but also to succeeding objectives (x + 1...x + n).

It involves plotting proven sequences of events over a specified period of time. The establishment of such relations facilitates systematic achievement of recurring objectives.

The objectives of LOB are:

1. To identify activities which may need special management attention

2. To identify time relations and evaluate deficiencies at specific control points

3. To establish management consciousness of interdependencies, interrelations, interactions and interfaces.

LOB can be used as an educational management tool in planning and managing such recurring activities as:

1. Regularly scheduled school board meetings

2. Regularly scheduled in-service programs

3. Regularly scheduled administrative cabinet meetings

4. Other regularly recurring activities.

Operationally, LOB can be used to:

1. Measure the significance of performance relations

2. Determine the feasibility of objective achievement

3. Determine performance areas requiring management attention and corrective action

4. Provide reliability checks on control actions

5. Establish a framework for inputs allocation

6. Report progress in recurring types of activities

7. Communicate actual program status relative to plans and objectives.

Development of a Line of Balance Chart

Developing a Line of Balance chart involves four fundamental processes:

1. Establishing network flow by plotting activities requiring control in the program
2. Time phasing the network flow using prespecified requirements and criteria
3. Plotting recurring objectives on a time-metered baseline
4. Establishing a matrix for determining individual event status.

To develop a LOB chart, a large (e.g., 22" x 34") sheet of metered paper is divided into three sections as shown in Figure 19.

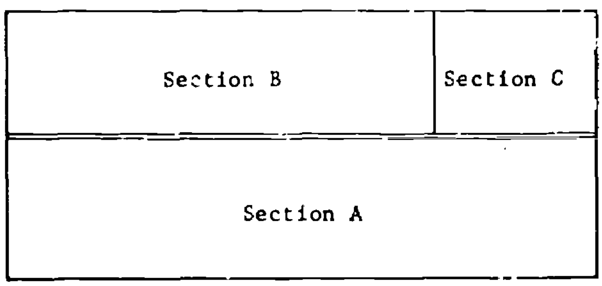

Fig. 19--LOB Chart Sections

Dimensions of each section may be varied to meet the spatial needs for recording available information.

Establishing Network Flow by Plotting Activities Requiring Control in the Program. On a LOB chart, milestones (events) are designated by the symbol △. The milestones are plotted through time in Section A of the LOB chart.

Lines of relation are drawn between milestones to illustrate interrelations between activities. Unlike PERT or CPM networks, activity lines may intersect at any point on the activity continuum. This eliminates the necessity for lead time and dummy activities as required in PERT or CPM networks. The same relation can be shown using PERT and LOB techniques (Figure 20).

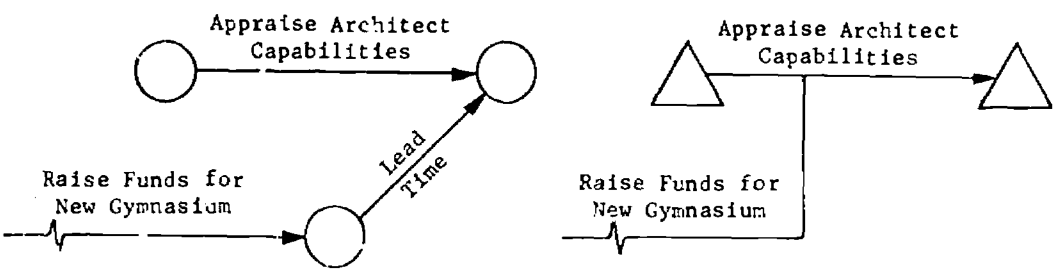

Fig. 20--PERT and LOB Relations

<u>Time Phasing the Network Flow Using Prespecified Requirements and Criteria</u>. In Section A (Figure 19) of a LOB chart, events are plotted through time on a day-to-day basis. The horizontal axis is divided into single and 5-day divisions. Specific dates are not considered at this time. The purpose is to establish a logic flow of milestone-activity relations through time. LOB charts are most effective in repetitive-type operations. Time standards for recurring processes should be based on previous performance experiences. An exemplary LOB chart for Section A is presented in Figure 21 The activities presented are not labeled. For purposes of explanation, they shall be referred to as activity 1-2, activity 2-3, . . . and activity 6-7.

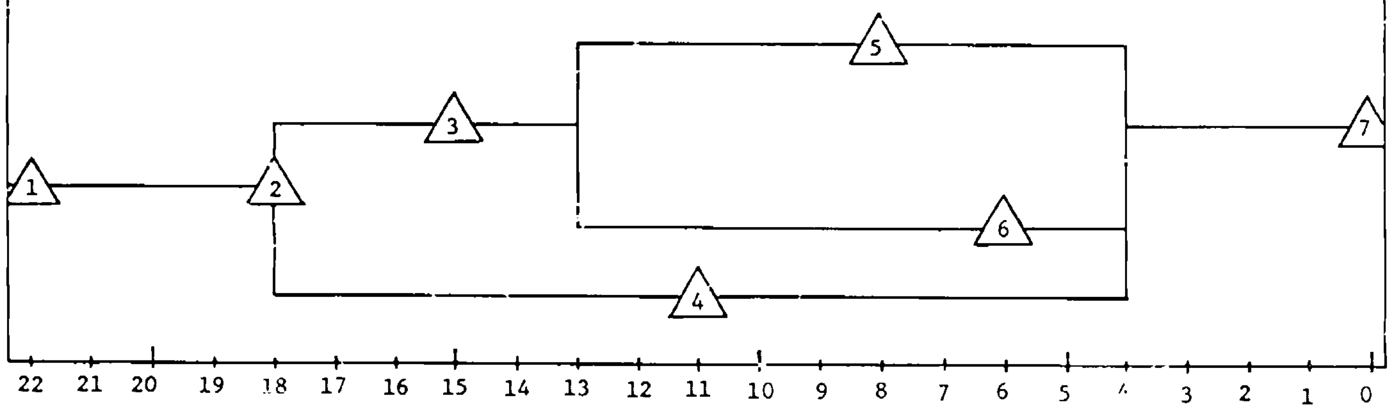

Fig. 21--Section A of a LGB Chart

Milestone 7 represents the objective to be achieved. Activities 1-2, 2-3, 2-4, 3-5, 3-6, 4-7, 5-7 and 6-7 must be performed prior to its achievement. Each activity can be located in a time sequence using the metered baseline. For example, activity 1-2 is scheduled to be performed in 4 days, activity 2-3 in 3 days and activity 2-4 in 7 days. Twenty-two days are scheduled for achievement of the objective. Scheduled days are numbered from the end milestone in reverse order to the first milestone. Day zero is the target date for achievement of the objective. Work required to achieve the objective must begin 22 days before this deadline.

Plotting Recurring Objectives on a Time-Metered Baseline. Results of plotting recurring objective achievement on a time-metered baseline are shown in Section B of the LOB chart. Section B reveals recurring target dates for achievement of milestone 7 on a 52-week metered time line.

The initial activity in charting Section B is to determine the number of times per year that a recurring objective must be achieved and the length (in weeks) of each time interval required for its occurrence. The intervals through time can be entered across the bottom of the horizontal axis of Section B. Dates cannot be plotted on the vertical axis with necessary degrees of certainty until the relation between data presented in Sections B and C are appraised. Each date can, however, be plotted along the time-metered baseline. For example, Figure 22 plots milestone 7 occurrences once every 4 or 5 weeks. A tentative mark is made on the time axis to record these data in Section B (as indicated).

Establishing a Matrix for Determining Individual Event Status. Section C of a LOB chart plots instances of milestone occurrence in ascending order on the vertical axis. If the recurring objective is to conduct monthly

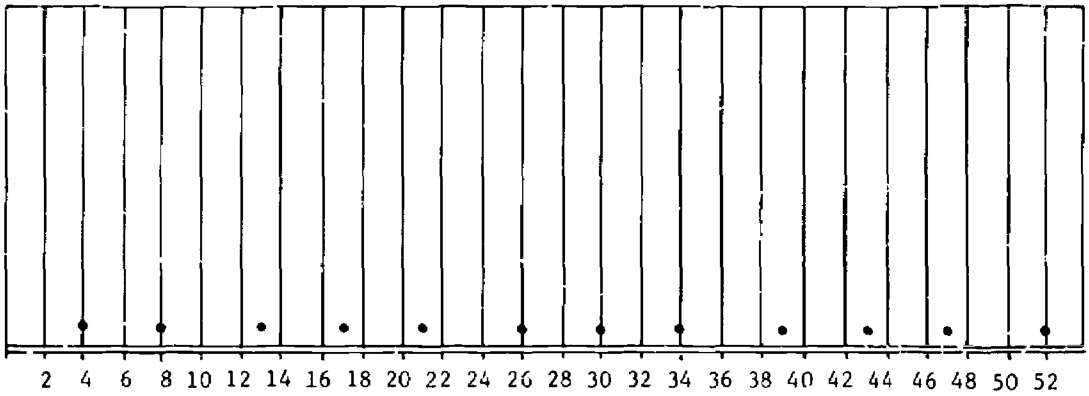

Fig. 22--Section B of a LOB Chart--
Preliminary Plotting of Planned Objectives Through Time

board meetings, the vertical axis is numbered from 1 to 12. Location of instances of milestone occurrence on the vertical axis is dependent on the number of times the objective is to be achieved. The number of instances of objective achievement determines spatial requirements on the vertical axis.

The horizontal axis of Section C contains the number of milestones in the network flow (from Section A). Figure 23 is an example of Section C. There are 12 recurring instances of objective achievement as shown in Figure 22. There are 7 milestones as shown in Figure 21.

The instances of occurrence for each milestone must be equal to the number of times that the objective must be achieved (performance cycle). The numbers 1-12 along the vertical axis will be used to represent the number of instances that a particular milestone has occurred. The numbers 1-7 along the horizontal axis represent the numbers assigned to individual milestones that occur during the achievement of the objective as indicated in Section A.

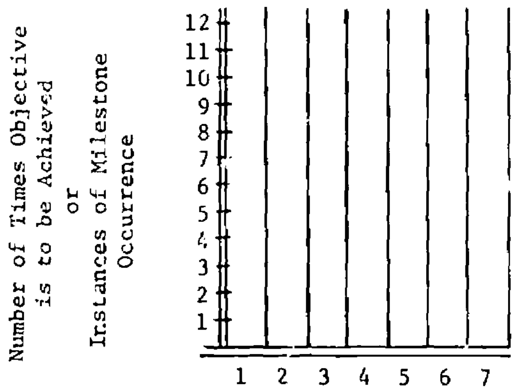

Fig. 23--Section C of a LOB Chart

Striking the Line of Balance (lob). Figure 24 plots planned, recurring, objective achievement through time (expressed in selected time units on a metered baseline). To make the LOB chart a functional tool it is necessary to plot the instances of milestone recurrence (status of milestone) on the vertical axis as shown in Figure 23 (Section C). A planned line of recurring objectives achievement through time can then be plotted in Section B. This line serves as a baseline for striking the line of balance along an on-going course of performance. Figure 24 illustrates this relation between Section B and Section C. Note that the horizontal axis of Section B represents weeks through a year. The vertical axis of Section C represents recurring objective achievement. The first instance of achievement is to occur in week 4, the second instance in week 8, . . . and so on, to the twelfth instance in week 52. The dotted lines in Section B are used for illustration purposes only to show how the recurring achievements relate through time in Section B to instances of planned occurrence of objective milestones revealed in Section C.

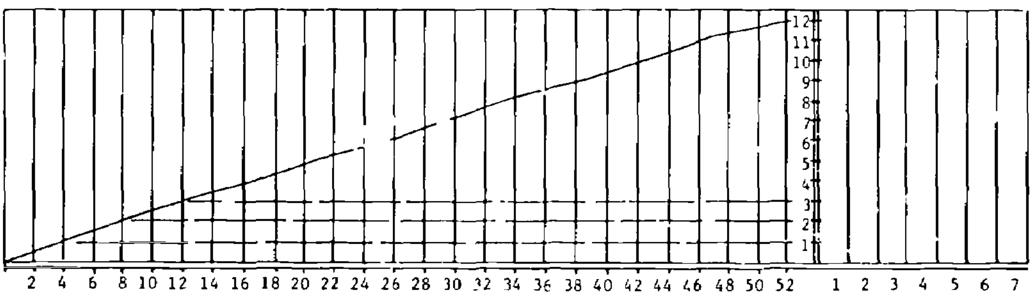

Fig. 24--Integration of Sections B and C--
Final Plotting of Planned Objectives Through Time

Operational Use of Line of Balance (LOB) as A Management Tool

Striking Lines of Balance for Operations

Major reasons for using LOB as a management tool are: (1) it incorporates the principle of "management by exception;" (2) it can be used to plan and control overlapping activities required to achieve recurring objectives. Activities and/or control points requiring corrective action must be identified at points of departure from plan. Determining actual status and comparing status to performance plans provide a basis for comparison of achievements to plans.

The first step in making LOB an operational tool is to determine the status of actual performance using information supplied by responsible managers. Status must be determined for each milestone in Section A (Figure 19) This status is then related to the matrix in Section C (Figure 19).

Section A (Figure 21) has seven control points (milestones) in the network flow. For example, status of these control points is appraised at the end of week 12. Status must be determined in terms of prespecified requirements and criteria. Week 12 is chosen for demonstration purposes only. In actual operations, status would be determined weekly. Feedback from responsible managers shows that:

1. Milestone 1 has recurred in ten instances
2. Milestone 2 has recurred in four instances
3. Milestone 3 has recurred in two instances
4. Milestone 4 has recurred in four instances
5. Milestone 5 has recurred in two instances
6. Milestone 6 has recurred in two instances
7. Milestone 7 has recurred in two instances.

Figure 25 illustrates the charting of the above data. The data are entered in Section C of the LOB chart.

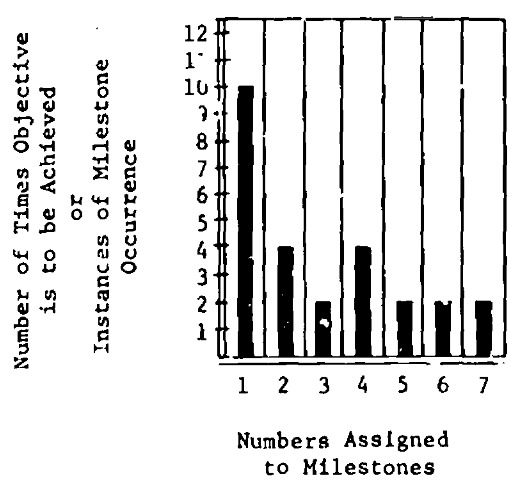

Fig. 25--Section C--Actual Performance Data

The second step in making LOB an operational tool is to "strike" the line of balance (lob). This requires coordination of data between Sections A, B and C of the LOB chart. The result of this activity is to develop a composite stair-step effect that indicates where performance should be. For illustrative purposes, week 12 is the point in time that status is determined. Week 12 is one week prior to the next planned occurrence of objective achievement. From Section A of the LOB chart, milestones 5 and 6 are located in the week before the planned occurrence of milestone 7. A horizontal line is drawn from the intersecting point in Section B (week 12) across milestones 5 and 6 in Section C. The horizontal line (line of balance) is revealed in Section C (Figure 26). The horizontal dashed line across Section B is used for illustration purposes only.

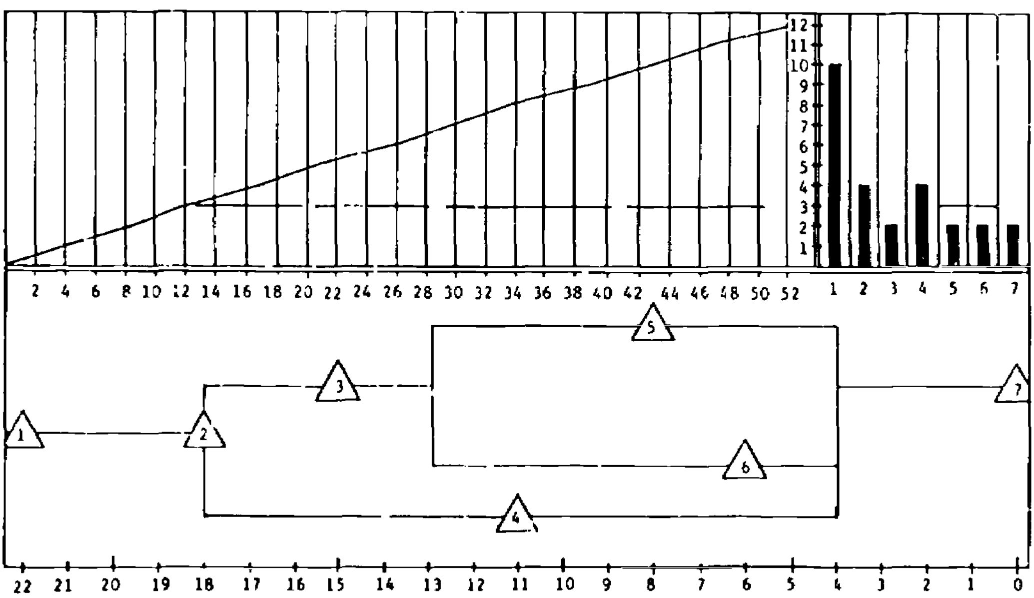

Fig. 26--Striking the lob

This horizontal line across milestones 5 and 6 in Section C indicates where the level of performance should be to achieve milestone 7 on schedule. Vertical status in Section C indicates the status of actual performance. It is evident that performance is not progressing to plan. Actual status indicates that milestones 5 and 6 have occurred in two instances. The line of balance indicates that milestones 5 and 6 should have occurred in three instances. Further analysis will indicate which of the control point(s) is constraining performance.

To strike the line of balance for milestones in <u>preceding</u> weeks it is necessary to move forward in time along the planned course of objective recurrence presented in Section B. For example, in week 11 (Section A) milestones 3 and 4 are events that were scheduled for occurrence. As status is determined in week 12, they were scheduled to occur one week in the past. To strike the line of balance, locate the intersecting line one week in the future (week 13) in Section B. Draw a line across milestones 3 and 4 at that point to determine the line of balance (Figure 27). The horizontal dashed line across Section B is used for illustration purposes only.

To strike the line of balance for milestones in <u>succeeding</u> weeks, it is necessary to move further backward along the planned objectives through the time continuum presented in Section B. The LOB chart is used for repetitive programs. Work to be performed in future weeks need not be performed to as high a milestone occurrence level. For example, in week 13 (Section A) milestone 7 is the only control point that is scheduled to occur. To strike the line of balance, locate the intersecting line for week 11 in Section B. Draw a line across milestone 7 at that point to determine the line of balance (Figure 28). The horizontal dashed line across Section B is used

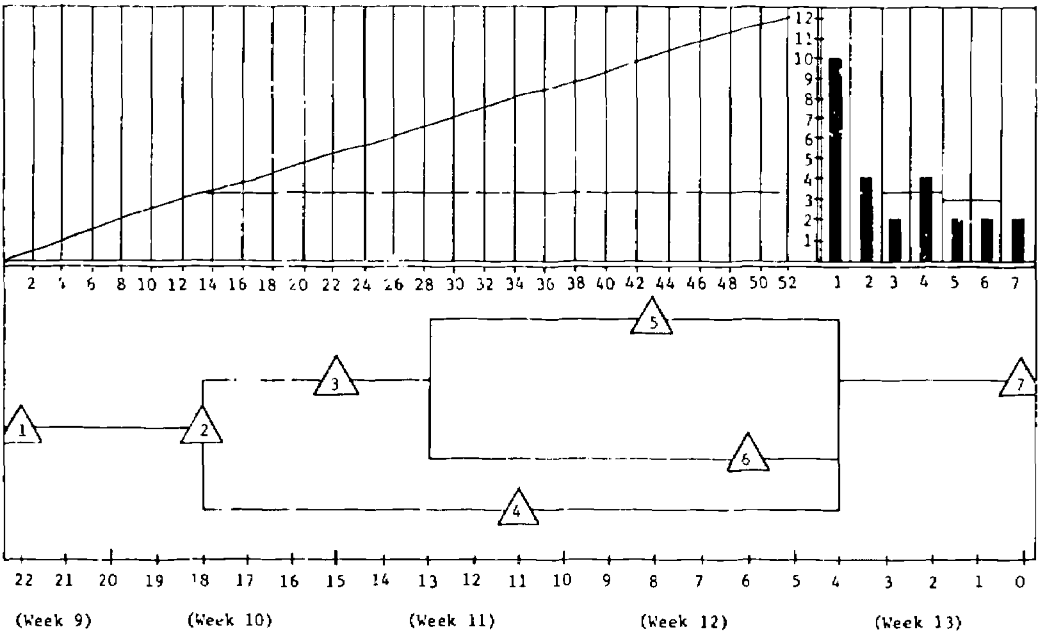

Fig. 27--Striking the lob

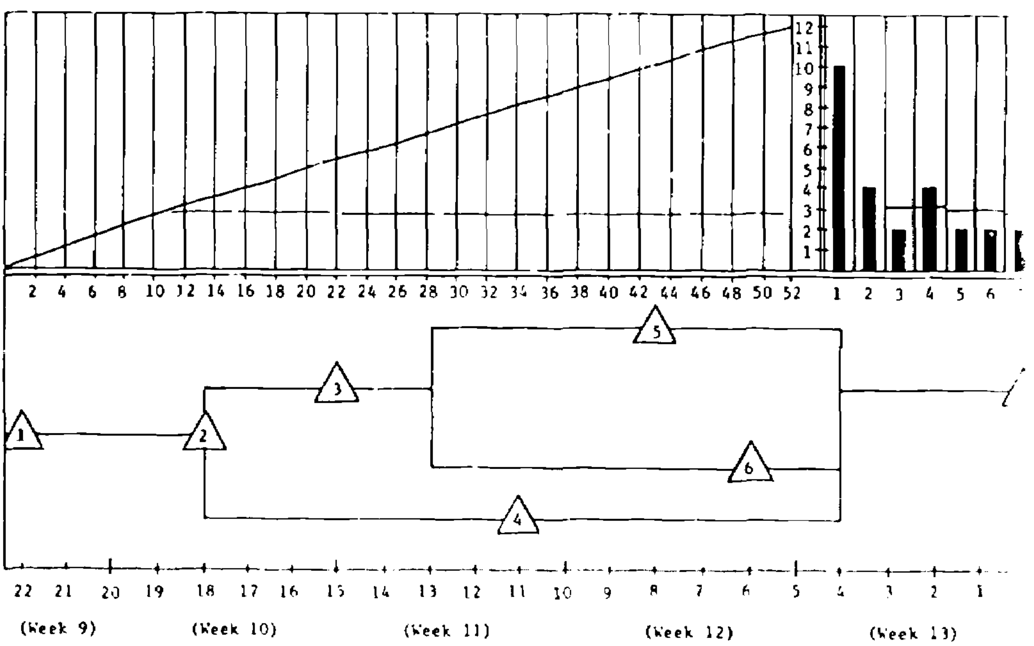

Fig. 28--Striking the lob

for illustration purposes only.

Milestone 4 (Figure 27) is ahead of schedule. Status of work performed indicates completion through four event occurrences. The line of balance is determined at the third event occurrence. Milestone 4 is not a constraining event.

Milestones 2 and 3 are located in week 10, i.e., two weeks prior to week 12 (Section A). To strike the line of balance, locate the intersecting line two weeks after week 12 (week 14) in Section B. Draw a line across milestones 2 and 3 at that point to determine the line of balance (Figure 29). The horizontal dashed line across Section B is used for illustration purposes only.

Milestone 1 is located in week 9 (Section A). To strike a line of balance, locate the intersecting line for week 15, three weeks after week 12 in Section B. Draw a line across milestone 1 at that point to determine the line of balance (Figure 30). The horizontal dashed line across Section B is used for illustration purposes only.

The "management by exception" principle specifies that management focus attention on deviations from plan to improve sub-standard performance. Figure 30, a completed LOB chart, is a tool that can be used to aid the problem-finding process. Milestones 1, 2 and 4 are ahead of schedule. Milestones 3, 5, 6 and 7 are behind schedule. The cause is located at milestone 3. Management should focus attention and concentrate efforts on improving performance related to activity 2-3. Something is constraining the performance of that activity. Milestones 5 and 6 are constrained by milestone 3. Milestone 7 is constrained by milestones 4, 5 and 6. Activity 2-3 constrains the occurrence of milestone 3. When deviations in performance are evidenced, the suspect area is the one nearest the beginning event in

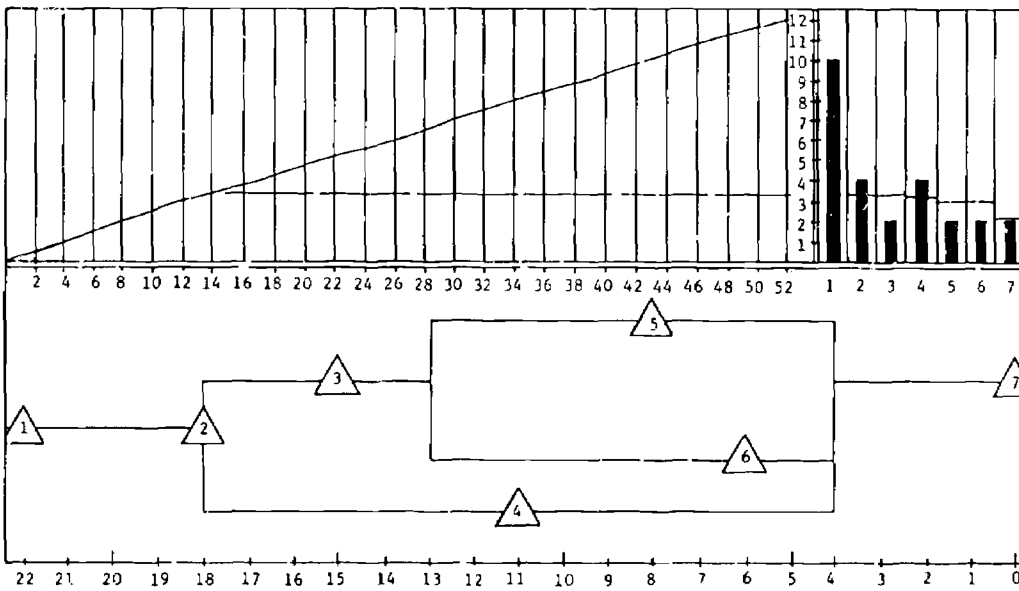

Fig. 29--Striking the lob

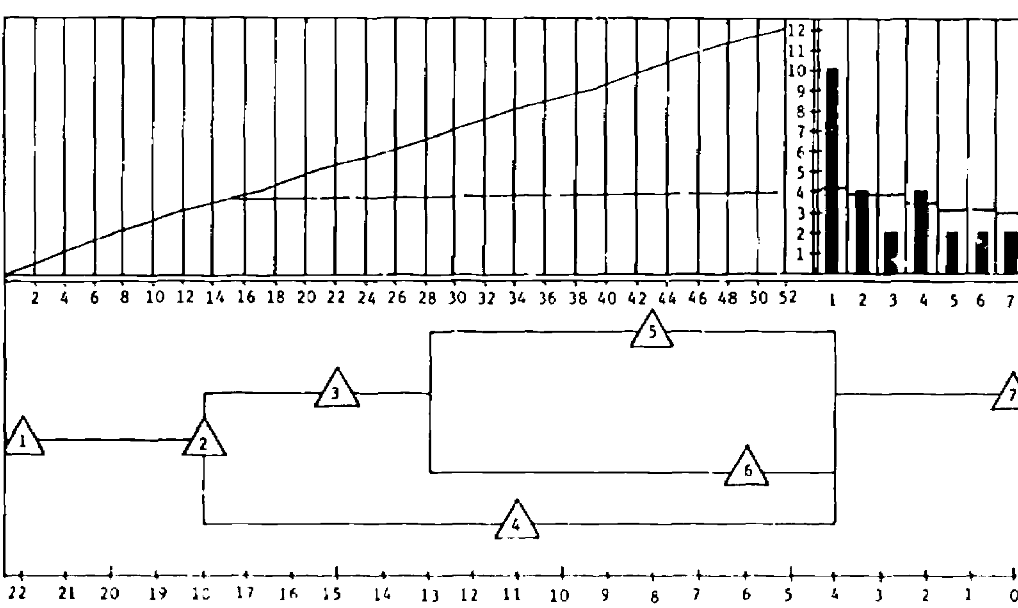

Fig. 30--Completed LOB

the performance flow.

As a reporting medium, LOB charts indicate status of individual milestones at any given point in time. They aid management in determining effectiveness of performance by comparing planned performance with actual achievement.

Like PERT, LOB techniques assist in identifying problem areas prior to their "becoming a disaster" and permit managers to take corrective action. Networks indicate to management those areas where decisions may be required. The tool itself does not do the work; it can only identify a point where decisive action is needed. Management must make the decisions. The benefits of network-based plans and controls accrue from recognition of need for action and initiation of action by management in those areas that require attention if program objectives are to be achieved (Figure 31).

The interim steps in an integrated LOB are displayed in a flow chart which represents a plan. Performance is monitored by comparing achievements with expectations at control points. The plan establishes logical control points, their interdependencies and interactions and arranges them in time-phased sequence.

Time phasing estimates in LOB are based on past performance. Unlike PERT estimates, LOB estimates require prior experiences that have determined temporal and technical requirements.

The principal difference between PERT and CPM techniques and LOB techniques is that PERT and CPM techniques are applicable tools for non-recurring research and development programs. LOB is more applicable in recurring programs of such significance that they warrant close attention by management.

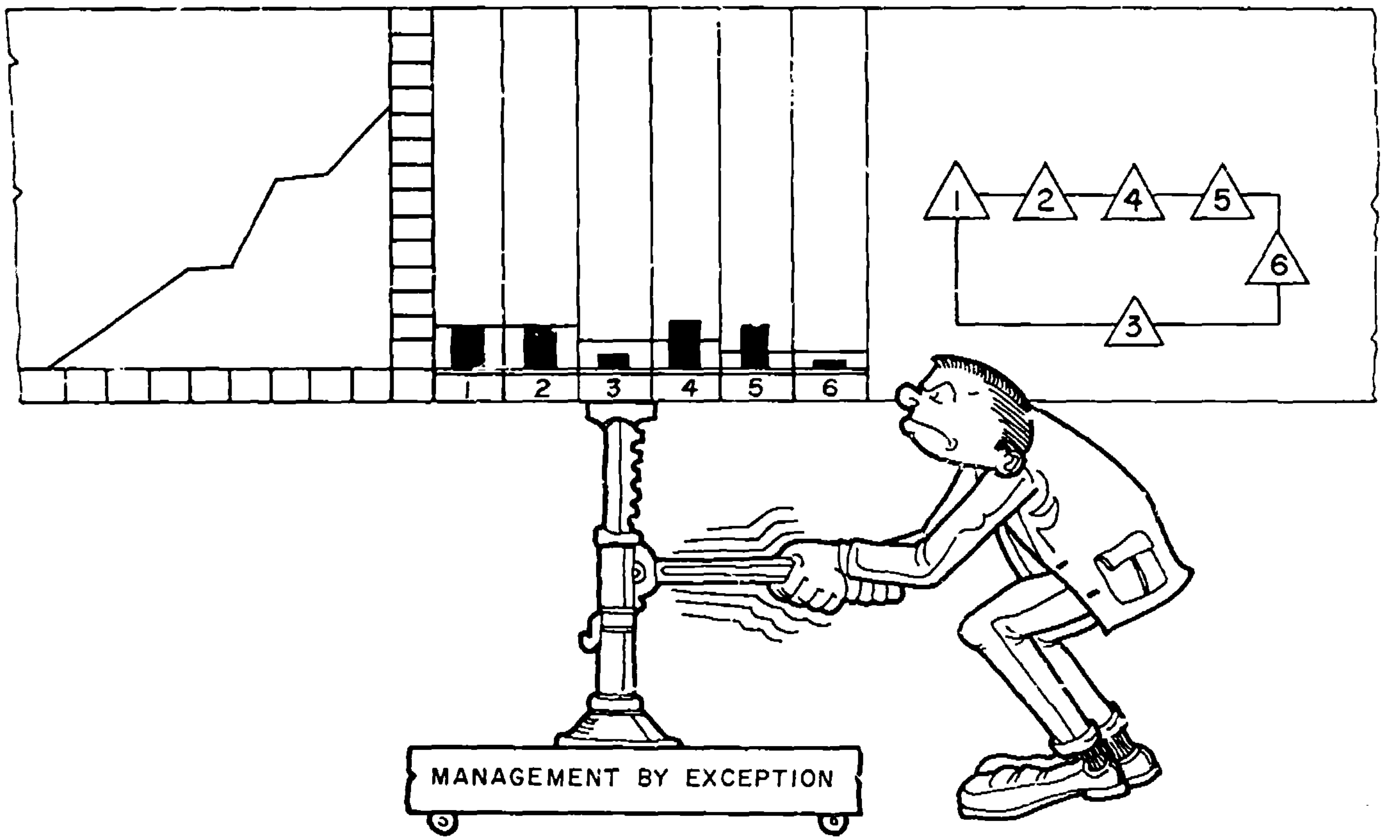

Fig. 31--A Benefit of LOB Networking

PERT/LOB Considerations

An innovation in network techniques, which combines the research and development planning elements of PERT with the recurring event control elements of LOB, is identified by the acronym PERT/LOB. PERT/LOB coordinates the major benefits of both techniques and represents an integrated planning discipline with emphasis on ease of control. PERT/LOB "broadens PERT by allowing inclusion of repetitive activities in the network."[31]

A logic-based, time-oriented network is fundamental in the PERT/LOB concept. The network flow is based on a WBS and FFBD. The nth level elements are further delineated in work packages which constitute the lowest level for planning and control.

Output reports in PERT/LOB use data from milestone reports, status reports and activity reports. The milestone report considers major events and their occurrence in relation to plan. Status reports indicate achievement at each control point and include revised projected realization dates for milestone occurrences. Activity reports relate planned to actual achievement by activity. Middle level management can use activity reports to advantage. Upper level management will find status and milestone reports valuable as control tools and for visual reports to policy-making bodies.

PERT/LOB is a technique which bridges the gap between development activities and completion of the program life cycle. It can be used by all levels of management for planning and control during the overlap between development and operation.

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[31]Peter P. Schoderbek and Lester A. Digman, "Third Generation, PERT/LOB," Harvard Business Review, September-October, 1967, p. 105.

Gantt Bar Charts

Gantt Bar Charts are process-oriented networks to plan and manage performance functions and/or tasks through time. They are time-oriented tools that can be used in controlling and evaluating performance. Primarily, they are used to measure progress in planned sequences of activities leading to the realization of objectives. Gantt Bar Charts enable processes to be made highly visible.

These charts are a simple means for representing schedules. They serve as tools to display over-all status of program progress. They are readily understandable. Gantt Charts are process oriented and are particularly useful for planning and managing manpower and machine processes.

Limitations include:

1. Interrelationships are not charted
2. Performance measurements during an on-going course of performance tend to be subjective.

Milestone Charts

Milestone Charts are product-oriented networks to plan and manage performance events. They can be detailed or they can be general in nature. Milestones are synonymous with events in PERT networks. "Milestones . . . are specific, definable tasks or accomplishments, recognizable at a particular instant in time."[32] Milestone Charts are like Gantt Charts since they do not readily pictorialize interdependent and/or sequential correlations. Summary Milestone Charts, with detailed PERT-type networks as back-up tools, may be useful to management as gross status-report media.

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[32]AMETA, PERT/COST & Control, p. 3-2.

Flow Charts

Flow Charts are process-oriented networks that depict event-activity-event relations through time.

Flow Charts combine the processes of Gantt and Milestone Charts. As an immediate predecessor to PERT and CPM, Flow Charts include provisions for detailing limited interrelations and interface junctions. Unlike PERT and/or CPM, however, Flow Chart development depends on data from previous experience. Flow Charts are more suitable in recurring programs that require close management attention. Temporal estimates used in the charts must reflect data accumulated from previous experience.

Figures 32, 33 and 34 are examples of Gantt, Milestone and Flow Charts. Differences in charting reflect either the process or product orientation. Similarities include time line provisions and methods of delineating functions. Data from previous experience are required to determine the period of time required to perform specific activities. Analysis is required to determine the activities that must be performed. Gantt, Milestone and Flow Charts are used for planning, controlling, evaluating and visually displaying recurring courses of performance. They also serve as reporting instruments that can be used in conjunction with other management procedures.

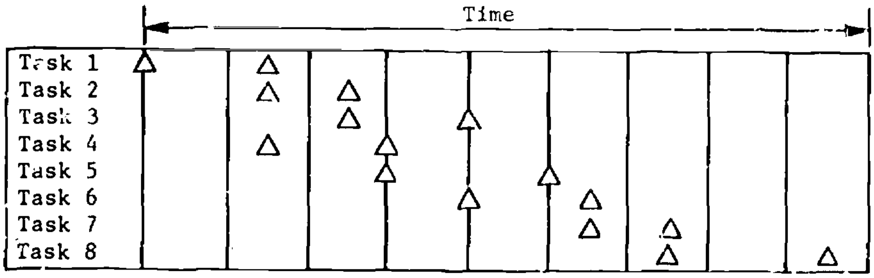

Fig. 32--Milestone Chart

The Gantt Chart is process oriented. Tasks are spread through time. Tasks are identical to activities as used in PERT/CPM.

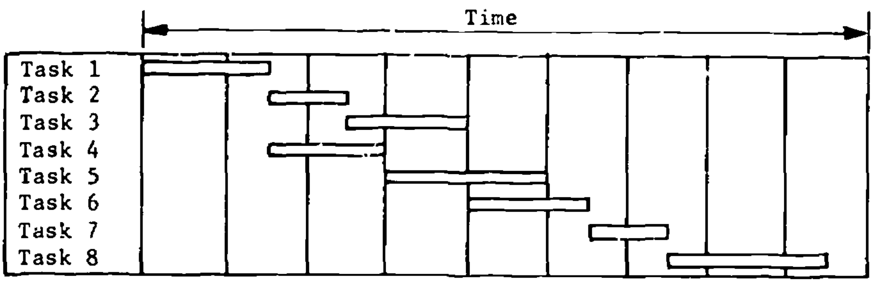

Fig. 33-- Gantt Chart

The Milestone Chart is product oriented. The starting and ending points of tasks are spread through time. Milestones are identical to events as used in PERT/CPM.

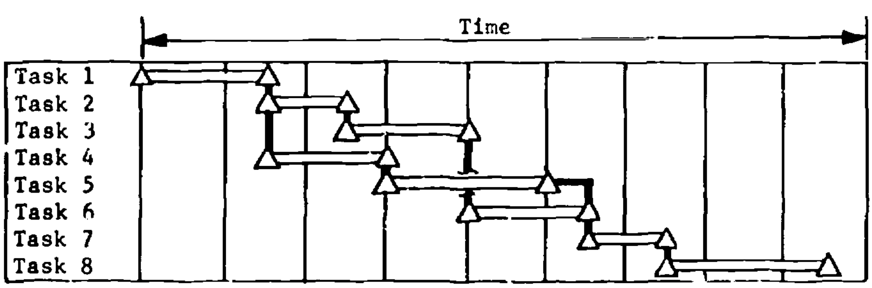

Fig. 34--Flow Chart

The Flow Chart is a direct predecessor of PERT/CPM. The Flow Chart is spread through time. Interdependencies and interactions are displayed.

CHAPTER VII

CONCLUSION

AMETA philosophizes:

> A management device or technique, regardless of the degree of sophistication, is only a tool and can never be a substitute for effective managers. The tool or technique must be an integral part of the entire management process. Logically, therefore, in any presentation of a management technique such as PERT, a sound concept of the management process must first be established.[33]

Network-based management procedures, including the FFBD, WBS and related work packages, offer advantages to educational managers as tools in long-range planning and in controlling performance activities. Probability factors can be projected. Feasibility of objective(s) achievement within temporal, cost and technical requirements can be determined. Reports can be designed to provide up-to-date information on cost and schedule status.

Summary and detailed networks may be designed for use by all levels of management. Criticality is easily determined and detail planning can be designed and managed for critical activities. Leveling is a management planning and controlling factor for allocating inputs to achieve desired/required program objectives. Consideration of criticality and need for resources management stem from event slack time and activity float time.

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[33] Ibid., p. 1-4.

Critical path(s), slack and float time determinations are possible after scheduling T_E (earliest expected time), T_L (latest allowable time) and t_e (expected elapsed time).

The five basic steps involved in PERT are:

1. Assess and organize program objectives
2. Plan the program
3. Schedule the program (considering resources availability)
4. Control the program
5. Replan (recycle) as required.

Scientific methods of problem solving result from "a systematic approach to definition of a problem and the development of a solution.[34] Basic requirements of network-based management techniques involve mathematics and, possibly, the use of computers.

Computer Requirements for Network-Based Management Procedures

Technical mastery of computer processes is not essential for their use in network management procedures. Speed, volume and cost are requisite conditions for computer applications.

PERT Guide for Management Use asks, "Can PERT be used without a computer? Definitely. . . . However, the use of EDP equipment speeds data processing for larger networks."[35]

Guidelines for computerization of networks involve:

1. Desired/required frequency of reports

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[34] Martino, Applied Operational Planning, p. 13.

[35] PERT Coordinating Group, PERT Guide for Management Use, p. 10.

2. Desired/required configuration of reports

3. Duration of applied program

4. Cost required for application

5. Availability of required facilities

6. Program complexity.

NASA-PERT Fundamentals evaluate the need for data processing by stating: "No general formula can be given, since each factor will vary with each particular situation."[36] Computation of t_e, T_E, T_L, Slack, Float and Critical Path(s) can be made either manually or by using a computer. Computer programs have been developed and are available in either program-oriented Common Business Oriented Language (COBOL) or Formula Translation (FORTRAN) language for these determinations.

Computers can also discover logic flaws (e.g., closed loops in the network). As a control mechanism, EDP compiles reports more quickly than such reports could be compiled manually. In complex programs involving 200+ events and/or extensive expenditure forecasts, performance measurement probably will require quick feedbacks of status. Computers, by nature of design, offer advantages in providing quick feedback data. Decisions to utilize EDP as a tool require objective evaluation as well as economic justification by management. To iterate: Literature surveyed consistently reports that while computer utilization may be extremely valuable, it is not essential to network-based management procedures.

[36] PERT Orientation and Training Center, PERT Fundamentals, Vol. II, p. 86.

PERT Uses for Educational Programs

Programs or situations, where the "PERT" PERT/COST technique has been particularly useful include planning, scheduling and controlling:

1. School construction
2. Curriculum planning
3. In-service training programs
4. School board meetings
5. Master plans (short, intermediate and/or long term)
6. School publications
7. Implementing new and/or reorganized business operations
8. Planning for opening/closing of school year
9. Installing a system computer center.

PERT is best utilized if it is applied at the beginning of a program lifecycle, but it can be introduced at any phase, particularly if critical scheduling and/or cost problems are evident. Programs of large size and/or complexity may, in fact, require the use of networking for strategic management and operational planning and control. Allocation and scheduling of inputs are necessary to achieve desired/required performance end-item results for minimal expenditure(s). As a management tool, network construction and utilization also aid decision making if they are used in forecasting and/or simulating the effects of alternatives. They assist decision makers in determining where they are going. Networks aid educational leaders in visually forecasting potential problem areas. Management can then initiate corrective action before a problem becomes a disaster. Two basic objectives of network use are (1) utilization of management by exception principles and (2) increased delegation of responsibility and authority.

A requisite step in the use of network-based management procedures is a management-issued statement endorsing appropriate network techniques and acknowledging them as "authorized technique(s) for program planning and control."[37]

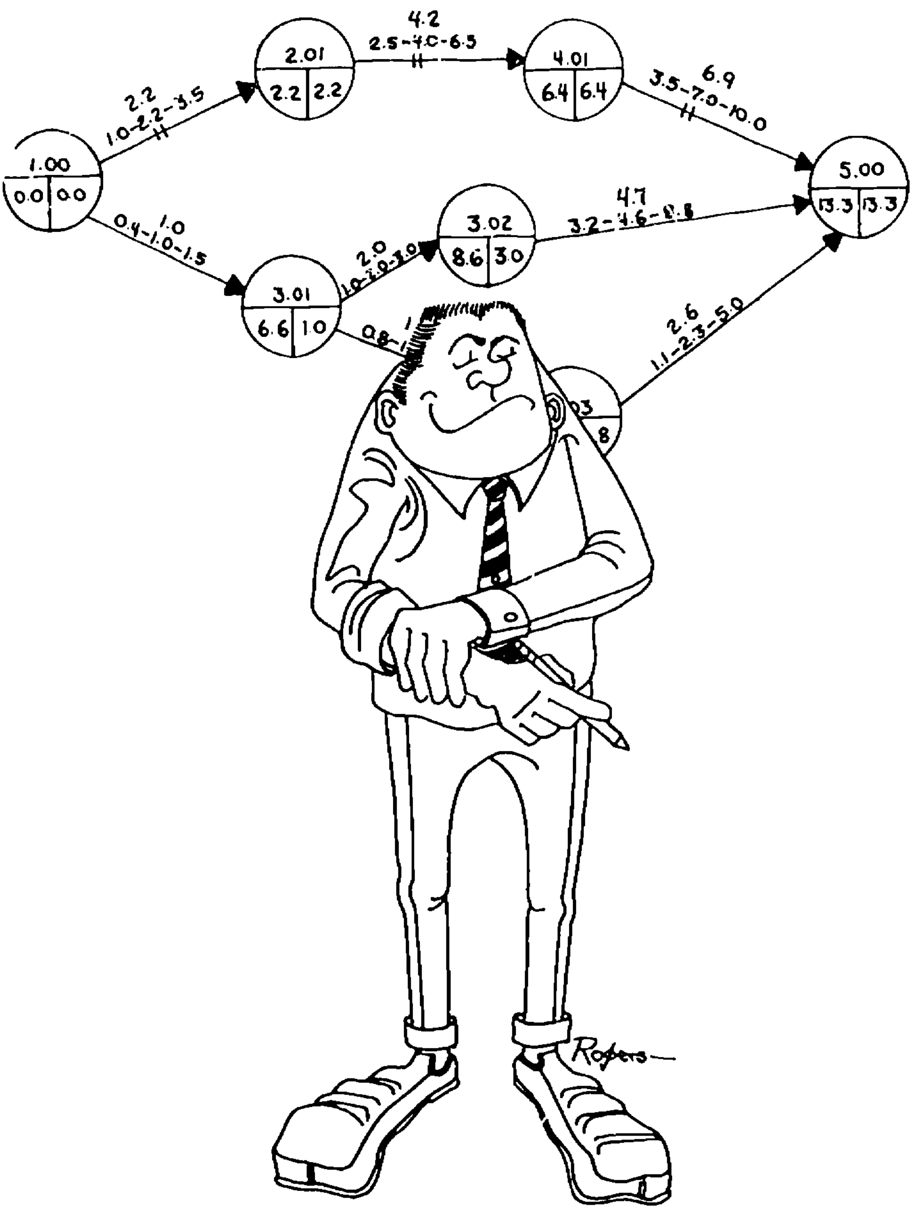
Conceptual adaptability and simulation of alternative choice-consequences are prime advantages offered by networks that are based on system analysis principles. New school construction and other complex and/or critical programs which involve multitudinous and complex interrelationships can be planned and managed by utilizing PERT and/or other graphic techniques. Network design improves discrimination and reasoning as well as sharpens intuition and judgment. Network-based management procedures not only permit, but they also require, continuing revision and re-analysis. Complex programs require continuing evaluation and frequently require replanning. PERT/CPM are, by definition, geared toward this end.

Implications for Change

An adoption decision to use network-based management procedures in planning, controlling and evaluating performance and progress toward goal attainment may or may not require a change in managerial and/or organizational philosophy. Management must secure a broad base of involvement and participation before the tools can be utilized effectively. In-service training programs for managerial and operational staff members are required. As personnel develop an understanding of network-based management procedures, they begin to appreciate the need for better planning, control and evaluation

[37]PERT Coordinating Group, PERT Guide for Management Use, p. 42.

procedures. As they work with network-based procedures, they begin to realize their value and limitations as practical management tools. The most important aspects of adoption are a well planned and carefully implemented in-service education program and managerial actions that support adoption of network-based procedures.


1.00
0.0
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4.01
6.4
6.4
5.00
13.3
13.3
3.02
8.6
3.0
3.01
6.6
1.0
2.2
1.0-2.2-3.5
4.2
2.5-4.0-6.5
6.9
3.5-7.0-10.0
1.0
0.4-1.0-1.5
2.0
4.7
2.6
1.1-2.3-5.0
Rogers

APPENDIX A

GLOSSARY

GLOSSARY

Terminology	Definition
Account Code Structure	. A programming numbering schema to plan, accumulate and control direct costs related to a program . Used for cost analysis . Separate assigned numbers for each functional area of responsibility and further broken down into sub-element numbers within work packages
Activity	. A performance function or task . Utilizes information, energy and resources and represents an active, mandatory task between two events to achieve successor event occurrence; (e.g., Plan Agenda, Identify Alternatives, Perform Analysis, Make Decision, etc.)
Assess	. Identify, analyze and define
Appraise	. Analyze and valuate

Control	. Ability to measure performance achievement compared to plan and to regulate operations
	. Utilizes management by exception principle
	. Proportionate to communication effectiveness
	. Tests
	    . Reliability
	    . Validity
	    . Relevancy
	    . Feasibility
	    . Acceptability
	    . Functional relativity of network and communication

Critical Path (CP)	. Longest (time-oriented) path(s) of sequence(s) or activities in a network

	. A path is critical when $T_E = T_L$ and there is zero or negative float time
Critical Path Method (CPM)	. A networking planning technique that is . event-oriented . computer-oriented and used to plan and manage critical and/or complex programs of planned change
	. Used interchangeably with PERT
	. Generally uses one time estimate
Dummy	. An activity that is used for clarity of communications or to depict a logical dependency
	. Does not utilize information, energy nor resources
Event	. A specific, definable point in time, an occurrence
	. Consumes neither resources nor energy
	. Must precede and/or succeed activities; (e.g., Start Planning, Start Assessment, Complete Testing)
Float	. A positive, negative or zero temporal quantity related to activities
	. T_L of succeeding event, minus T_E of preceding event, minus t_e of referenced activity
	. Used to schedule resources to minimize non-productive utilization
Function	. An organizational activity
	. Required, active performance unit
Functional Management	. Personnel responsible for managing organizational activities
	. Personnel who must make activity-time estimates for a network

Gantt Bar Chart	. A process-oriented networking technique to plan and manage performance functions and/or tasks through time . Means of displaying planned schedule and status of progress
Interface	. Transfer of constraining or limiting event from one area or responsibility to another . Displays interrelations between events
Job Account Code	. Assigned job and task-charge number for budgeting, measuring and controlling tasks within a work package
Lead Time	. Time required after start or completion of one activity before a concurrent activity can be started or completed . Requires time estimates by responsible manager
Leveling	. A management technique to minimize non-productive resources utilization in program scheduling . Consideration when scheduling priorities . Dependent upon "float" determinations
Line of Balance (LOB)	. A product-oriented networking technique that enables management and subordinates to visualize "where they are" and "where they should be" for any given milestone at any given time . Applicable to recurring-type programs where control is essential but research and development activities are minimal
Management by Exception	. A system of information gathering and processing for the purpose of problem finding that enables . Application of management energies to those areas of

Planning, Evaluation and Review Technique (PERT)	. An activity-oriented time and cost-phased network that displays objectives, functions and tasks and their prerequisite occurrences arranged logically in sequence and/or parallel
	. Based on detailed analysis and delineation of desired objectives
	. Inculcates the processes of planning, organizing, directing and controlling
	. Depicts interrelationships, interdependencies and integration
	. Permits determination of probability factors and feasibility of schedule
Reports	. Feedback control mechanisms to identify performance deviations that . Aid choice-consequence determination of possible alternatives . Measure planned against actual achievement and expenditure . Enable measurement of effectivness and efficiency of system . Assist in evaluating problems
Resources	. Five in number (m^4t) . Men . Money . Machines . Materiel . Time
Rolling Wave	. Process by which immediate future is planned in greater detail than long-range future
	. Continuous updating (as time progresses) incorporates detail as need develops

	program (as determined by network flow and control procedures) which require special attention
	. Requires clear and succinct identification and communication of requirements, specifications and objectives
	. Depends upon clarification of responsibility and authority assignments
Milestone Chart	. A product-oriented networking technique to plan and manage performance events
	. Milestones are considered as are events in PERT Charts
Network	. A networking flow chart depicting event-activity-event sequences and relations
	. Based on an analysis of performance functions and tasks
	. Integrates interdependencies, interrelations and interfaces
Planned Value of Work Accomplished (PVWA)	. A PERT/COST technique to plot relations between planned performance benefits and actual performance results
Planned Value of Work Scheduled (PVWS)	. A PERT/COST technique to plot relations between planned performance and estimated cost
Planning	. The conscious determination of alternative courses and/or methods of action for accomplishing a valued target in light of relevant situations and conditions, future probabilities and perceptions of consequences to be experienced
	. Involves assessment, evaluation, organization and communication of program objectives

Scheduling	. Time phasing of a network flow diagram to plan performance functions and/or tasks through time
	. Related to PERT, the following processes must be performed
	  . Determine activity-oriented expected elapsed time (t_e)
	  . Determine event-oriented earliest expected time (T_E)
	  . Determine event-oriented latest allowable time (T_L)
	  . Determine event-oriented slack time
	  . Determine activity-oriented float time
	  . Determine critical path(s)
	. Bridges the gap between planning and implementation

Simulation	. Assessment, evaluation and selection of planned alternatives to determine most advantageous course of action through choice-consequence relations comparisons
Slack	. A positive, negative or zero temporal quantity related to events . Indicative calculation of criticality . Positive slack indicates "spare time" . Negative slack indicates "crisis" and a limiting event . Zero slack indicates "criticality"
Status	. Objectively derived indications of actual achievements compared to planned performance
Task	. An individual performance activity
Work Breakdown Structure (WBS)	. A sub-setting framework which is developed during analysis from

objective(s) backward to lowest sub-units of work required for planning and control

- Based on analysis, logic principles, simulation of alternatives choice-consequence determinations, and selection
- Basis for network graphic flow and cost, and schedule status summarization
- Aids identification and organization of objectives
- Groups of activities, functions and sub-level objectives which, when accomplished in a simulated and priority-arranged sequence, lead to desired/required objective achievement

Work Package

- Sets of related tasks that are detailed in analysis of low-level activities in a Work Breakdown Structure
- Plan against which performance measurement is possible for detailed tasks
- Represents n + 1 level of detail
- Fundamental element on which PERT/COST systems are based
- Serves as "lesson plans" to plan, guide, measure and control work effort

APPENDIX B

NETWORK SYMBOLS

APPENDIX B

NETWORK SYMBOLS

a	Optimistic time estimate--indicates one percent chance for success
b	Pessimistic time estimate--indicates one percent chance for success
m	Most likely time estimate--indicates fifty percent chance for success
T_E	Earliest expected time (date) for an event to occur
T_L	Latest allowable time (date) for an event to occur
t_e	Estimated expected elapsed time required to perform a network activity
○	A network event
⟶	A network activity
—‖→	Critical network path--sometimes the other symbol (⟹) is used
◌ (dashed circle)	A dummy or constraining or limiting network event
- - - →	A dummy or constraining or limiting network activity
⧈	A network interface event
◎	A network end event
△	A network milestone
Ⓐ	A mandatory "and" gate used in FFBD to denote more than one simultaneous and mandatory course of action
Ⓞ	An "or" gate used in FFBD to denote a point in a network where a choice must be made between alternative courses of action
WBS	Work Breakdown Structure
FFBD	Function Flow Block Diagram

APPENDIX C

PERT AND CPM PRACTICUM EXERCISES

PERT AND CPM PRACTICUM EXERCISES

The following practicum exercises have been designed for reader use as an aid in developing such network-based management skills as:

1. Developing a network flow diagram
2. Determining the activity-oriented t_e values
3. Determining the event-oriented T_E and T_L values
4. Determining event slack time values
5. Determining activity float time values
6. Determining critical network paths
7. Scheduling and allocating available inputs.

Requirements for the following practicum exercises include that of working within the framework of supplied information. No assumptions need be made. Time to complete the exercise is not to be a limit.

Indicators of demonstrable competencies in exercises 1 through 6 will be based on accuracy of solutions. Each participant is expected to evaluate his degree of conceptual comprehension. Indicators of skill development in Exercise 7 will be based on individually developed solutions and capabilities to explain and "sell" the solutions developed to a group of peers.

The following practicum exercises are included:

1. Developing a network flow diagram using activity-event relations detailed in the exercise
2. Determining the activity t_e using the formula provided in the exercise
3. Determining event T_E and T_L values using the t_e values calculated in Exercise 2
4. Determining event slack time using T_E and T_L values derived in Exercise 3
5. Determining activity float time using t_e, T_E and T_L values calculated in Exercises 2 and 3 respectively

6. Determining network critical path(s) using the time values calculated in Exercises 2 through 5

7. Using a mandated latest allowable (T_L) event time for the end event:

   7.1 Determine

   . whether or not the requirements are feasible

   . how to manage the program

   . what "trade-offs" would and/or should be made

   7.2 Explain

   . how "trade-offs" were made

   . the implications and/or expected results of each

   . what evidence and steps were employed in reaching conclusions.

The objective of these practicum exercises is to develop skills in the use of network-based management procedures. Accordingly, practicum exercises were selected rather than exemplary problems which would require extensive analysis. Each practicum exercise facilitates development of network-based management skills using limited and simplified variables.

Exercise 1

The following activity-event relations were determined as necessary in achieving an objective. Event A is the beginning event and event J is the end event in a series of events required to achieve the objective. Each participant is expected to develop a network flow diagram from the following delineated activity-event relations:

Event A, the beginning event, is succeeded by activities A-B, A-C and A-D

Activity B-D must be completed before event D can occur

Activity C-E succeeds activity A-C

Activities D-F and E-F must be completed before event F can occur

Activity F-H succeeds event F but precedes Activity H-I

Activity F-I succeeds event F

Activity E-G succeeds activity C-E but precedes activity G-J

Activity I-J succeeds event I.

Each participant is expected to develop a network flow diagram using the foregoing data. No dummy events and/or activities are required to complete the assignment.

Exercise 2

Using the formula:

$$t_e = \frac{a + 4m + b}{6}$$

1. Determine the expected elapsed time (t_e) for each activity detailed in the network flow diagram developed in Exercise 1. The following table of activities and most likely (m), optimistic (a) and pessimistic (b) times are given.

Activity	a	m	b	t_e
A-B	2.0	2.5	4.0	
A-C	0.2	1.0	1.5	
A-D	0.5	1.5	2.5	
B-D	1.0	1.8	2.5	
C-E	1.2	2.0	3.5	
D-F	0.5	1.6	3.0	
E-F	1.5	2.2	3.0	
F-H	0.2	1.0	2.5	
F-I	0.2	0.5	1.6	
H-I	0.6	1.2	2.0	
E-G	1.2	2.0	3.5	
G-J	0.8	1.5	3.0	
I-J	1.0	3.0	4.5	

2. Detail calculated t_e values on the network flow diagram developed in Exercise 1.

Exercise 3

Using the activity t_e values determined in Exercise 2, calculate each event's earliest expected time (T_E) and latest allowable time (T_L). The T_E value for event A is 0.0.

Exercise 4

Using event T_E and T_L time values determined in Exercise 3, calculate event slack time using the equation:

$$\text{Event Slack Time} = T_L - T_E$$

Exercise 5

Determine activity float time values using the t_e values calculated in Exercise 2 and the T_L and T_E values determined in Exercise 3. The following formula will be used:

$$f = T_L - T_E - t_e$$

Exercise 6

Determine the critical path(s) of the network. The critical path is determined when event T_E time values are equal to T_L time values. Thus, along the critical path there is zero event slack time and zero activity float time.

Exercise 7

The manager has dictated that event J must occur before 10.0 weeks elapse. This requirement emphasizes the need to manage available inputs (no additional resources will be made available) to reduce the objective's achievement time from 11.4 weeks to 10.0 weeks. Assume that the work required to perform critical path (CP) activities will be completed by one group and the non-critical path work required will be completed by a separate but related group.

1. Determine whether the 10.0 week time requirement is feasible.
2. If the requirement is feasible, develop a list of proposed management activities.
3. Designate what trade-offs can be made.
4. Specify the bases for determining trade-offs.
5. Explain implications and/or expected results of trade-offs.
6. Specify what evidence and steps were employed in reaching the foregoing conclusions.

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