PERT AND PERT/COST: A STUDY AND EVALUATION OF ITS INDUSTRIAL UTILIZATION IN ALABAMA

BY:

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J F B.
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CHAPTER I

INTRODUCTION

The past decade has witnessed a tremendous growth of management techniques for use in planning and controlling complex defense and industrial projects. Business has been searching for more realistic and reliable methods to cope with the ever-increasing problems of managing intricate projects in a more sophisticated manner. Program Evaluation and Review Technique (PERT) is one of the most useful and familiar techniques to emerge in the search for a dependable management tool.

PERT is a new management planning and analytical tool which makes use of a graphic display called a network. This network is used to depict the essential relationships between the various events comprising complex research, development, production, and distribution

programs. The estimated costs (PERT/Cost)[1] can be added to the network for more effective control of cost through efficient utilization of resources among the alternative activities. These activities, occurring between the interrelated and complicated events of a total network system, have a remarkable similarity to standard costs in a job order cost system.

From its beginning in 1958, PERT (developed by the U. S. Navy Special Projects Office) has gained wide acceptance in Canada, Great Britain, Europe, and the Far East, as well as the United States. The construction of pavilions in Montreal, Canada, for the World's Fair in 1967, made extensive use of networking techniques.[2] The Defense Department of the United States was so impressed with the technique that it required all

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[1]Some authorities use PERT/Cost as an all-inclusive term for time and cost. However, the term PERT is used in this study to include only the time element; PERT/Cost is used to mean only the cost element of a network; and, PERT and PERT/Cost is used herein as a singular management planning and analytical tool.

[2]"Expo '67 Follows 'Critical Path,'" Business Automation, Vol. XIV, No. 3 (March, 1967), 40.

prime contractors to use PERT in the mid-1960's. The Department has since acquiesced and now leaves the decision to the discretion of individual project managers as to whether or not to require prime contractors to use PERT.[3]

For the manager to realize the full value of PERT and PERT/Cost, this new management technique must be integrated with the company's accounting system.

> It is clear that PERT/Cost is not intended as a complete accounting system and, in fact, relies heavily upon a sound underlying cost system to maximize the usefulness of the technique.[4]

Most accounting systems must be altered to make full use of PERT/Cost. The amount of alteration depends upon the structure of the cost accounting system in use by the company. "The effectiveness of using PERT/Cost depends to a great degree upon the sophisti-

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[3] NASA/MSFC PERT TIME: Operations Manual (Huntsville, Alabama: George C. Marshall Space Flight Center, National Aeronautics and Space Administration, 1965), Sec. I, pp. 1-3.

[4] Wilbur R. Ross, "Accounting Aspects of PERT/Cost," Management Accounting, Vol. XLVIII (April, 1967), 49.

cation of the basic cost accounting system in use."[5] Most of the PERT/Cost output reports are prepared, with little change, from information available in the regular accounting system; the primary change is cost breakdown and coding.

Purpose of the Study

The purpose of this research study is to:

1. Investigate the extent PERT and PERT/Cost is being used in the various industries in Alabama;
2. Evaluate PERT and PERT/Cost feasibility in the various industries;
3. Determine and assess procedures for estimating cost used in the PERT network;
4. Analyze and evaluate the influence and the effect that accounting data and accounting systems have upon PERT/Cost programs; and,
5. Identify and elaborate on major factors

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[5] *Ibid*.

affecting the implementation and operation of PERT/Cost.

An investigation into the extent of usage by the various industries is appropriate and timely since PERT has appeared in the literature of accounting for approximately ten years, and PERT/Cost for approximately six years. The results of this investigation provide insights into the areas of business where PERT and PERT/Cost have enjoyed acceptance and success. Also, pointing out areas where these techniques have been attempted with little or no success should be of interest and value. The success of PERT and PERT/Cost depends not only upon the types of projects to which it is applied, but also upon many other factors, among which are awareness and acceptance by management; validity of cost estimates; and extent and depth of planning.

A review of the literature indicates that the use of PERT and PERT/Cost is not as prevalent in non-defense projects as it is in defense projects. This

condition is understandable since the technique was first developed and used primarily for large defense projects. However, an increasing number of nondefense tasks are making excellent use of PERT as well as PERT/Cost.

PERT/Cost is lagging behind PERT use. Certain reasons for this lag are apparent: (1) PERT/Time was introduced first and as it is an outgrowth of older scheduling devices, managers were more knowledgeable of its capabilities and applications; (2) time estimates showed a higher degree of refinement than cost estimates, making for greater acceptance and application of the time element; (3) cost estimates were more difficult to make with an acceptable degree of accuracy; and, (4) many managers were reluctant to rely upon accuracy as a basis of evaluating their performance. This study investigates other indications of the lag in the use of PERT/Cost and the factors which account for this lag.

Need for the Study

Recent accounting publications have contained numerous articles on PERT and PERT/Cost. Most of these writings describe small segments of the technique with little emphasis or explanation of how the entire process is formulated and operated. Still other works merely relate a company's experience, with limited concentration on the total technique. This study, however, presents detailed techniques of PERT and PERT/Cost, with a supporting survey of businesses to indicate adaptation to various business enterprises and application to different type projects in actual practice.

The survey of business in the sample industries should be valuable not only to managers who have used PERT and PERT/Cost, but also to managers who have never used this technique yet contemplate its use in the future. The results of the survey should provide managers with additional knowledge in considering the probable degree of success in the application of PERT and PERT/Cost to company activities. A manager becomes

more valuable to his company in knowing when and how to implement PERT and PERT/Cost.

Research Methodology

A search was made of the literature pertaining to PERT, PERT/Cost, and the predecessors of these management techniques. Unclassified manuals, pamphlets, and unpublished papers were acquired from the U. S. Army Missile Command and the George C. Marshall Space Flight Center at Redstone Arsenal, Alabama. Materials were made available in the operating offices of the Defense Department and certain private companies. This material (enlarged network system, input reports, output reports, operation manuals and instructions) is not of a classified nature, but it is unavailable for distribution. Approximately twenty personal interviews were held with officials of governmental units and private companies using PERT and PERT/Cost. These interviews provided information on the actual operations of PERT and PERT/Cost.

A listing of the 100 largest companies in each

of the eight major industrial classifications in the State of Alabama provided the universe for a statistical study.[6] A questionnaire survey was mailed to a random sample of 25 companies in each industrial classification. Follow-up interviews were held with officials of companies using PERT or PERT and PERT/Cost.

Scope and Limitations of the Study

Analysis of statistical material reported in this research study is limited to a tabulation and summarization of information received from replies to the survey questionnaire. This method of presentation of materials supports the purpose of the study and is sufficient to justify the conclusions formed.

The survey of the extent of PERT and PERT/Cost use is limited to companies in the eight major indus-

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[6]The eight major industrial classifications, taken from an Index of Divisions and Major Groups, Industrial Classification, State of Alabama, 1957, are: Mining; Contract Construction; Manufacturing; Transportation, Communication, and Utilities; Wholesale and Retail Trade; Finance, Insurance, and Real Estate; Services; and Government.

trial classifications in the State of Alabama. No attempt is made to provide definitive answers to all the problems encountered in the use of PERT and PERT/Cost.

Organizational Plan

Chapter I presents an introduction into the areas of PERT and PERT/Cost. This introduction covers the purposes of the research study, includes a statement of the need for the study, and outlines the research method.

To provide essential background material, the first part of Chapter II is devoted to a description of the origin of PERT. Its evolution reveals similarities with other known management techniques. Illustrations are provided to clarify the objectives and operations of the networking tool. The latter part of Chapter II introduces cost to the time network, explores the origin of PERT/Cost, describes the cost breakdown procedures, illustrates how estimated costs are applied to the time network, and sets forth the control function

provided by PERT/Cost.

Other networking techniques are presented in Chapter III since similar techniques have been introduced after the advent of PERT. These techniques are compared with PERT to point out similarities as well as dissimilarities. Some of these other networking techniques may be more appropriate to a specific project than PERT. Consequently, the use of any given technique is left to the discretion of the individual project manager.

The results of the questionnaire survey are presented in Chapter IV. Also, the method of determining the recipients of the questionnaire is described. The information received is tabulated and evaluated. Extent of PERT and PERT/Cost use by companies in the various industries in Alabama is presented and conclusions are drawn from the results of the survey.

Chapter V identifies and describes factors affecting the implementation and operation of PERT and PERT/Cost techniques in business. The necessity for,

and use of, pertinent accounting data is discussed and analyzed. Deficiencies in accounting data and accounting systems are noted and recommendations are made for more effective utilization of accounting records in PERT/Cost projects.

A summary of the findings of the research study is presented in Chapter VI. Conclusions are drawn from the study and recommendations are given for additional research areas of PERT and PERT/Cost.

The Appendices contain: a copy of the survey questionnaire with the two accompanying letters (Appendix A); examples of output reports discussed in Chapter IV (Appendix B); and a glossary of symbols and terms used in the study (Appendix C).

CHAPTER II

THE ORIGIN, STRUCTURE, AND REFINEMENT OF PERT AND PERT/COST

The Background and Use of PERT

PERT is not an entirely new concept as a planning and analysis technique, but it represents a synthesis of the best concepts of various other management networking tools. The importance of PERT lies in its demand for thorough planning and its highlighting of exceptions to any given plan. The advantages of PERT are clarified when some of the finer points of the networking are detailed, when the time element is added, and when the "most critical path" is identified. The prime contributors to PERT are Gantt charts, milestone charts, flow process diagrams, and line-of-balance analysis.

Origin and Structure of PERT

Gantt charts.--A forerunner of PERT is the Gantt chart, one of the best known schematic and scheduling techniques. Henry Gantt used horizontal lines to reflect the relationship of activity to time, as well as the interrelationship of activities in the entire project.[1] A major defect in the Gantt chart is that the interrelationship of activities is not clearly established (Fig. 2-1).

The milestone chart.--This type chart goes one step further, breaking down each task into even smaller segments. The milestones are specific accomplishments recognizable at a specific time. The milestone technique is not applicable for rigorous planning and control of complex projects because it does not portray the time relationships between the milestones in a clear and concise manner. In the PERT network, milestones are synonymous with events.

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[1] Gabriel N. Stilian, et al., PERT: A New Management Planning and Control Technique, AMA Management Report No. 74 (New York: American Management Association, 1962), p. 3.

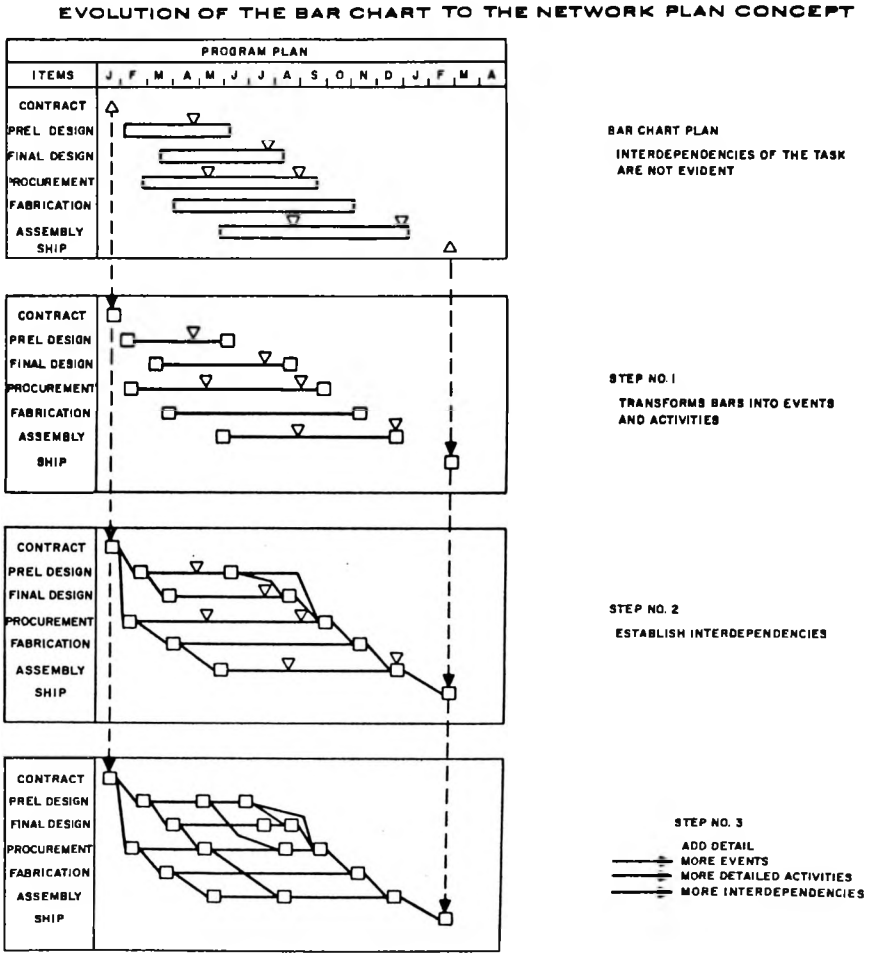

Fig. 2-1.--Evolution of Gantt Chart to PERT Network.

Source: Bruce N. Baker and Rene L. Eris, An Introduction to PERT - CPM (Homewood, Illinois: Richard D. Irwin, Inc., 1964), p. 54.

Flow process charts.--Frank Bunker and Lillian Moller Gilbreth, as well as other management scientists, are credited with the design and development of flow process charts. These charts portray the sequential relationship of activities in a project. They present graphically the orderly sequence in which individual tasks must be performed, but the process fails to take into account the time element. This lack is detrimental to effective management of complex projects.

Line of balance analysis.--This technique is a combination of the flow process chart and the Gantt chart in that it portrays the sequential relationships and the time relationships of activities. These activities are shown on a time scale, in sequence and according to their leadtime relationships to the end objective. However, the line-of-balance technique does not show when each activity is to be started or the constraints upon starting an activity. Line-of-balance is best suited for projects of a repetitive nature; therefore, the technique is not a substitute for PERT.

In the mid-1950's, E. I. du Pont de Nemours and Company, together with Sperry-Rand Corporation, jointly sponsored a venture into the application of a network or arrow diagram to an engineering project. The objective was the improvement of planning, scheduling, and coordinating of du Pont's engineering projects. The network or arrow diagram technique was tried first in 1957, and the resulting Critical Path Method (CPM) was pronounced successful.[2] CPM is concerned with only one of many possible paths in a network and restricts itself to the use of a one-time estimate, the expected time.

In 1957, the U. S. Navy Special Projects Office selected a research team to develop a program evaluation technique to aid in the Fleet Ballistic Missile Weapons System. This research team was composed of representatives from the Special Projects Office; the

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[2]Bruce N. Baker and Rene L. Eris, An Introduction to PERT - CPM (Homewood, Illinois: Richard D. Irwin, Inc., 1964), p. 1.

Lockheed Missiles and Space Company; and the management consulting firm of Booz, Allen, and Hamilton. Through the team's efforts, the Program Evaluation and Review Technique (PERT) was developed and implemented as a research and development project management tool for the Navy's Polaris Program.

> PERT was not designed to replace management or methods of planning presently in use, such as Gantt charts (bar charts), milestone charts, and the line of balance techniques, but rather it was designed to supplement these planning tools and to give management better information upon which to base its decisions.[3]

Objectives, Advantages, and Disadvantages of PERT

As originally proposed, the specific objectives of PERT were:

1. To develop methodology for providing the Director of the Special Projects Office (SP) and the top SP managers with continuous program evaluation, i.e., the integrated evaluation of

   (a) the progress to date and the progress outlook toward accomplishing the

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[3] *Ibid*.

objectives of the Fleet Ballistic Missile (FBM) program;

(b) the changes in the validity of the established plans for accomplishing the program objectives; and,

(c) the effect of changes proposed for established plans.

2. To establish procedures for applying the methodology as designed and tested to the overall FBM program.[4]

Since its introduction in 1958, PERT has provided for more rapid and better progress in the development of management information and control systems. PERT is a management-by-exception system, with strong emphasis on the "critical" items of a project. The time required to complete a project is normally dependent upon only a small portion of the total activities involved. These activities, which make up the "critical path" of a network, are the principal analytical tools of PERT. Therefore, management can concentrate upon

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[4] U. S. Department of the Navy, PERT Summary Report, Phase 1 (Washington, D. C.: Special Projects Office, Bureau of Naval Weapons, 1958), preface.

this critical path of activities and thus make necessary reallocation of resources for optimum completion of a project.

PERT systems have attracted widespread interest (as revealed in the literature), and are being implemented in the defense industry; the construction industry; and to a lesser extent, in other industries such as the entertainment industry and service-type industries. An obvious explanation of the wider use of PERT in the defense and construction industries is that the system was primarily designed for one-time projects.

Basically, PERT is a management planning and analysis tool which makes use of a graphic display called a network to portray essential relationships between various tasks comprising a complex research and development project.[5] PERT's prime objective is to provide management with an integrated system of forced planning and evaluation, with timely information on any departure from such a plan.

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[5]Baker and Eris, op. cit.

PERT has withstood certain drawbacks throughout its approximate ten years of existence. These setbacks do not necessarily imply inherent weaknesses, but are due to the fact that the technique was forced upon many companies. The Defense Department made the use of PERT a requirement of all prime contractors holding defense contracts. Chapter I of this study points out that this authoritarian approach caused many managers to resist PERT, and with this resistance a number of projects have not been as successful as they possibly may have been otherwise. However, the Defense Department has relaxed its requirements on the exclusive use of PERT and it now authorizes each project manager to determine and specify the techniques (if any) that must be used in a defense project. This relaxation of rules gives some relief, but many managers have already built up a bias against the use of PERT and are reluctant to participate in, or even promote its use on future projects. Additional factors affecting the implementation and operation of PERT and

PERT/Cost are enumerated and discussed in Chapter V.

Refinement of PERT as a Management Networking Tool

PERT effectively utilizes a sequential network consisting of all activities required for the accomplishment of a final objective. As shown in Fig. 2-2, each event represents a completed component of a project, with the event being represented on the network by a circle or square. Events do not require time or the use of resources, but represent meaningful accomplishments within the overall plan. They also signify the start or completion of one or more activities.

Events are usually identified by a number or short phrase of the work completed (Fig. 2-3). Activities are represented by lines connecting the various events. Such activities fall into two broad categories --"real" and "dummy." A real activity requires the use of resources and consumes time for its completion; a dummy activity is a constraint which represents the dependency of one event upon another event. Dummy

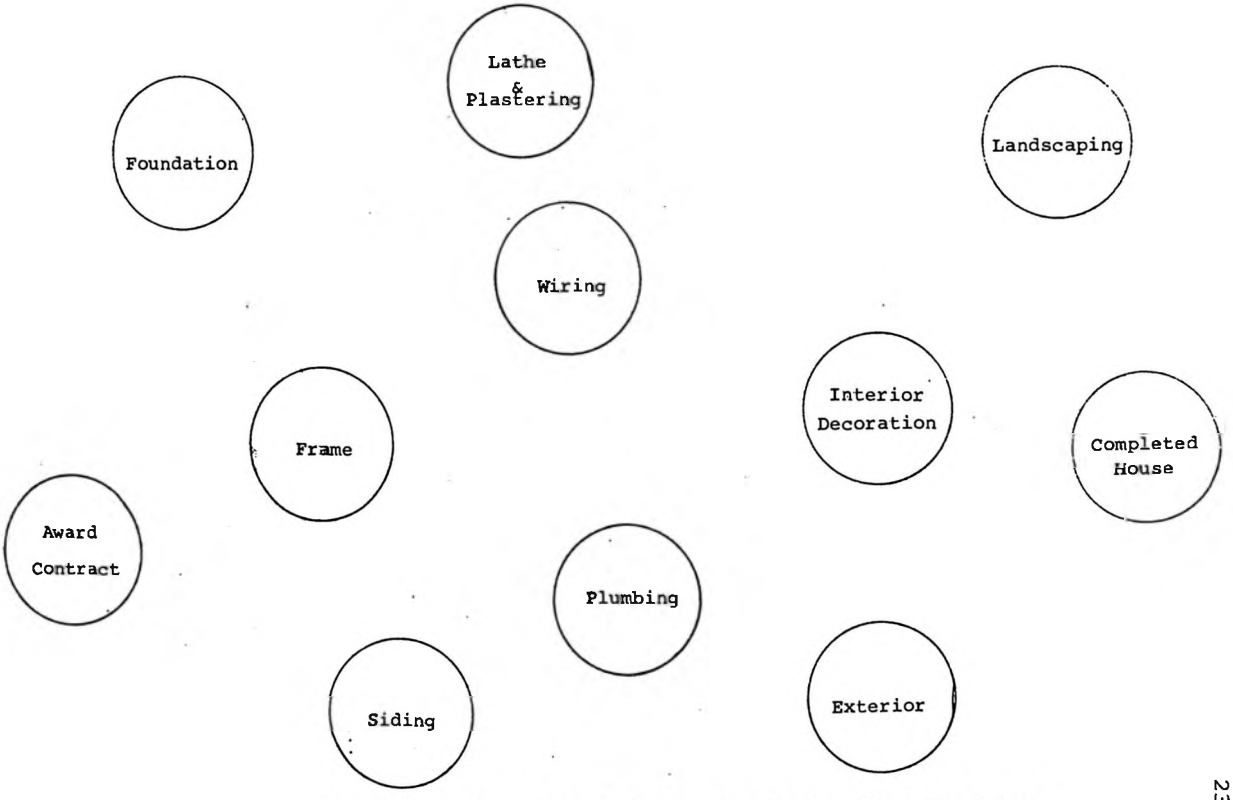


Fig. 2-2.--PERT Events Identified for Construction of a House.

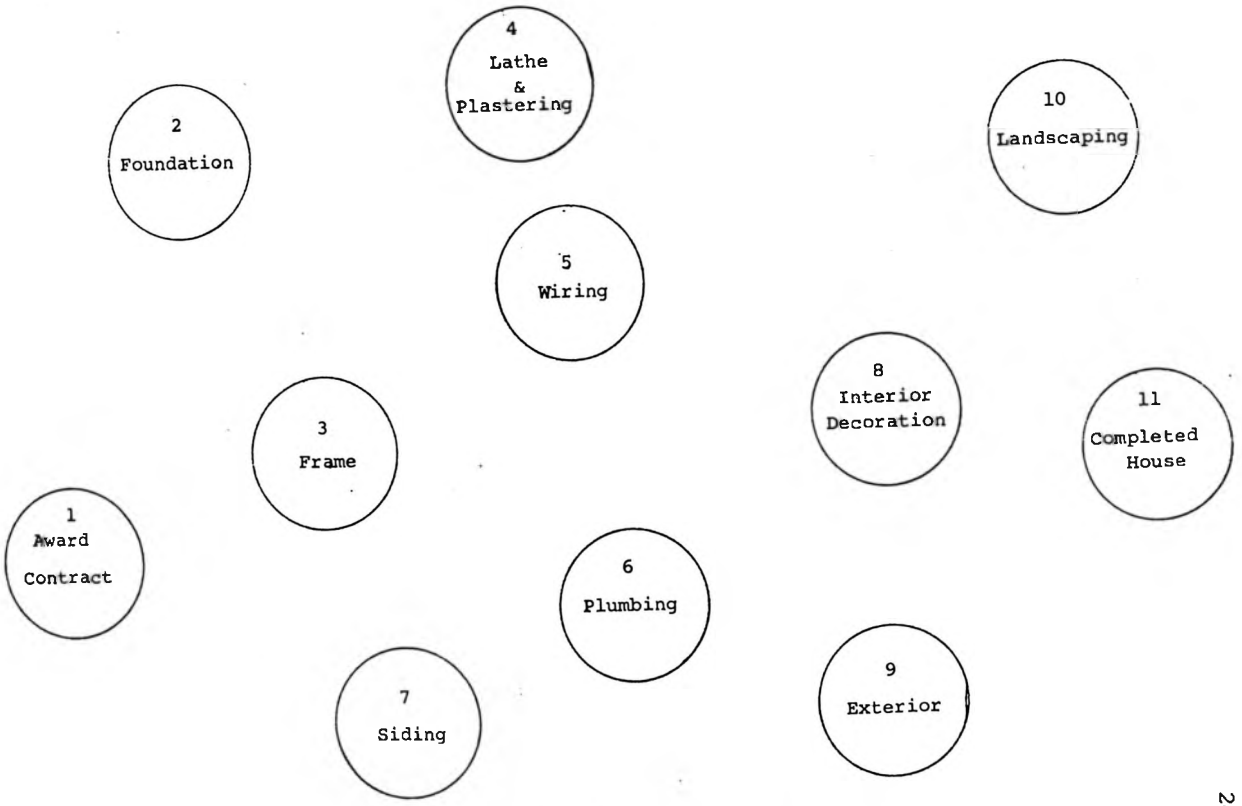


Fig. 2-3.--PERT Events Identified and Numbered.

activities do not require resources and usually do not consume time.

For further clarification, lines are added in Fig. 2-4 to represent the activities necessary to proceed from one event to the next event. Each event must be completed before the succeeding event can be reached.

A realistic time estimate is made for each activity. However, since PERT is frequently used on new and complex research and development projects, many project engineers are reluctant to commit themselves to a one-time estimate. They are aware of the many uncertainties; therefore, three-time estimates are often used for each activity. The three-time estimates (usually expressed in weeks) are designated as follows:

Optimistic Time Estimate (a).--The estimated length of time required if no complications or unforeseen difficulties are encountered in performing the activity. In most instances, a result which would be obtained only if unusually good luck is experienced.

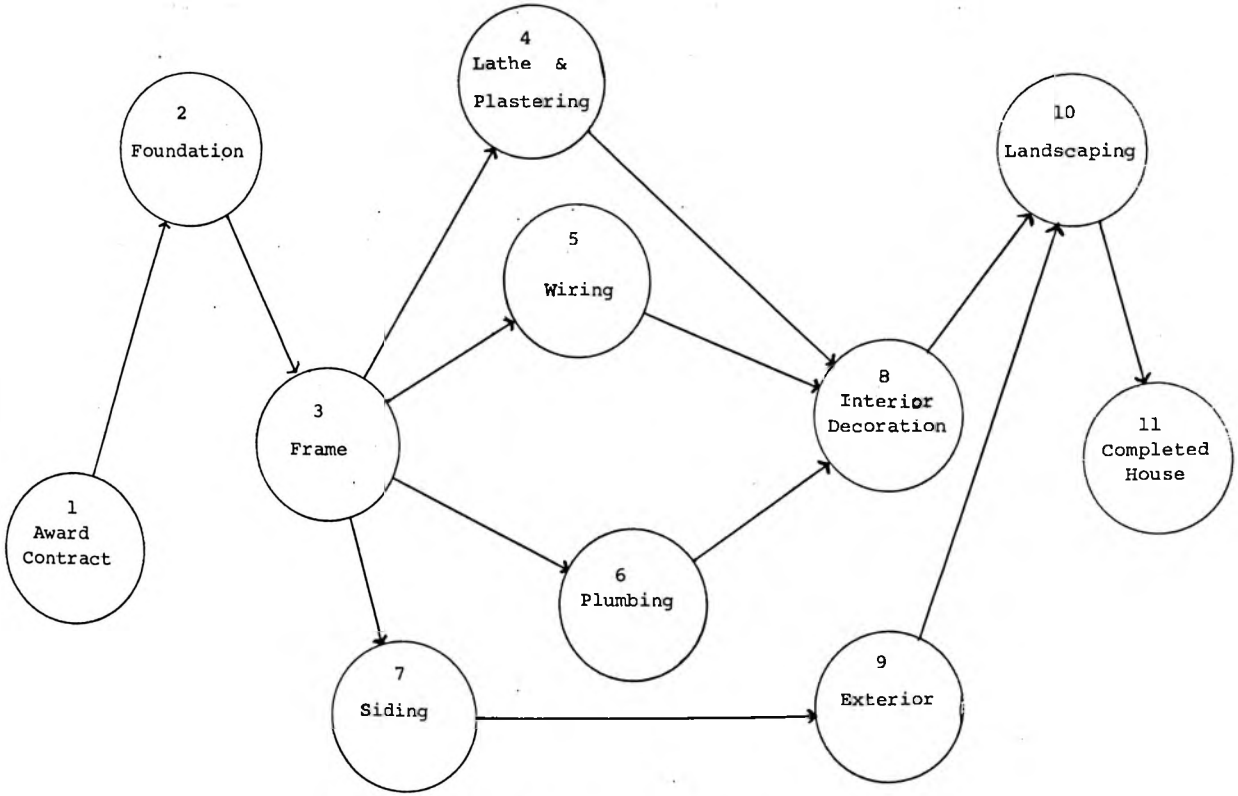


Fig. 2-4.--Activity Lines Drawn to Completed PERT Network Diagram.

Most Likely Time Estimate (m).--The estimated length of time required to complete the activity under normal circumstances. A result which would occur most often if the activity were repeated many times.

Pessimistic Time Estimate (b).--The estimated length of time required in unusually difficult circumstances. This estimate represents the maximum time required under adverse conditions.

The three-time estimates are normally entered on the PERT network above the activity arrow line to which they apply (Fig. 2-5), in the following order: (1) optimistic time; (2) most likely time; and, (3) pessimistic time. From these three-time estimates, a mean elapsed time (t_e) for each activity is approximated using the equation:

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

where,

a = optimistic time estimate;

m = most likely time estimate; and,

b = pessimistic time estimate.

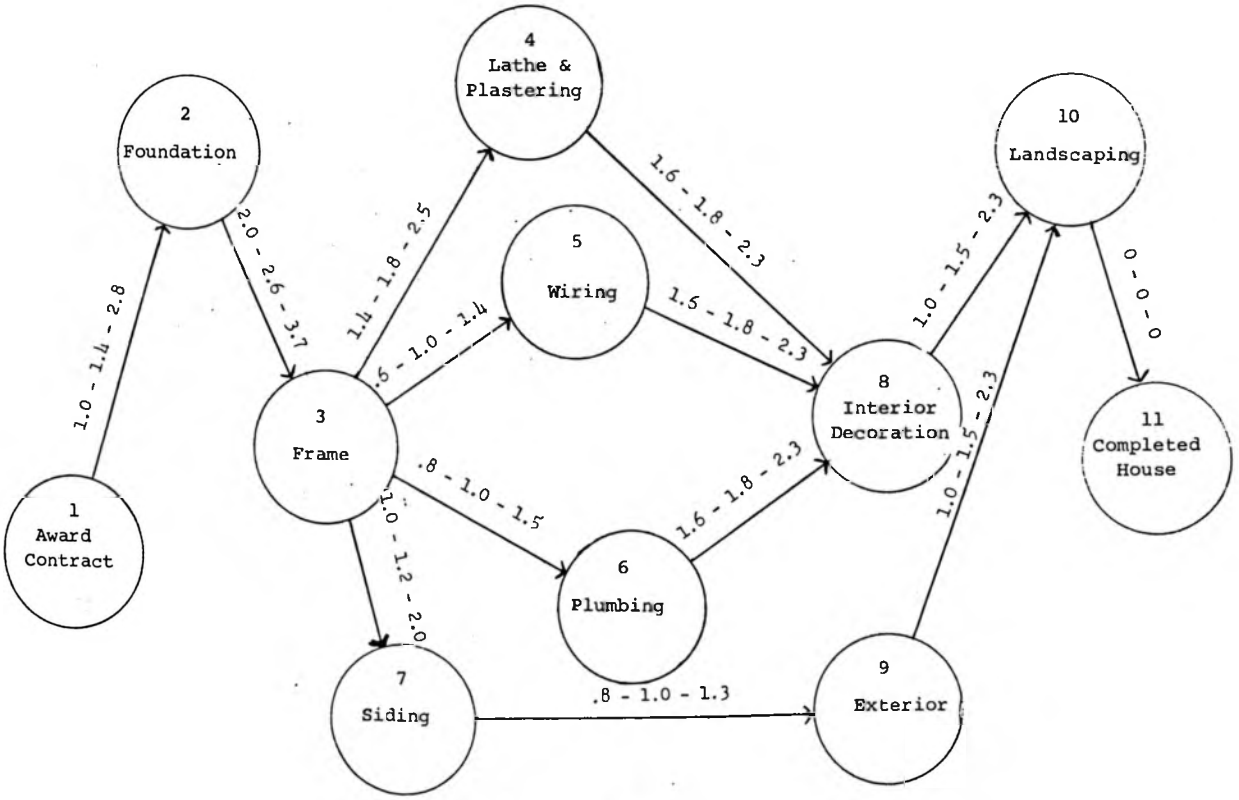
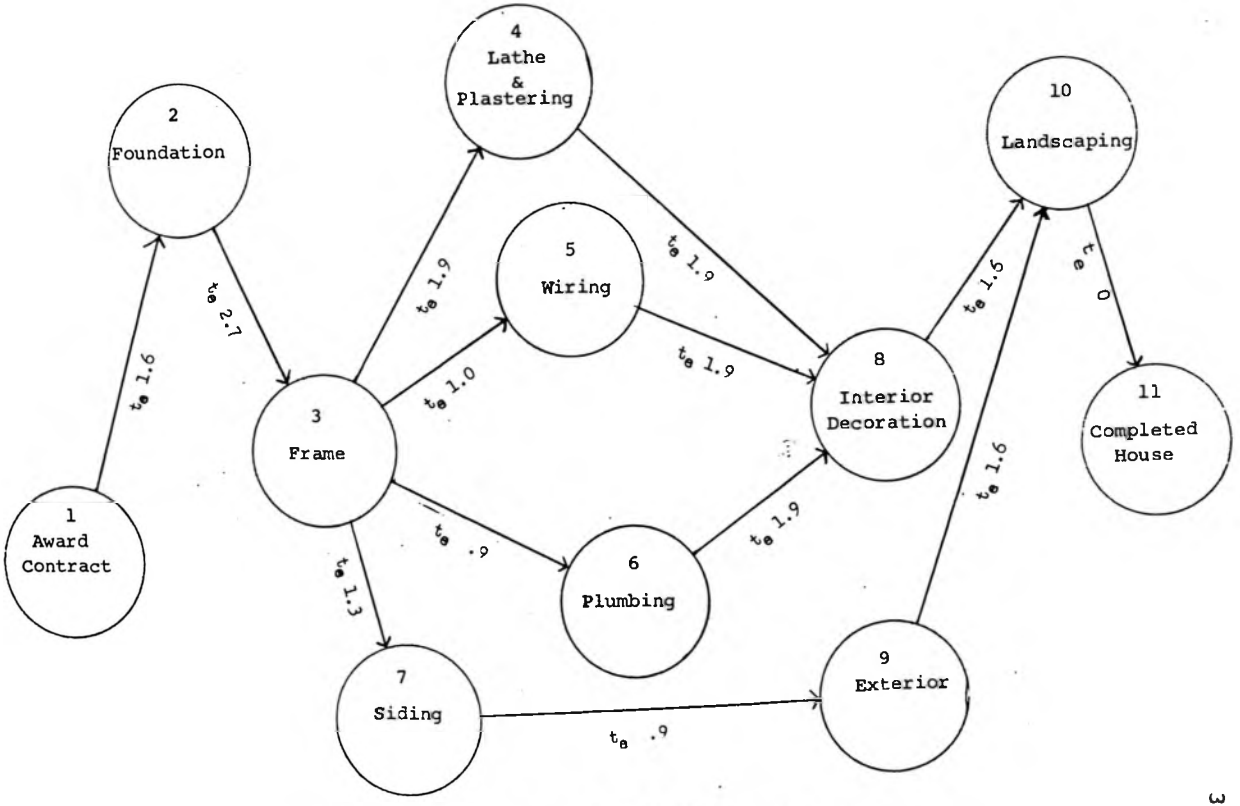


Fig. 2-5.--Three-Time Estimates Added to PERT Network.
[Time expressed in weeks & fractions of a week.]

The most likely time is given a weight of 4 in computing the expected elapsed time (t_e), since this time estimate should occur most frequently. The expected elapsed time is entered on the network under the activity line to which it applies (Fig. 2-6). In practice, time estimates are obtained from the individual responsible for the performance of each activity.

There is existing doubt as to the validity of the seemingly accurate time computed with the use of three-time estimates. There is lack of agreement in the use of a weight of 4 in the formula for computing expected elapsed time (t_e). However, little uncertainty exists when PERT is used on projects which have productivity levels specifically established by agreement or by union contracts. By way of contrast, the single-time estimate is the easiest for personnel to understand, and is the simplest procedure for computer calculation.

The activities on the critical path must (by



2-6.--Expected Elapsed Time (t_e) for Each Event.

the nature of the activities) be performed in sequence, thereby disallowing concurrent scheduling. Since there is usually more than one path in a network, selection of the one path with the greatest sum of activity times to establish the earliest completion time of a given project, is necessary. Such a path is the critical path in that it represents the greatest time restraint on completion of the project (Fig. 2-7). The activities along the critical path become the focal point for management's attention. Thus, the expected completion time may be shortened if some of the activities on the critical path are performed in parallel, or management may cause some shifting of resources from activities not on the critical path to achieve the same objective. Any activity on the critical path requiring more time than the original estimate will correspondingly delay the completion of the end event.

All paths, other than the critical path, are referred to as slack paths. Slack time is the difference between estimated time and the time allowed,

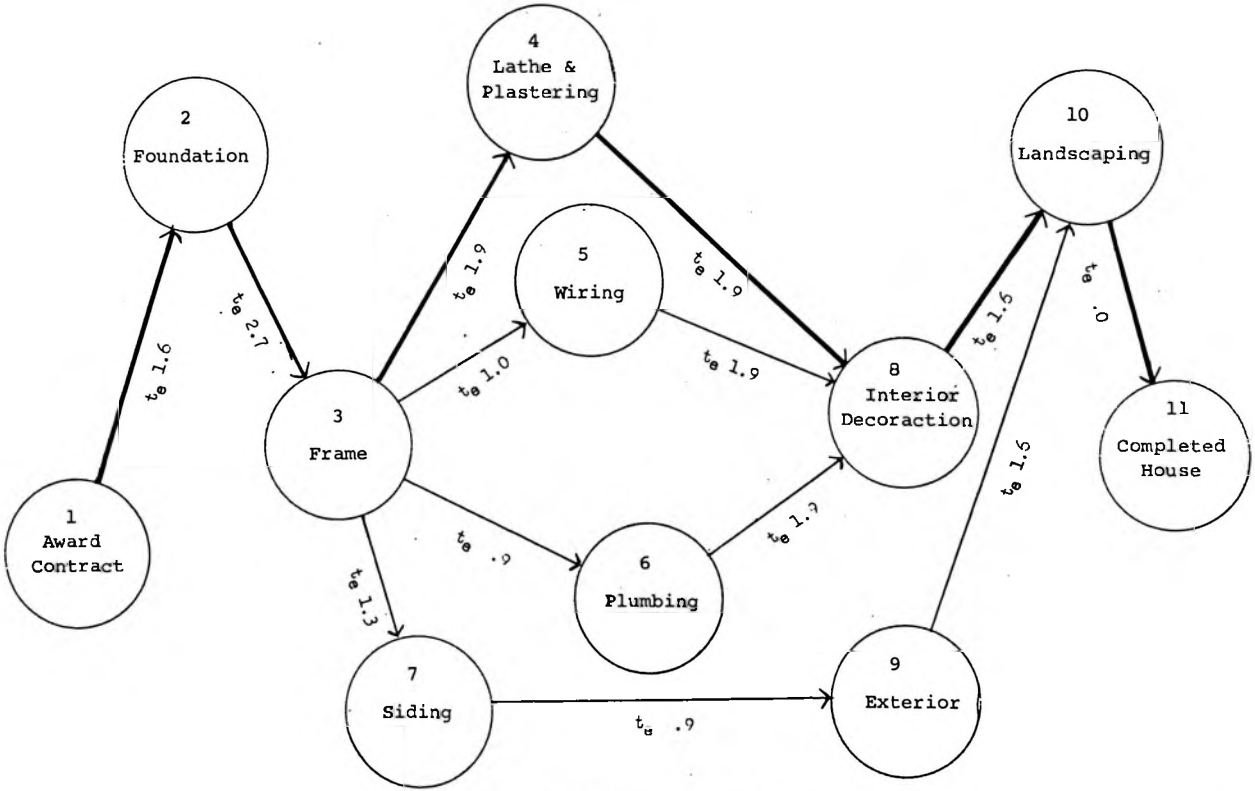


Fig. 2-7.--Most Critical Path Identified. Critical Path shown by use of Heavier Line.

without delaying the subsequent event. Slack may be positive, zero, or negative. Positive slack indicates an ahead-of-schedule condition; zero slack indicates an on-schedule condition; and, negative slack indicates a behind-schedule condition. Negative slack, moreover, is a signal for management to reconsider the activities to follow in order to determine the possibility of shifting resources to reduce time constraint on the critical path. The earliest calendar date on which an event can be expected to occur is referred to as the Earliest Expected Date (T_E). This expectation will be realized only if a project is started at the specified time and no negative slack occurs in the critical path.

PERT use assures notice of any significant program change, thereby typifying management-by-exception. This type information has strengthened acceptance of PERT as a planning and control technique in complex projects.

The probability that an activity will be completed within the calculated time period is measured in

terms of the standard deviation of an activity and its resultant variance. The standard deviation (σ) of the time that an activity should take is computed as approximately one-sixth of the span of time between the pessimistic time and the optimistic time, as illustrated by the following equation:[6]

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

where,

b = pessimistic time estimate; and,

a = optimistic time estimate.

Another measure of the distribution range is the variance which is obtained by squaring the standard deviation. The total variance for the entire project, obtained by computing the sum of the individual variances along the critical path, is used to predict the probability of completing the project on schedule.

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[6] James M. Antill and Ronald W. Woodhead, Critical Path Methods in Construction Practice (New York: John Wiley & Sons, Inc., 1965), p. 240.

It seems that management's use of probability information in PERT has not been employed extensively even though such information provides useful data for evaluating schedules. Overall, the probability concept has not been readily adapted, possibly because of the concept's appearance of statistical exactness, and management's lack of experience in the understanding of probability techniques.

With the initial success of PERT, managers searched for methods of extending this new technique into other phases of a project. Acquiring time-cost data in usable form for each activity is one of the basic problems in using PERT/Cost in development projects.

The Introduction and Application of PERT/Cost to the Network

At the planning stage, particularly, the determination of time-cost relationships in a specific manner, either for individual activities or for combin-

ations of activities, is difficult.[7] However, a method which provides for both time and cost factors is more useful in planning and controlling a project. PERT/Cost, when used properly, gives a manager the cost, time, and progress in a three-dimensional form. He can readily assess progress at any given date, and determine the level of achievement, the time constraint, and the resources required to complete the project. Also, the use of PERT/Cost enables the manager to (1) assess the possible need and advisability of shifting resources to accelerate the completion date of the project; and, (2) project the effect of completion date on cost.

Schedule slippage and associated cost overruns of many defense projects made it necessary for management to integrate resources (manpower, materials, and machines) with the time factor to develop a control technique. Approximately four years after the Depart-

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[7]Robert H. Bock and William K. Holstein, Production Planning and Control (Columbus, Ohio: Charles E. Merrill Books, Inc., 1963), p. 154.

ment of Defense initiated PERT, this same department published its first directive on adding cost to the basic network of PERT Time.

> Complex research and development projects can be managed effectively if project managers have the means to plan and control the schedules and costs of the work required to achieve their technical performance objectives. The serious schedule slippages and cost overruns that have been experienced on many weapon and space programs indicated that managers at all levels need improved techniques at all stages in a project to:
>
> (a) define the work to be performed;
>
> (b) develop more realistic schedule and cost estimates based on the resources planned to perform the work;
>
> (c) determine where resources should be applied to best achieve the time, cost, and technical performance objectives;
>
> (d) identify those areas developing potential delays or cost overruns, in time to permit corrective action.[8] [Alphabetical letters added.]

Performance in large complex defense projects

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[8] DOD and NASA Guide: PERT Cost--System Design (Washington, D. C.: Department of Defense and National Aeronautics and Space Administration, 1962), p. 1. Hereafter cited as DOD and NASA Guide.

pointed up the fact that each level of management must participate in planning and control of the overall task. "The PERT/Cost System, an extension of the basic PERT Time System, has been developed to meet these planning and control needs of each level of management."[9]

PERT/Cost increases the effectiveness and control for any project that lends itself to the use of the PERT technique.

> . . . It greatly facilitates the assessment of project status in relation to financial planning. It highlights the interrelationships of time and costs and the financial effects on the project of possible changes in resources and/or schedules. It permits evaluation of progress from multiple sources of information, and it provides a single set of reports for appraising both the financial and the physical status of a project.[10]

The Work Breakdown Structure

PERT/Cost provides a means whereby both cost

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[9] Ibid., p. 2.

[10] Peter P. Schoderbek, "PERT/Cost: Its Values and Limitations," Management Services, Vol. V, No. 6 (Jan.-Feb., 1966), 29.

and time are planned and controlled from a common network. The network depicts major work areas and their interrelationships, assuring an integrated time-cost management system.[11] The work breakdown structure begins with an end objective and works backwards, breaking each division into smaller subdivisions until work units reached are manageable for planning and control (Fig. 2-8). Each subdivision reduces the size, complexity, and dollar amount of the unit under consideration. The number of subdivisions, or levels of the work breakdown structure, should not be predetermined; each project should be broken down depending upon the complexity, time span, and cost of the total project. Management must use its judgment and discretion in specifying the degree of breakdown necessary for optimum management and control of the work. This type breakdown provides management with a graphic

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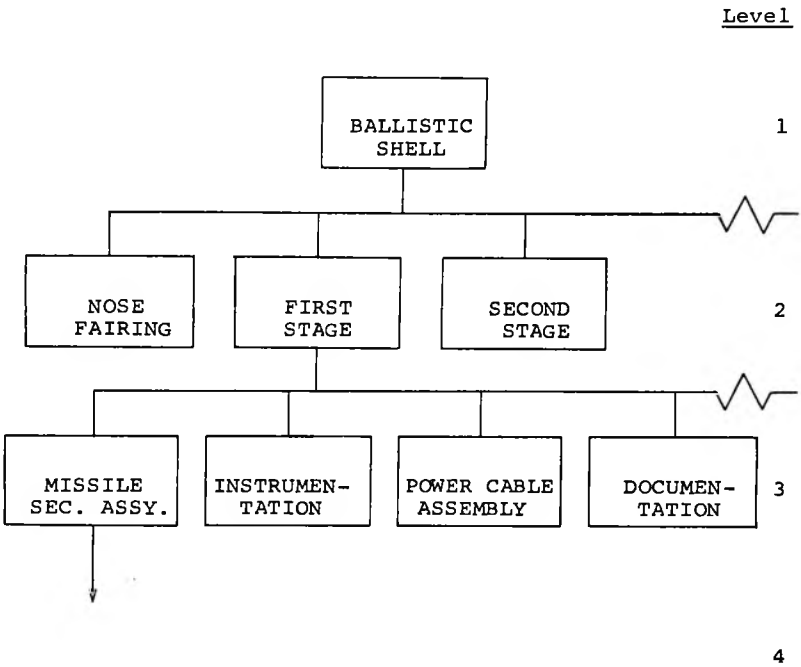
[11] NASA PERT and Companion Cost System Handbook (Washington, D. C.: Director of Management Reports, National Aeronautics and Space Administration, 1962), Sec. II, p. 1.



*While each of these perhaps would be broken into other work packages in an actual situation, the work package designations here are sufficient for illustrative purposes.

Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D. C., March, 1963.

Fig. 2-8.—**Partial Work Breakdown Structure Used in the Exemplary Output Reports.**

presentation to use in tracing the relationship of each part of the plan to other parts of the total structure.

The development of the work breakdown structure is a valuable tool in that it

> . . . defines the project tasks to be performed and establishes their relationship to the project end item(s) and project objectives;
>
> . . . establishes the framework for integrated cost and schedule planning and control;
>
> . . . establishes a framework for summarizing the cost and schedule status of the project for progressively higher levels of management.[12]

The work breakdown structure provides a basis for the construction of the network of project activities and events and assures that all pertinent activities have been included. The end items, appearing in the lowest level of the work breakdown structure, are subsequently divided into major work packages (sometimes along functional lines, i.e., engineering, manufacturing, testing). At this point, responsibility for these work

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[12] DOD and NASA Guide, op. cit., p. 26.

packages are assigned to departmental managers within the organization.[13]

This lowest and most detailed breakdown in the project is described as:

> A work package . . . a specific job to be accomplished; i.e. a design, a drawing, a task, a piece of hardware, or a service which is within the responsibility of one operating unit in an organization and which contributes to one item on the work breakdown structure.[14]

A further refinement states:

> The work package is the basic unit for assigning schedule and cost responsibility to first-level supervision and, as such, is the basic foundation for the PERT COST System.[15]

The work package represents a measurable unit of work in time and cost. Even though the work package may be distributed along functional lines, product orientation

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[13] Ibid., p. 27.

[14] "Common Problems Associated with Implementation and Operation of the PERT Cost System," Technical Paper #1 (Washington, D. C.: Inter-Agency PERT Coordinating Group, Department of Defense, 1964), p. 1.

[15] Ibid.

is a necessity for smooth operation.

> The work packages formed at the lowest level of breakdown, then, constitute the basic units in the PERT/Cost System by which actual costs are (1) collected and (2) compared with estimates for purposes of cost control.[16]

In summary, the PERT network reveals to management (1) when each work package should be started; and, (2) the degree of completion at any point in time. PERT/Cost, compared with actual costs at any stage of completion, measures the efficiency of an operation. If the actual costs are running more than anticipated costs, the excess is referred to as cost overrun. If the operations are more efficient than anticipated, the excess of estimated cost over actual cost is termed cost underrun. Both the time factor and the cost factor are compared to physical accomplishments to determine the overall achievement at any given time.

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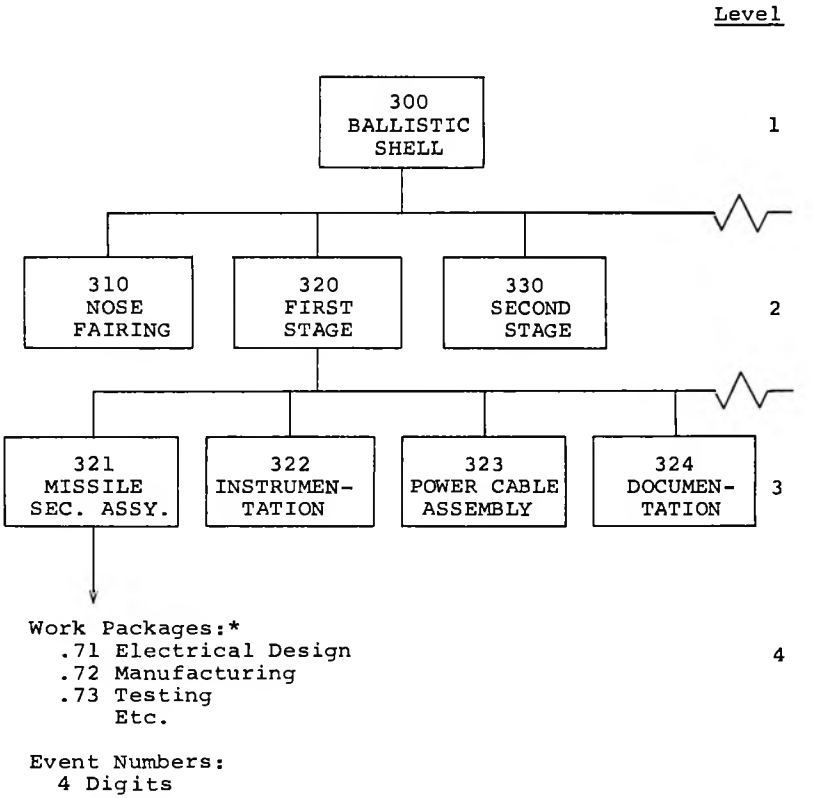
[16] DOD and NASA Guide, op. cit., p. 29.

Account Code Structure

In using the Account Code Structure, each project is assigned a framework of numbers (chart of accounts) to accumulate and summarize costs of a given project. This chart of accounts corresponds with the work breakdown structure to make such summarization of data more meaningful. In the account code structure, summary numbers are assigned to each end item subdivision, and charge numbers are assigned to each work package. The work package is usually the lowest level of cost accumulation. Costs are accumulated according to work packages; this procedure seems to enjoy wider acceptance than the functional breakdown.

An illustrative example of assignment of charge numbers and the account code structure in relation to the work breakdown structure is shown in Fig. 2-9. To assure accuracy and order of cost assignment, each work package should be assigned a separate and unique charge number.



*While each of these perhaps would be broken into other work packages in an actual situation, the work package designations here are sufficient for illustrative purposes.

Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D. C., March, 1963.

Fig. 2-9.—**Partial Work Breakdown Structure Used in the Exemplary Output Reports.**

An organization's cost accounting system may need revision to accommodate the accumulation and summarization of costs at the work package level. The PERT/Cost work breakdown structure, as well as work packages, must be integrated into the regular cost accounting system. Two separate sets of accounting records for the collection of accounting data are neither necessary nor feasible for a company using PERT/Cost. Certain companies have experienced adverse results in maintaining dual accounting systems.

Identification of cost variance and assessment of differentials between actual costs and estimated costs are necessary if the control function of PERT/Cost is to be utilized properly. The accumulation and presentation of accounting data, with accounting system limitations, are explored in detail in Chapter V.

Supplements to PERT/Cost

In reviewing and comparing possible alternatives available in any proposed project, a manager is faced

with three determining factors: time, cost, and risk involved. The manager's responsibility includes the selection of the one alternative that best provides the lowest cost, in the shortest time, with the least amount of risk--taking into consideration such outside factors as completion date requirement and resource limitations.

The Time-Cost-Risk Option

Under the Time-Cost-Risk Option, as a supplement to the use of PERT/Cost, a manager may make use of an option which provides the media for effective decision making in a given set of circumstances. This type option provides for three alternative plans to be considered: (1) the Directed Date Plan; (2) the Shortest Time Plan; and, (3) the Most Efficient Plan.

Directed Date Plan.--This is a plan designed to accomplish the project by a specific and directed completion date.

Shortest Time Plan.--This plan requires a network design that will enable the project manager to

meet technical requirements of a job in the shortest time possible. Such a plan does not necessarily make the total costs higher, but it increases the risks involved. Time may be shortened by the elimination of certain activities or performing a larger number of activities in parallel.

Most Efficient Plan.--This plan is a network plan designed to meet the technical requirements of a project with the most efficient utilization of the available or obtainable resources. Fewer risks are involved in this alternative plan.

A manager, considering these three alternatives under the Time-Cost-Risk Option, is in a position to select the one plan most appropriate to the project in question. Thus, the Time-Cost-Risk Option is a

> . . . supplemental approach to the basic PERT/Cost planning procedures and may be used in the proposed stage or whenever an expansion or contraction of project time is under consideration.[17]

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[17] Ibid., p. 104.

The Resource Allocation Procedure

A manager must continuously search for methods of allocating resources at his command to efficiently accomplish tasks assigned to him. PERT and PERT/Cost are effective tools designed to combine resources available with the time element in the completion of desired objectives. However, these planning and control tools, in themselves, may not form the most efficient alternative when given resources are considered. The Resource Allocation Supplement to PERT/Cost usage has been developed to cover such circumstances.

The Resource Allocation Supplement assists the manager in the allocation of given resources in the best possible way. Resources are assigned in such a manner for the accomplishment of objectives of the project in either the shortest time with a specific cost limitation, or at the lowest cost within a specific time period. One publication states:

> . . . Whereas the PERT/Cost System is specifically intended for application in

> planning and controlling entire projects, the Resource Allocation Supplement may be effectively used in planning a small group of associated activities representing only a minor portion of the overall project.[18]

The Resource Allocation Supplement assumes that project activities can be performed in more than one way, and that alternative procedures will most likely reflect differing cost estimates and time requirements. Basically, the procedure for the preparation of a Resource Allocation Supplement is as follows:

> Management first defines the project by a network of activities with technical specifications for the work. Alternative times and costs are then estimated for each of the activities. (Any number of meaningful time-cost combinations may be estimated.)
>
> The duration of an activity is initially set at the time associated with its lowest cost alternative. Then, by selecting shorter time/higher cost points on certain critical-path activities, time is 'bought' on the critical path until the project duration is equal to or slightly less than the target duration.[19]

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[18] *Ibid.*, p. 108.

[19] *Ibid.*, p. 109.

The procedure for preparing a Resource Allocation Supplement emphasizes the time/cost alternative. The manager can trade time for a saving in cost, or he can expend additional money to gain a reduction in the time element. The manager can also continue to trade between time and cost until an optimum point is reached within the overall time limitation of a given project.

The basic elements of PERT and PERT/Cost are reviewed in this chapter, the refinement of each concept is detailed, and two associated supplements of PERT/Cost are discussed. Chapter III presents other management networking techniques developed in recent years which bear similarity to PERT and PERT/Cost.

CHAPTER III

A REVIEW OF MANAGEMENT NETWORKING SYSTEMS RELATED TO PERT AND PERT/COST

A Comparison of Selected Techniques

The need for more sophisticated planning, scheduling and monitoring of complex, interrelated industrial activities, and the resources required to perform these activities, has produced an abundance of network planning and control techniques. Such systems are designated by a wide variety of acronyms. The network approach is a major achievement in improving the planning, analysis, and control of complex defense projects as well as smaller industrial programs. Management must have high-quality quantitative information to aid in making sound decisions.

> No management tool can make decisions, but tools such as network planning can provide the basis on which to build a realistic,

> economical management information system which will permit more informed decisions to be made.[1]

A selected number of networking techniques that have emerged in recent years are discussed in this chapter, although these techniques are not pursued in the survey questionnaire which is limited to PERT and PERT/Cost. Each system is described briefly and compared with PERT and PERT/Cost to identify similarities and dissimilarities. No attempt is made to place the techniques in any determinable order, nor does the study make a comprehensive evaluation of all known techniques.

Critical Path Method (CPM)

A unique arrow-diagram or network method known as the Critical Path Method was developed by Morgan R. Walker of E. I. du Pont de Nemours and Company, and James E. Kelly, Jr., of Sperry-Rand Corporation in late

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[1] Russell D. Archibald and Richard L. Villoria, Network-Based Management Systems (PERT/CPM) (New York: John Wiley & Sons, Inc., 1967), p. ix.

1957. CPM and PERT are often used interchangeably since they were developed at approximately the same time, with similar objectives. Each technique evolved from the Gantt charts and bar charts, adding identification of connecting interdependencies of individual tasks in the completion of a project (Fig. 3-1).

Some of the environmental factors affecting the development of the CPM technique include: (1) projects well defined; (2) one dominant company involved; (3) relatively minor uncertainties; and, (4) project located in one geographical area.

The development of PERT was influenced by the following environmental elements: (1) complex program with hard-to-define objectives; (2) two or more organizations with divided responsibility; (3) a large degree of uncertainty in time and cost estimates; and, (4) geographical decentralization with complex logistics.[2] Consequently, PERT has proved more applicable to large-scale research and development activities

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[2] Ibid., p. 15.

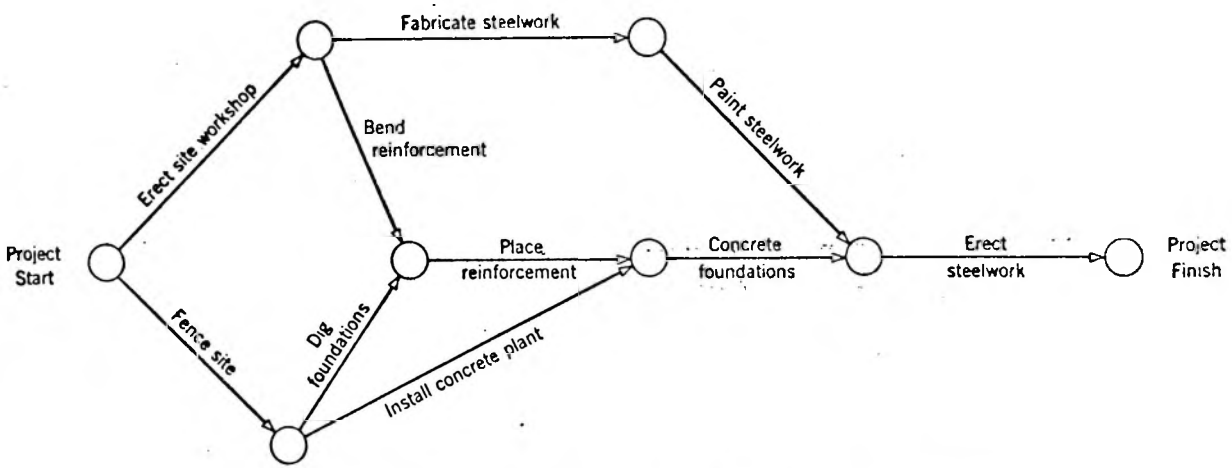


Fig. 3-1.-- Network diagram for a simple project, showing component operations.

Source: Russell D. Archibald and Richard L. Villoria, Network-Based Management Systems (PERT/CPM) (New York: John Wiley & Sons, 1967), p. ix.

which involve a high degree of uncertainty, whereas CPM is more adaptable to smaller projects with limited uncertainty.

PERT and PERT/Cost, and CPM as networking systems have certain other similarities and differences.

1. PERT and PERT/Cost makes use of the one-time estimate and a three-time estimate with a probability feature. CPM generally uses only a one-time estimate--the most likely time.
2. Cost estimates were added to PERT soon after the time network was developed, but CPM incorporates, less frequently, a cost-of-activity in the network.
3. PERT evolved from a combination of bar charts, Gantt charts and milestone charts, and is more event oriented. CPM is activity oriented, having been developed from detailed bar charts.

PERT and PERT/Cost, and CPM are management control techniques so closely related in their procedures, objectives, and applications that many users make no

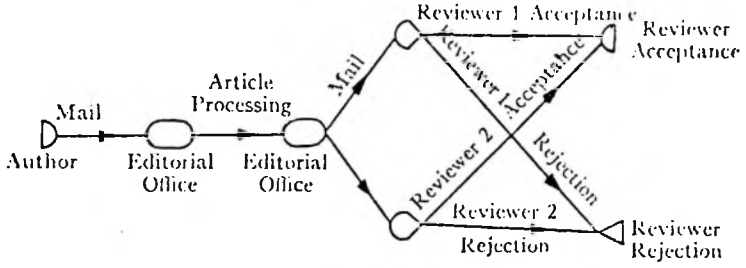
attempt to differentiate between the two, but often refer to the systems as the PERT/CPM network.

Graphical Evaluation and Review Technique (GERT)

GERT is a management technique which analyzes stochastic networks. It is statistically oriented as it is a means to compute the probability that an event will be realized, as well as the probability of the time required to reach the event (Fig. 3-2).

Basic steps of the GERT approach to problem solving follow a logical sequence. These steps:

1. Change a qualitative description of a system or problem to a model in the network form;
2. Assemble the necessary data to identify events in a network;
3. Identify the events as realizable accomplishments;
4. Determine two measures for each event in the network [the probability that a specific



Stochastic Network Model of a Two Reviewer Process.

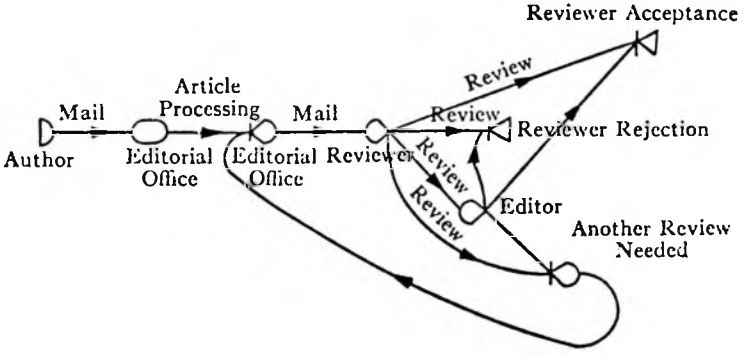


Fig. 3-2.--Stochastic Network Model of a Sequential Review Process.

Source: A. Alan B. Pritsker and W. William Happ, "GERT: Graphical Evaluation and Review Technique, Part I Fundamentals," The Journal of Industrial Engineering, Vol. XVII, No. 5 (May, 1966), 268.

event will be realized, and the probability of time required to accomplish the event]; and,

5. Draw inferences about the problem under study from information obtained from Item 4.

The GERT approach combines certain features of the PERT network, with other flowchart concepts not included in PERT. The event, representing a definite accomplishment, and the estimated time required to perform an activity are taken from PERT. The flowchart theory provides GERT the analysis procedure which incorporates a topological equation.[3] This system does not consider the estimated cost of resources required.

The possibility of alternative courses of action in reaching objectives of a project, as well as probability features in case of rejection of activities

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[3] A. Alan B. Pritsker and W. William Happ, "GERT: Graphical Evaluation and Review Technique, Part I Fundamentals," The Journal of Industrial Engineering, Vol. XVII, No. 5 (May, 1966), 268.

or events upon inspection and review, is recognized in the GERT approach. GERT places emphasis on the uncertainties of future events being accomplished.

Project Evaluation and Review Graphic Output (PERGO)

PERGO is a computer-oriented tool designed to provide technical managers in small companies with an accurate, meaningful, and easy-to-analyze aid. Its purpose is designed to answer the questions: (1) Is the company staying within the budget? (2) What job is delaying the project? (3) Can resources be reallocated to improve project performance?[4]

The PERGO approach is not comparable with PERT and PERT/Cost in some respects, but many of the basic concepts are similar. PERGO utilizes a hierarchical summarization model (HSM) in developing graphical displays of technical progress and costs. These graphs depict estimated and actual costs, and estimated and

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[4]Larry L. Constantine and James F. Donnelly, "PERGO: A Project Management Tool," Datamation, Vol. XIII (October, 1967), 33.

actual technical performance, thus yielding a continuous updated projection of estimated completion date and estimated completion cost. Output reports in PERGO differ from such reports in PERT and PERT/Cost. PERGO output reports are in graphic form, whereas PERT and PERT/Cost make extensive use of the numerical report.(Fig. 3-3).

Compensation of slack developments is not provided for in PERGO. A delay in one task automatically delays completion of the overall project by an equivalent amount of time. PERGO is particularly useful in resource allocation since a manager is aware of the progress of each area, and where and how much resources are available or required. The PERGO technique, designed primarily for small, semi-complex work tasks that do not justify the expense of a cost specialist, is a simplified model which is flexible and user-oriented. It also provides practical graphical output reports (Fig. 3-4).

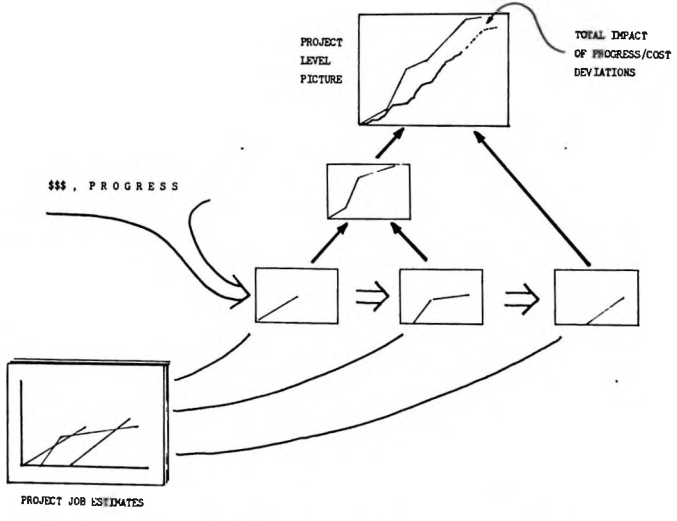

Fig. 3-3.--The hierarchical summarization model.

Source: Larry L. Constantine and James F. Donnelly, "PERGO: A Project Management Tool," Datamation, Vol. XIII Vol. XIII (October, 1967), 33.

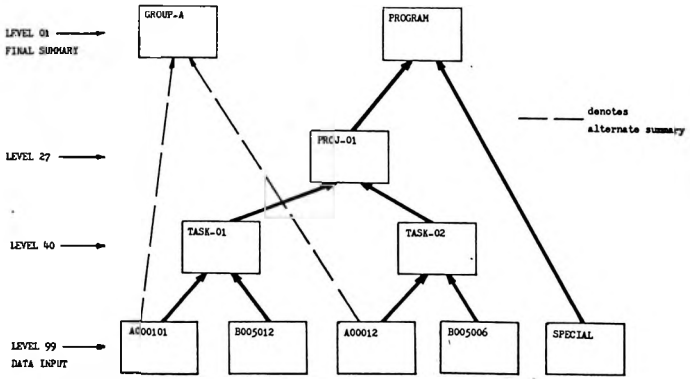

Fig. 3-4.--A summary structure.

Source: Larry L. Constantine and James F. Donnelly, "PERGO: A Project Management Tool," Datamation, Vol. XIII (October, 1967), 33.

DYnamic NETwork Planning Technique (DYNET)

DYNET is a computer adaptation of a networking system providing for better planning and more timely reports. Emphasis is placed upon the division of planning responsibility in the initial stages of a project. The project director assigns areas of responsibility to certain individuals, provides graphic charts of the project which highlight duties of each participant, and regularly reviews progress in all interrelated areas (Fig. 3-5).

The concept and the computer program of DYNET was developed to overcome apparent deficiencies of other approaches. DYNET:

1. Prepares a clearly defined management and information system;
2. Provides periodic feedback from centers engaged in the execution of the project;
3. Detects schedule delays early enough to take appropriate action;

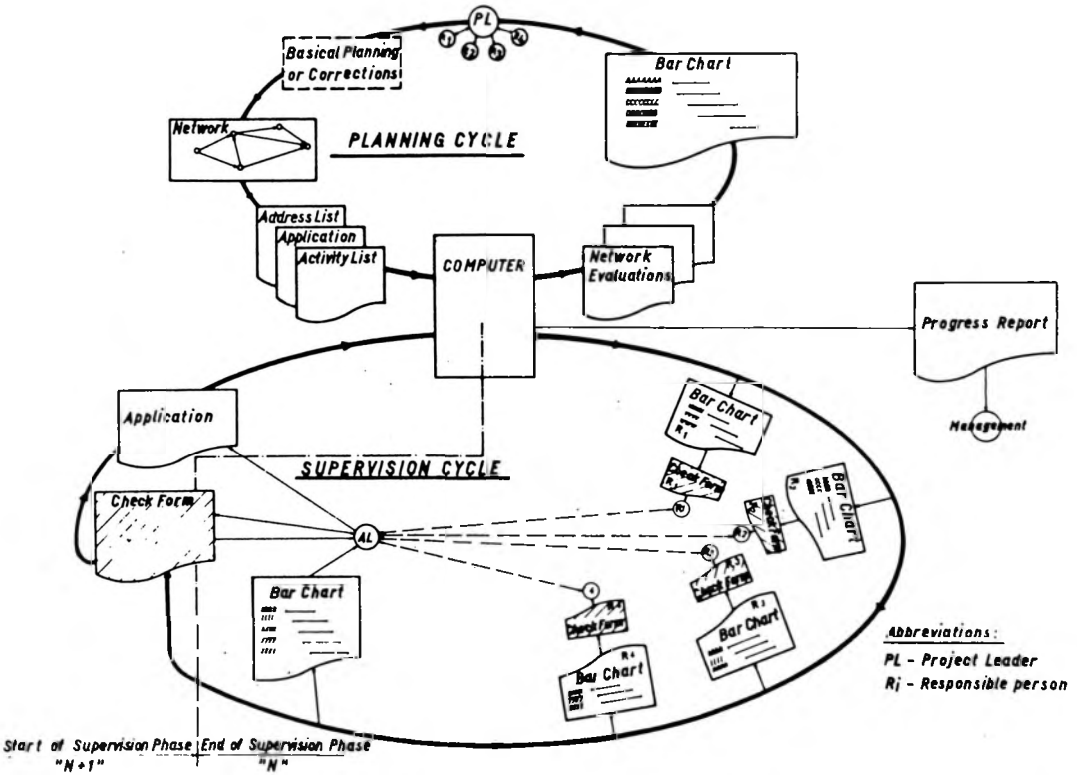

Fig. 3-5.--DYNET Planning and Supervision Cycles.

Source: A. M. Becker, "DYNET--A Dynamic Network Planning Technique," Datamation, Vol. XV (April, 1969), 114.

4. Summarizes actual-desired comparison of the progress of the project for immediate release;
5. Minimizes the number of output reports;
6. Makes use of graphs instead of numerical tables;
7. Assures maximum flexibility of the system;
8. Maintains feasibility of reconstructing development of the network; and,
9. Simplifies handling of input data to minimize errors.[5]

This planning and control technique is similar to PERT and PERT/Cost in its emphasis on preplanning, identifying important events, network development, and follow-up supervision. However, DYNET differs from PERT and PERT/Cost in two important areas: (1) DYNET is strictly a computer adaptation of networking, and (2) it does not provide for regular output reports, but produces up-to-date reports at the request of

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[5] A. M. Becker, "DYNET--A Dynamic Network Planning Technique," Datamation, Vol. XV (April, 1969), 114.

operating personnel. In summary, DYNET is a computer adapted version of PERT and PERT/Cost; DYNET provides for continuous supervision whereas PERT and PERT/Cost supplies periodic supervision.

Computer Operated Management Evaluation Techniques (COMET)

COMET is the Army Materiel Command's version of PERT and PERT/Cost. All projects are adapted to a standard universal network which provides the maximum number of events and activities necessary for development and production of the most complex programs. The network is scaled down for smaller tasks by placing zero time on the inapplicable activities.

Another major deviation from PERT and PERT/Cost is COMET's use of scheduled time estimates rather than estimated time. Events are considered significant management control points in the production process. The COMET system does not require the reporting of detailed resource expenditures.

The Army Materiel Command recommends that COMET

should be used in simultaneously controlling complex projects. PERT and PERT/Cost is more adaptable in controlling individual projects.[6] The standard universal network approach of COMET makes the system applicable to decentralized operations where a networking specialist is not available for each project.

Contractual Requirements Recording, Analysis and Management (CRAM)

CRAM is an automated management control system designed by the U. S. Air Force to expedite procurement activities. The method automatically schedules, controls, and reports on the status of purchasing orders until a contract is completed.

CRAM was developed to support PERT in the area of procurement, with three major advantages expected:

1. Reduction in manual effort imposed on the buying office;

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[6] Bruce N. Baker and Rene L. Eris, An Introduction to PERT - CPM (Homewood, Illinois: Richard D. Irwin, Inc., 1964), p. 59.

2. Automated pyramid reporting of necessary information to provide each level of management pertinent data with minimization of inapplicable details;
3. Continuous reporting of the current status of a procurement project with forecast adjustments as current information dictates.[7]

CRAM is time oriented and does not consider the cost element. This technique is not a substitute for PERT; it is a further development in specific areas within the network system. As such, CRAM is essentially a complementary refinement.

Resource Allocation and Multi-Project Scheduling (RAMPS)

The primary objective of RAMPS is to explicitly schedule limited resources among an arbitrary number of separate projects. It uses the conventional arrow diagram to describe the interrelationship of activities in a project.

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[7] *Ibid.*, p. 60.

Unlike PERT and PERT/Cost, RAMPS emphasizes the amount of work required, while recognizing that different rates of resource utilization at varying efficiencies may be used in accomplishing a given level of work effort. Resource utilization is considered nonlinear to amount of work performed in most projects (Fig. 3-6).

RAMPS is an automatic networking technique providing schedules, subject to resource constraints, which portray the completion of a project (1) at minimum cost, (2) in minimum elapsed time, (3) using resources at a level rate, or (4) guided by other objectives of management. In essence, use of RAMPS enables management to detect errors in work plans, and to efficiently utilize available resources. This resource scheduling tool also provides a basis for making better decisions in planning the levels to maintain different resources.[8]

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[8] Jack Moshman, "RAMPS: A Resource Scheduling Tool for Multi-Projects," Data Processing for Management (December, 1963), 6.

PROJECT SCHEDULE

PROJECT IDENTIFICATION, DESCRIPTION, AND COMPLETION INFORMATION

UTILIZATION RATES

AMOUNT OF WORK

SCHEDULED PERIODS AND RESOURCES ASSIGNED

PROJECT B RENOVATE OFFICE

AVAILABLE START DATE: 11
DESIRED COMPLETION DATE: 20
INDICATED COMPLETION DATE: 20
DELAY COST AT $1000:

PERIODS

ACTIVITY / RESOURCE	S-DOWN	NORMAL	S-UP	WORK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1-2 REMOVE FURNISHINGS				4																				
CARPENTERS	1	2	4												4									
2-3 INSTALL NEW FIXTURES				4																				
ELECTRICIANS	1	2	4													2	2							
2-4 REMOVE OLD PARTITIONS				8																				
CARPENTERS	1	2	4													4	4							
4-5 INSTALL NEW PARTITIONS				12																				
CARPENTERS	2	4	6															4	2	2	2	2		
2-5 INSTALL AIR CONDITIONER				24																				
ELECTRICIANS	2	4	8															4	8	4	4	4		
3-5 PAINT				8																				
PAINTERS	1	2	8															2	2	2	2			
5-6 INSTALL FURNISHINGS				4																				
CARPENTERS	1	2	4																				2	2

EVENT NUMBERS

ACTIVITY DESCRIPTION

RESOURCE REQUIREMENTS

Fig. 3-6.--RAMPS Resource Schedule.

Source: Jack Moshman, "RAMPS: A Resource Scheduling Tool for Multi-Projects," Data Processing for Management (December, 1963), 6.

Least Cost Estimating
and Scheduling (LESS)

Developed by International Business Machines Corporation, LESS is an activity-oriented, arrow-diagramming technique to determine the quickest and least-cost method of completing a project. Like PERT and PERT/Cost, it uses time estimates and resource requirements.

IMplementation, Planning, And
Control Technique (IMPACT)

IMPACT is a specialized technique designed to aid management in controlling computer systems. Any level of management can monitor and control the computer programs effectively, even if employees are unfamiliar with details of computer programming. IMPACT was designed to determine what a program will cost, the amount of time necessary in its development, and the number and type of personnel to make the computer system operational.

IMPACT, like PERT, uses a network system of events and each event represents an accomplishment of

a specific job. Also, IMPACT makes use of management-by-exception, a characteristic of PERT and PERT/Cost.

Time estimates are measured in terms of hours for IMPACT, whereas PERT employs the use of weeks and fractions of weeks. Primarily, the use of hours is a necessary requirement because the time durations of projects using IMPACT are significantly less.

Summary

All networking techniques provide partial solutions to the problem of increased demands for the up-grading of methods in facilitating efficient utilization of scarce resources. A networking technique, in and of itself, can not make a decision for management, but it can give management reliable and up-to-date information.

Many of the management networking systems developed in recent years show similarities to PERT and PERT/Cost, but all related approaches also contain a number of differences in this particular concept. Some

systems are necessarily limited in scope as they are designed to apply only to specific types of projects. Other systems are developed for more universal application. However, most of the systems seem to perform well the functions for which they were initially formulated. However, their contributions to management in solving other types of problems have been varied. Proven concepts, partially borrowed from related techniques, have been combined with refinements for the creation of newer systems of wider magnitude.

No one technique has proved superior in all types of situations; therefore, some of the networking systems are more appropriate to specific projects. The use of any given technique should be left to the discretion of the individual project manager for much of its success will depend upon the knowledge and acceptance by the individual responsible for overall project completion.

This chapter reviews nine selected techniques with brief discussions of their comparison with PERT

and PERT/Cost. The examples are furnished for a more thorough overview of networking techniques in general. The selected systems are the ones that seem to occur most frequently from studying the literature.

Chapter IV is a further development and discussion of the extent of PERT and PERT/Cost use in industrial companies. The chapter also provides results and conclusions drawn from a survey questionnaire.

CHAPTER IV

EXTENT OF PERT AND PERT/COST USE IN VARIOUS INDUSTRIES IN ALABAMA

Although PERT and PERT/Cost originated in the Department of Defense for monitoring and control of projects vital to national defense, the use of these tools is by no means confined to defense-oriented programs. PERT and PERT/Cost may be applied to a variety of nondefense projects. A need exists to determine some of the nondefense uses of these management control techniques and to summarize characteristics of the user industries.

This chapter is a presentation and analysis of a survey of businesses in Alabama for the purpose of determining the extent to which PERT and PERT/Cost are used in the State. Included in the survey are the types of industries, kinds of projects, costs involved,

problems encountered, technique limitations, as well as certain other aspects for management control. Specific information in the following areas was expected to be secured by use of a questionnaire:

1. The ratio of companies in the various industries in Alabama using PERT and PERT/Cost;
2. The reasons nonusers are not utilizing PERT and PERT/Cost in the operation of their businesses;
3. The kinds of projects and the specific areas where PERT and PERT/Cost are being utilized;
4. The major factor(s) used to determine whether or not to use PERT and PERT/Cost in a project;
5. How the cost estimates are determined for a PERT/Cost project;
6. How the accounting records and accounting data are utilized in applying the technique;
7. The problems encountered and limitations confronted with the accounting systems employed;

8. The cost of and benefits derived from the use of PERT and PERT/Cost;
9. The major problems encountered in applying PERT and PERT/Cost techniques; and,
10. The PERT and PERT/Cost output reports prepared by nondefense companies.

The Survey Sample

The survey is composed of a random selection of 25 businesses from the 100 largest companies in each of the eight major industrial classifications in the State of Alabama. The 100 largest companies in each industrial classification are based on the number of employees reported to the state in January, 1968.

A questionnaire (Appendix A) was mailed to the 25 selected companies. A follow-up mailing of the questionnaire, three weeks from the first request, was sent to those companies that did not reply initially. In addition, telephone calls and personal visitations were made to many of the nonrespondents. Usable replies

were received from 159 of the 200 selected companies (Table 1). A tabulation and analysis of the responses are presented in this chapter by stating each question in the questionnaire and using statistical illustrations to detail the nature of the responses.

Nonusers of PERT

Of the 159 respondents to the survey questionnaire,[1] 146 (or 91.8 per cent) are not using PERT. By way of contrast, however, the number and percentage of respondents in each classification using this technique are shown in Table 2. The following questions are designed for determining data on nonusers of PERT:

> Question 1.--Is your company using PERT Time on any projects?

Three additional questions were asked of the nonusers to gain some insight into their experiences, expectations of future use, and reasons for not using

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[1]Questions 1-25 on the survey questionnaire used in this study were adapted from Schoderbek, Peter Paul, "PERT: An Evaluation and Investigation into its Applications and Extensions," a Ph.D. dissertation, University of Michigan, 1964.

TABLE 1

DATA ON QUESTIONNAIRE RESPONSES*

Classification	No. Mailed to Selected Companies	No. of of Replies	Per Cent of Response
Mining	25	20	80.0
Contract Construction	25	22	88.0
Manufacturing	25	22	88.0
Transportation, Communication & Utilities	25	18	72.0
Wholesale & Retail Trade	25	23	92.0
Finance, Insurance & Real Estate	25	23	92.0
Services	25	17	68.0
Government	25	14	56.0
TOTAL [Per Cent of Replies Received: 79.5]	200	159	

*Data in Tables 1-29 derived from responses to items on questionnaire mailed to selected companies in Alabama, 1968.

TABLE 2

USE OF PERT TIME

Classification	Users No.	Users %	Nonusers No.	Nonusers %
Mining	0	0.0	20	100.0
Contract Construction	6	27.3	16	72.7
Manufacturing	4	18.2	18	81.8
Transportation, Communication, & Utilities	0	0.0	18	100.0
Wholesale & Retail Trade	1	4.0	22	96.0
Finance, Insurance & Real Estate	1	4.0	22	96.0
Services	0	0.0	17	100.0
Government	1	7.0	13	93.0
TOTAL	13		146	

PERT at the present time. Only one of the nonusers indicated that PERT had been used in the past, but was not being used at the present. Ten of the nonusers, or 6.9 per cent, indicate that their company is planning to use PERT within the next three years. The main reasons given for nonuse are: (1) unfamiliarity with the PERT technique; and, (2) inapplicability to company operations. Tables 3 and 4 give a breakdown of these replies.

A comparison of companies by size, responding to the questionnaire, is presented in Chart 1. A review of the 100 largest companies in each industry indicates that the responding companies are representative of their industry according to size. A tabulation of responding companies by industry and size is given in Chart 2.

As expected, PERT is used more by large companies, but is not confined to them. Twenty per cent of the companies with over 1,000 employees reported using PERT. PERT is used by 14.4 per cent of the

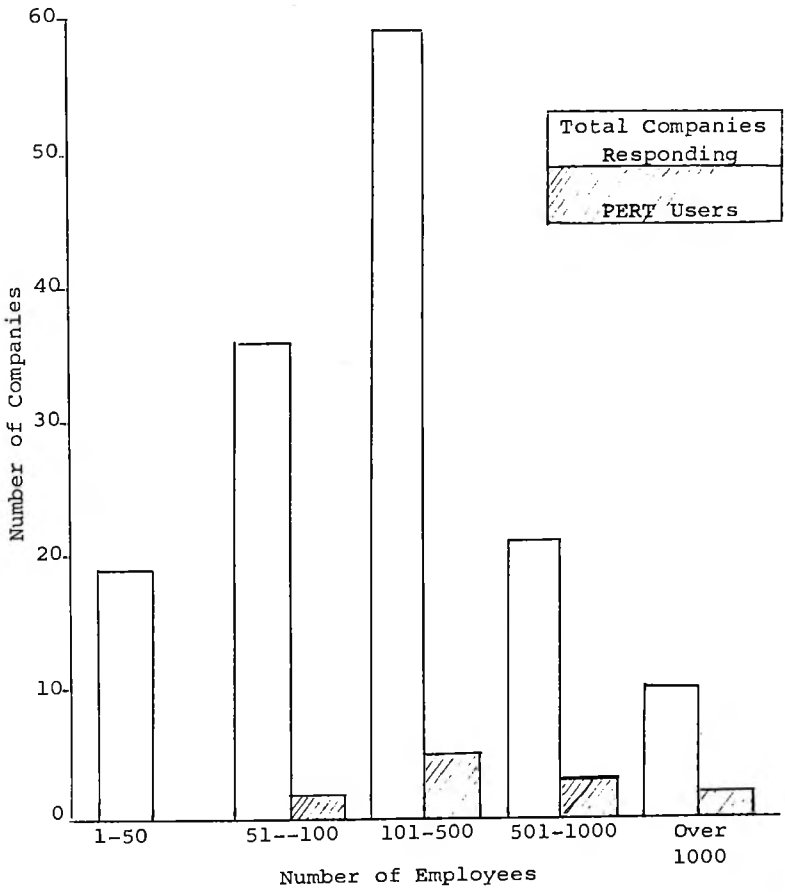

CHART 1. A DISTRIBUTION OF RESPONDING COMPANIES BY SIZE.

INDUSTRY	NUMBER OF EMPLOYEES					
	1-50	51-100	101-500	501-1,000	Over 1,000	Total
Mining	14	3	2	1	0	20
Contract Construction.	2	7	10	2	1	22
Manufacturing.	0	1	1	14	6	22
Transportation, Communication, & Utilities	1	7	8	1	1	18
Wholesale & Retail Trade	2	2	15	2	2	23
Finance, Insurance & Real Estate.	0	13	9	1	0	23
Services	0	3	14	0	0	17
Total.	19	36	59	21	10	145

CHART 2. NUMBER OF RESPONDING COMPANIES BY SIZE.

companies with 501 to 1,000 employees; 8.8 per cent of companies with 101 to 500 employees; and, 5.5 per cent of companies with 51 to 100 employees.

No companies with 50 or less employees were found to be using PERT. Apparently these companies are engaged in small projects where the use of complex management tools is unnecessary. In these situations management can visualize the entire job and anticipate problem areas without the use of formal networking tools.

The percentage of users by company size is plotted in Chart 3. The trend line begins at zero for companies with less than 50 employees and proceeds upward to the right at a relatively constant rate. Therefore, a definite correlation is indicated that as the size of the company increases, then the more likely the use of PERT. A likely assumption, therefore, is that a large per cent of companies with several thousand employees are using PERT.

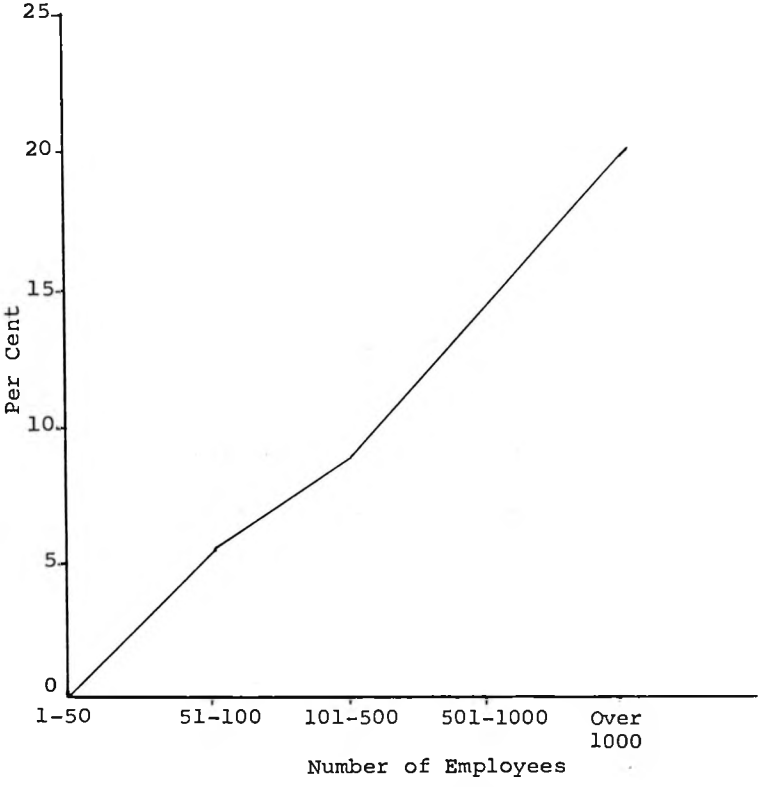

CHART 3. PER CENT OF RESPONDING COMPANIES USING PERT BY SIZE.

The governmental classification is omitted from this analysis because the employment figures are not obtainable. However, the one federal agency using PERT is in the more than 1,000 employee category and is engaged in construction of dams, locks, and other one-of-a-kind projects.

Question 2.--Has your company ever used PERT Time on any projects?

The one company (a construction company) that used PERT previously but has since discontinued its use, indicates that PERT was required on all the jobs in the past. Cost is given as a reason for the discontinued use of PERT, even though the costs fell between 1 per cent and 2 per cent of total project costs. This particular company had used PERT on eight different projects, ranging in time from 26 weeks to 64 weeks; 100 events to 600 events; and $400,000 to $2,240,000 --with a typical number of two major revisions in the network. This same company also believes that the use

of PERT neither saves time, saves money, nor provides greater control of the projects.

Question 3.--Does your company plan to use PERT within the next three years?

Ten of the nonusers expect to use PERT within the next three years (Table 3). The largest number of nonusers (3) are in the wholesale and retail trade. These ten nonuser companies consider that PERT can be used to good advantage in product distribution.

Question 4.--Are there any specific reasons why you are not using PERT?

Table 4 cites some of the reasons given for not using PERT. Forty-six, or 31.5 per cent, of the nonusers felt that PERT was inapplicable to their operations. Thirty-five indicated that they were not familiar with the technique. Many of those who feel the technique is inapplicable to their operations apparently may also be unfamiliar with PERT applications, since some of the companies in their industry indicated a satisfactory use of PERT. Since PERT and PERT/Cost

TABLE 3

NONUSER COMPANIES EXPECTING TO USE PERT WITHIN THE NEXT THREE YEARS

Classification	Number	
	Yes	No
Mining	0	20
Contract Construction	1	15
Manufacturing	2	16
Transportation, Communication & Utilities	2	16
Wholesale & Retail Trade	3	19
Finance, Insurance & Real Estate	0	22
Services	1	16
Government	1	12
TOTAL	10	136

TABLE 4

REASONS GIVEN FOR NOT USING PERT

Reason	Number
Inapplicable to our operations	46
Not familiar with PERT technique	35
Too costly	15
Other techniques give better results	12
Discontinued projects where PERT used	1
Found method unsatisfactory	2
No reason given	52
TOTAL*	163

*Multiple answers given in some instances.

were developed and applied to large, complex defense projects originally, many smaller, nondefense companies seem to think--without a valid basis, however--that the use of PERT and PERT/Cost is not applicable to their operations. The nonusers are generally in industries other than construction and manufacturing.

Users of PERT

Most users of PERT fall into the construction and manufacturing industry classifications; one user in the wholesale trade; one also in the insurance field; and one user in the governmental classification. Classification by industry permits the grouping of similar companies, thereby permitting their related activities to be correlated to the use of refined management techniques such as PERT.

The use of PERT was found to be directly related to the industry classification. The users of PERT are primarily in the construction and manufacturing industries, with rare exceptions of companies

in other industries applying this technique. The size of the company, as well as the type of activities performed, has some relationship to the use of PERT. The 13 respondents using PERT indicate the following breakdown in type of projects:

> Question 5.--In what kind of projects have you used PERT Time?

Table 5 indicates that the majority of the companies using PERT show that nonmanufacturing projects are the predominant type of work to which PERT has been applied. Its use in other types of projects is about evenly distributed.

> Question 6.--Of all projects PERT Timed in your company, what percentage have been: Commercial projects (nonmanufacturing); Defense projects; Industrial projects (manufacturing & fabrication); Service projects?

Number and kind of projects using PERT are grouped in Table 6 by distribution percentage. The frequency of PERT use when compared to different types of projects in a particular company indicates that PERT is used most often, and to a larger extent, in

TABLE 5

KINDS OF PROJECTS USING PERT

Kind of Project	Number
Commercial Projects (nonmanufacturing)	10
Defense Projects	4
Industrial Projects (manufacturing & fabrication)	5
Service Projects	4
TOTAL*	23

*Number exceeds thirteen because of multiple answers.

TABLE 6

PER CENT OF DIFFERENT PROJECTS
USING PERT

Kind of Project	Per Cent Distribution 0-25	26-50	51-75	76-100	Total Usage
	[No. of Projects]				
Commercial Projects (nonmanufacturing)	1	2	1	6	10
Defense Projects	2	0	0	1	3
Industrial Projects (Manufacturing & fabrication)	2	2	0	0	6
Service Projects	2	2	0	0	4
TOTAL*	7	6	1	9	

*The total exceeds thirteen due to different kinds of projects performed by the same company.

commercial projects. A further breakdown of use was requested in Item 7 of the survey questionnaire.

> Question 7.--In which of the following areas has PERT been applied in your company? (Check all answers that apply.)

Response to this question, summarized in Table 7, reveals that construction and machinery installation are the areas most often using PERT.

A computer is not mandatory to apply PERT to project planning. Four of the 13 PERT users do not have access to a computer. Logically, however, as the number of events increase, the complexity of manual applications is extended, and the use of a computer would ultimately be desirable.

Factors Influencing the Use of PERT

Many factors are considered in the decision-making process of selecting one management technique over all other possible tools. PERT rates high in some respects. The majority of PERT users indicate control of resources and saving of time as the leading factors

TABLE 7

AREAS AND FREQUENCY OF PERT APPLICATION

Area	Frequency of Use		
	Often	Frequently	Seldom
Repair & Maintenance	1	0	2
Research & Development	0	4	0
Product Distribution	1	1	0
Machinery Installation	2	1	2
Construction	4	5	3
Product Planning	1	0	0
Service Engagements	2	0	1
Others	0	3	0
TOTAL*	11	14	8

*Total exceeds thirteen due to multiple answers.

considered in their decisions to use PERT. Table 8 summarizes the responses to the following question:

> Question 10.--What are the major factors used to determine whether or not to use PERT in a project?

Two additional questions, relating to factors contributing to the selection of PERT, solicited answers which provide additional evidence of the validity of PERT as an effective management tool.

> Question 11.--Do you feel that the use of PERT saved time, saved money, gave greater control?

Of significant interest is the fact that one company indicated that contract requirement was the only factor used in determining whether or not to use PERT in a project. This same company stated that the use of PERT neither saved time, saved money, nor gave greater control to any of the six projects involved. The company's management may have resented being required to use PERT; therefore, management may have exerted little or no effort to make the technique work. Only one other company states that the use of PERT failed to save money (Table 9).

TABLE 8

FACTORS USED TO DETERMINE WHETHER TO USE PERT

Factors	Number
Contract requirement	5
Control of resources	8
Cost saving	5
Time saving	8
Complexity of project	1
TOTAL*	27

*Total exceeds thirteen due to multiple answers.

TABLE 9

BENEFITS DERIVED FROM USE OF PERT

QUESTION	In All Projects to Which Applies	To Majority of Projects	To only a few Projects	To None of the Projects	Total Firms
Saved Time?	5	5	2	1	13
Saved Money?	5	3	3	2	13
Gave Greater Control?	8	4	0	1	13
TOTAL*	18	12	5	4	39

*Totals exceed thirteen due to multiple answers.

Usually a company will make some effort to measure the success or lack of success of all major projects undertaken or new methods attempted. Measurement may be in quantitative form, or it may be based on the general knowledge of the personnel involved. If the success is not measured in quantitative form, then

the person attempting the measurement must have adequate experience and good judgment in formalizing the results of a new method, tool, or technique.

Question 12.--How does your company measure the success of PERT used in a project?

The success of many projects rests upon the attitudes and desires of those individuals who administer the project. Table 10 enumerates measures used to evaluate the performance of PERT.

Many of the companies listed more than one method used to measure the success of a project. Significantly, not a single company stated that it did not attempt to measure the success of PERT in a project. There is a fairly equal distribution of the number of times each of the measures were indicated. Some companies made a comment to the effect that "it just got the job done correctly and on time." This appears to be reward enough for many involved with the present-day complexities of work assignments.

TABLE 10

HOW THE SUCCESS OF PERT IS MEASURED

Measure Used	Number
Ability to meet schedules	11
Better informed personnel	9
Elimination of some costs	7
Better overall planning	10
Better coordination of projects	10
Other	1
No attempt to measure	0
TOTAL*	48

*Total exceeds thirteen due to multiple answers.

Responsibility for Applying PERT to a Project

The authority necessary to accomplish activities in an organization must be delegated to responsibility centers. Each company generally tries to assign duties to the department most logical for the performance of the task. A majority of PERT users have a specific department to which they assign the responsibility of applying PERT to projects.

Question 13.--Is there a specific department in your company to which the responsibility of applying PERT to a project is assigned?
Yes 9 No 4 .

There is wide divergence in the designation of the department responsible for applying PERT. Some of the typical names are revealed by answers to Item 14 of the survey questionnaire.

Question 14.--What is the name of the department?

The responses were:

1. Project Coordinating Department,
2. Planning and Scheduling Department,
3. Project Engineering Department,

4. Marketing Engineering Department,
5. Operation Research Department,
6. Scientific Application Section,
7. Office Engineering Department.

There is also a wide divergence in the title of the next higher level in the organization to which the person responsible for PERT reports. Even though there is a wide range of titles, they are all in the upper levels of the company's organizational structure. The replies to Question 15 are representative.

Question 15.--What is the title of the individual to whom the manager of this department reports?

The responses were:

1. President of Company,
2. Executive Vice-President,
3. Vice-President,
4. Vice-President of Marketing,
5. Director of PERT Activities,
6. Estimating & Scheduling Manager,
7. Engineering Manager,
8. Project Manager,
9. Chief of Computer Center.

The title of some of these individuals, in relation to the size of their companies, indicates that many managers are assigned dual responsibilities. A particular person may be selected because of his

proximity to the project involved and/or because of his knowledge of networking techniques. In either case, as the company expands and more projects utilize PERT, there is a tendency for the responsibility of PERT to be assigned to a specific department, with similarity of departmental titles as an end result.

> Question 16.--Does the department in charge of PERT perform (or is classified as) a line function or a staff function? (i.e., does it have the authority to implement a major activity or is it primarily an advisory group?)

Nine of the respondent users consider that the department performs a staff function, while three classify it as a line function. One company indicates that performance is a combination of the line and staff functions, with the department having authority to implement PERT activities as well as advise top-level management. This company is relatively small where dual responsibilities are a general rule for all departments.

> Question 17.--For projects where PERT is not required by contract, what is the title of the individual(s) who decides whether or not to use PERT on a project?

There is almost as much difference in the title of the person who decides whether or not to use PERT on a project as there is in the name of the department implementing PERT, or the title of the next higher level in the organization. Table 11 indicates the titles of persons responsible for this type decision making.

Use and Limitations of Time Estimates

Time estimates, to be acceptable, must be prepared by someone who has knowledge of the complexities of a project being performed. He must also be aware of the resources required to complete the job within the time limitation. There is a variance as to title of the department responsible for time estimates, but in each instance the department named is closely associated with the project.

> Question 18.--What department in your company makes time estimates for PERT?

Departments and the number of respondents making time estimates in answer to Item 18 of the survey

TABLE 11

IDENTIFICATION OF DECISION MAKERS ON USE OF PERT IN PROJECTS WHERE NOT REQUIRED BY CONTRACT

Title of Decision Maker	Number
Project Director	3
Program Manager	2
President	1
Division Chief	1
Plant Manager	1
Engineering Manager	1
Vice-President	1
District Manager	1
Marketing Engineer	1
Not Indicated	1
TOTAL	13

questionnaire are shown in Table 12.

Items 19, 20, and 21 in the questionnaire deal with single-time estimates; three-time estimates; probability estimates; and advantages of three-time estimates over use of single-time estimates.

> Question 19.--Does your company use a single-time estimate or three-time estimate?

Eleven of the 13 user respondents indicates the use of one-time estimates. One company reports that it uses three-time estimates, while one other company states that it uses the three-time estimates only if required by contract.

> Question 20.--Do you think that probability estimates are sufficiently accurate?
> Yes 4 No 9.

Even though only one company (in manufacturing) used the three-time estimates by choice, four of the 13 thought the three-time estimates to be sufficiently accurate to provide information on the range of completion times. The three-time users said that they are able to project the time and cost impact of three probabilities for achievement, but weighting the most

TABLE 12

DEPARTMENT MAKING TIME ESTIMATES

Department	Number
Project Manager	3
Responsible Department	2
Engineering and Estimating Department	1
Engineering Department	1
Division Sales Office	1
Estimating Department	1
All Departments Concerned	1
Marketing Engineering Department	1
Not Answered	2
TOTAL	13

likely heavily. This is an indication that some of the users of single-time estimates may possibly explore the use of three-time estimates in the future. The other nine respondents apparently doubt the accuracy of the three-time estimates, or do not understand the mathematical formulas.

> Question 21.--What advantages do you think using three-time estimates have over the use of single-time estimates?

Some respondents feel that three-time estimates have certain advantages over single-time estimates. These advantages are listed as follows:

1. More detail planning required;
2. More experienced people involved;
3. Provides a range of times;
4. Psychological effect--more realistic approach.

A noted advantage is that a project director using the three-time estimates is better able to plan other activities and to anticipate possible unfavorable situations. One manager explained that a psychological effect is experienced because the estimator is aware that the time durations are uncertain, and the three

possible time requirements correspond to the experience of the estimator.

> Question 22.--What disadvantages do you think using three-time estimates have over the use of a single-time estimate?

Since the majority of responding PERT users prefer the single-time estimates, there are apparently several disadvantages of the three-time estimates. Table 13 lists some of the disadvantages; the most prevalent disadvantage is the additional time required in making proper estimates.

The amount of time spent appears to be the predominant disadvantage to the use of the three-time estimates. However, some lack of interest may be due to the inexperience of the respondents in using three-time estimates. The use of three-time estimates may have many disadvantages, but such estimates demand thoughtful and detailed planning by the estimator. If the estimator is required to spend more time in planning, this requirement fulfills one of the primary advantages of the PERT technique, namely, thorough

TABLE 13

DISADVANTAGES OF THREE-TIME ESTIMATES

Type of Disadvantage	Number
Additional time required	5
Expense involved	3
Confusing to supervisors	3
Inaccurate	2
Less usable information	1
Invites carelessness	1
TOTAL*	15

*Total exceeds respondents because of multiple answers.

planning.

The project manager needs to know the total range of possibilities both as to time and costs. If he is given the extremes in time expectations, he can better coordinate other activities in the network to compensate for possible, but unanticipated delays, in the completion of activities. Since the testing of the use of the three-time estimates in a controlled environment is impossible because of the factors involved, the degree of favorable influence on the planning of a PERT project using this type of estimate can only be projected.

Training of Personnel
in PERT Techniques

To introduce any new method, tool, or technique, the staff involved must be considered. The personnel must have ample opportunity to become familiar with the details of any technique. They should know when it is to be used; how it is to be used; and probably most important, what benefits are to be derived from its use. Most people seem re-

luctant to change their habits and methods of performing work assignments. If a particular method was satisfactory in the past, the natural response often is why change to something unknown, expecially with this company.

Any new method or procedure must be conveyed to personnel who are eventually expected to use the method or procedure. The media employed to relay this information may be any one of several possibilities, or combinations of any number of situations. Depending upon the extent and complexity of a new technique, printed descriptions and illustrations may be given to the employee; seminars may be held; training films may be shown; demonstrations may be presented; or, actual training may be given on a project using the new technique. The method selected depends upon the complexity of the technique and the aims of higher management.

One of the frequent fallacies of top management is its failure to communicate benefits to the company

and to the individual derived from the successful introduction of a new method or procedure. If operating personnel are not convinced of the usefulness and benefits, then chances are relatively small that any new innovation will produce desired results. The amount and quality of training a person receives usually have a direct correlation with employee performance in the job.

> Question 23.--Does your company have a program for the training of personnel in PERT techniques?

Seven of the 13 respondent users answered in the affirmative to the above question while six stated that their company does not provide any particular training for its employees. The type of training is significant, especially where a company has had little or no experience in a particular area. Difficulty is encountered by employees learning PERT by on-the-job training when no other means of instruction is available.

> Question 24.--If answer to No. 23 is Yes, is the training formal (special program); on-the-job; both?

Three of the reporting companies provide formal training only for their employees in the use of PERT techniques (Table 14). One company provides all the training on the job, while three companies make use of both methods. One of the companies, utilizing formal and on-the-job training, indicates that the formal portion amounts to approximately 5 per cent, and on-the-job training accounts for the remaining 95 per cent. Two companies using both methods split the training about equally between formal and on-the-job. Logically, the use of joint methods of training provides the best orientation in most circumstances. Basic facts may be learned with minimum difficulty in a formal atmosphere with application of such facts becoming solidified in actual demonstration.

The selection of personnel to be given special training is of prime importance in evaluating the ultimate success of any program.

TABLE 14

TYPE OF TRAINING FOR PERT

Type of Training	Number
Formal (special program)	3
On-the-job	1
Both types	3
TOTAL	7

Question 25.--What are the minimum requirements necessary for personnel to participate in this training program?

As revealed in Table 15, three of the responding companies require a bachelor's degree, and two companies require at least a high school education for participation in the PERT training program. This educational prerequisite indicates that a larger percentage of the younger employees may meet the minimum requirements more often than employees who have been with the company for a long period of time. Younger employees may also possess the broad formal education that is needed, and

TABLE 15

REQUIREMENTS FOR PARTICIPATION
IN TRAINING PROGRAM

Type of Requirement	Number
Education	
Bachelor's Degree	3
High School	2
None Given	2
TOTAL	7
Experience	
One Year	2
Some Experience	3
None Given	2
TOTAL	7
Other	
Some Demonstrated Knowledge	4
Minimum Level in Organization	1
None Given	2
TOTAL	7

younger personnel appear to be more receptive to change.

Most of the companies require participants to have at least some experience before beginning a training program. This requirement gives employees an advantage of familiarity with newer techniques and a wider range of association of knowledge gained in practical situations.

Analysis of PERT/Cost Users

Since PERT/Cost is considered by many to be a practical and desirable addition to the cost element in the time network, the remainder of the survey questionnaire used in this study is devoted to questions relating to PERT/Cost. When composing the questionnaire an assumption was made that if PERT Time were not used, the use of a costing technique identified as PERT/Cost would not be feasible. Therefore, the questionnaire requested companies not experienced with the use of PERT Time to omit all questions after No. 4.

Question 26.--Is your company using PERT/Cost now?

A tabulation and classification of responses based upon thirteen respondent users of PERT Time is shown in Table 16. It is noted that one respondent had used PERT Time, but was not using it at the present.

PERT/Cost use continues to lag behind the use of PERT Time. PERT/Cost is a newer technique, and an important fact to be noted is that cost estimates are somewhat more difficult to make than time estimates. Also, there is no widely known and accepted method for making pessimistic, most likely, and optimistic cost estimates similar to time estimates.

Conceivably, PERT/Cost will become more widely used when difficulties with cost estimates are minimized. Table 17 lists findings that certain companies that certain companies that once used PERT/Cost have discontinued its use for various reasons.

Two companies that had used PERT/Cost, but discontinued its use, estimate the expense of operating the cost system as falling between 1 per cent and 2 per

TABLE 16

PERT TIME USERS EMPLOYING
PERT/COST

Industry	Number	
	Yes	No
Construction	1	6
Manufacturing	2	2
Wholesale & Retail Trade	0	1
Finance, Insurance & Real Estate	0	1
Government	1	0
TOTAL	4	10

TABLE 17

PRIOR USERS OF PERT/COST WHO HAVE DISCONTINUED*

Industry	Number	
	Yes	No
Construction	2	4
Manufacturing	0	2
Wholesale & Retail Trade	0	1
Finance, Insurance & Real Estate	0	1
TOTAL	2	8

*Based on the ten nonusers of PERT/Cost but using PERT Time.

cent of total project costs. In these cases, PERT/Cost had been a contract requirement for both respondent companies. The difficulty of obtaining proper input information is the primary objection to the use of PERT/Cost in many other situations.

> Question 28.--If your company has never used PERT/Cost, does it plan to use PERT/Cost within the next three years?

Number of companies expecting to use PERT/Cost within the next three years is indicated in Table 18. This total is a substantial percentage of the PERT users, indicating confidence in wider use of the technique.

As revealed by the answers to Question 4 on the survey questionnaire, one of the principal reasons given for nonuse of PERT Time is lack of familiarity with PERT techniques. As more companies become familiar with this new technique through certain channels [i.e., literature, association with user companies, and practical experience], application of PERT/Cost should increase. The actual techniques adapted may not neces-

TABLE 18

ANTICIPATED USE OF PERT/COST*

Industry	Number	
	Yes	No
Construction	2	4
Manufacturing	2	0
Wholesale & Retail Trade	0	1
Finance, Insurance & Real Estate	0	1
TOTAL	4	6

*Based on the ten nonusers of PERT/Cost but using PERT Time.

sarily be an exactness of PERT/Cost, but may reflect modifications individual companies find, through experience, that meet special or unique needs.

As previously stated, PERT/Cost as a management control tool has proven to be one of the most difficult to apply. Most of the companies responding do not rely upon a single department to determine the cost estimates, but tend to gather cost information from several sources. One company states that it requested data from the most experienced and most knowledgeable individual or department involved.

Question 29.--What department makes cost estimates for your company?

A breakdown of departments making cost estimates, as reflected by responses, is given in Table 19. The engineering and accounting departments are most frequently requested to make cost estimates. Some of the companies are too small to adequately staff a specialized PERT department. An added disadvantage

TABLE 19

DEPARTMENT MAKING COST ESTIMATES

Department	Number
Engineering	5
Accounting	4
PERT	1
From Contractor's Bids	2
Estimating Department	1
Department Responsible for Activity	1
TOTAL*	14

*Total exceeds number of user companies because of multiple answers.

in this area is that the amount of PERT activity usually does not warrant a separate department in many of the respondent user companies, thus shifting the responsibility to the engineering and accounting departments.

> Question 30.--Does your company estimate cost for each: Activity; Work Package; Other? (specify)

Most companies estimate costs by activities, but some companies estimate cost on the entire work package. Table 20 furnishes data on companies' use of activities and work packages as units for estimating costs. A work package, as a unit for estimating costs, may contain one or several activities. A breakdown by activities provides more detail in most instances, and also provides for increased accuracy in cost estimates. One company reports that it is very satisfied with the results of cost estimates by work packages. The methods employed in collecting cost data have a positive in-

TABLE 20

UNITS FOR ESTIMATING COSTS

Unit	Number
Activity	5
Work Package	3
TOTAL*	8

*Total exceeds number of users due to multiple answers.

fluence on the validity of the cost obtained. Since PERT/Cost is used primarily on "one-of-a-kind" projects by a company, the determination of the best media available for making cost estimates is necessary.

Question 31.--How are the cost estimates determined?

All the companies using or having used PERT/Cost rely on the engineering department to prepare cost estimates and then refer to accounting records for a comparison with actual cost information of similar activities. Cost records were used only to a limited

TABLE 21

MEDIA FOR DETERMINING COST ESTIMATES

Media	Number
Accounting Records	4
Engineering Analysis	6
Manhour Requirements	1
TOTAL*	11

*Total represents multiple answers.

extent. The dissimilarity of activities was one reason for this action, but substantial changes in cost of activities on one project and cost of like activities on later projects was the basic factor.

Contributions and Limitations of Accounting Records

PERT/Cost is not a complete accounting system; it depends on a sound cost accounting system as its basis for effective operation. An organization's cost accounting system must provide the cost data in proper form to be accumulated into work packages for reporting

and control. With varying degrees of change, a company's accounting system can be modified to provide data for PERT/Cost reports and conventional reports, with little extra effort or expense.

Many companies are hesitant to make major changes in the accounting systems until they are convinced that a change is feasible. Probably, companies that fail to take advantage of the information and records to which they have immediate access, experience the least success with any new technique or procedure. However, the answers given may be of value to present or future users.

> Question 32.--If your company does utilize the accounting records in determining cost estimates, how are they utilized?

Existing accounting records are well suited for a PERT/Cost adaptation, but some companies are not utilizing these records effectively for optimum reporting and control.

> Question 33.--What have been the major contributions of your historical accounting records in PERT/Cost estimations?

TABLE 22

HOW ACCOUNTING RECORDS ARE UTILIZED

Method	Percentage of Replies
To help establish bid prices	50.0
Similar to standard cost system	33.0
No Reply	17.0
TOTAL	100.0

TABLE 23

CONTRIBUTIONS OF HISTORICAL ACCOUNTING RECORDS TO PERT/COST ESTIMATES

Contribution	Percentage of Replies
Provide for better accuracy	33.0
Provides breakdown of activities	33.0
None	17.0
No Reply	17.0
TOTAL	100.0

Question 34.--Have you made any major changes in your accounting records to facilitate cost determination for PERT/Cost projects? Yes 1, No 5

One company, reporting a change in accounting records to facilitate cost determination in Item No. 34 of the questionnaire, listed only one change. This company revised its entire coding (or numbering system) to accommodate the accumulation and summarization of cost data into responsibility areas or cost control centers.

Question 35.--What was the nature of such changes?

One company states that it is reconstructing its entire accounting system as part of an overall project control system, which will also provide information in usable form for PERT/Cost activities.

Question 36.--Do you contemplate any changes in your accounting records to comply with PERT/Costing? If Yes, what is the nature of these changes? Yes 3, No 3.

Several other companies are considering some changes. The changes anticipated in the accounting records reflect the apparent inadequacies of present

TABLE 24

CONTEMPLATED CHANGES IN ACCOUNTING SYSTEMS

Changes	Number
More specific cost collection	2
Refinement of cost breakdown	1
Major change in account numbering	2
TOTAL*	5

*Exceeds number contemplating change because of multiple answers.

accounting records.

Question 37.--What area in your accounting system is considered inadequate for proper utilization in PERT/Cost implementation?

All responses refer to one broad idea--cost behavior and responsibility accounting. Management realizes the need for a change in the traditional accounting methods to generate the type of information needed for a total information system. The change to

TABLE 25

INADEQUACY OF ACCOUNTING RECORDS

Area	Number
Improper breakdown of costs	2
Numbering system	2
More detail cost accounting	1
TOTAL*	5

*Exceeds number anticipating changes because of multiple answers.

a total information system has a definite impact on accounting. Accounting records adequate for previous methods of reporting are inadequate for the required breakdown and accumulation of cost necessary for the new reports.

Question 38.--Do you feel that the use of PERT/Cost: Saved Money? Gave Greater Control?

Again, one of the responding companies using PERT/Cost only because of contract requirement, indi-

TABLE 26

BENEFITS OF PERT/COST

Benefit	In All Projects to which Applied	To Majority of Projects	To Only a few Projects	To None of the Projects
Saved Money?	2	2	1	1
Gave Greater Control?	3	1	1	1
TOTAL	5	3	2	2

cates that its use neither saves money nor gives greater control. There may be some bias involved here, if the policy requirement was resented by management.

> Question 39.--What is the estimated cost of operating a PERT/Cost System, in your company, as a per cent of total project cost?

The costs of operating a PERT/Cost system are not deemed to be substantially high, even in the company reporting use of the tool only when required.

One company states that the cost of using

PERT/Cost on a project has varied, but has not exceeded 2 per cent of total project cost. This experience suggests that the more complex the project, the greater the cost of the PERT/Cost system.

The determination of exact costs in applying PERT/Cost estimates to a network is difficult. Even more difficult is the quantification of the cost savings incurred because of the use of certain control techniques. Many of the avoidable costs can be easily seen, but some unavoidable costs may never be considered.

> Question 40.--Have you made any modifications in the basic PERT and PERT/Cost approach? Yes __2__, No __4__. If Yes, what are these modifications?

Most management control techniques are subject to change or modification to fit the particular needs of the using company. PERT/Cost is no different. Two of the six user companies made some changes in the PERT and PERT/Cost technique.

TABLE 27

COST OF OPERATING A PERT/COST SYSTEM

Cost	Number
Less than 1 per cent	2
One per cent, but less than 2 per cent	4
TOTAL	6

The two companies reporting modifications in their application of PERT and PERT/Cost list the following:

1. Changed the numbering technique of events;
2. Used time-scaled, space oriented bars for activity indicators;
3. Used mid-activity nodes (events) on non-computerized schedules;
4. Changed to fit the specific company's requirements.

Question 41.--What have you found to be the major problems in applying PERT and PERT/Cost techniques?

The fact that management is not convinced of the usefulness of PERT/Cost is a frequently stated problem reported by responding companies. If management is not "sold" on a particular method or technique, then the chances for success of the particular innovation are minimized. Five companies do not list any existing problems; either they do not actually have any major problems, or these companies have not attempted to use PERT/Cost techniques.

Question 42.--What PERT and PERT/Cost Output Report(s) does your company use?

Timely and pertinent reports are a prerequisite for the proper utilization of any management control technique. PERT and PERT/Cost techniques are basically "management-by-exception" tools to monitor and control projects of a complex nature. A lack of any one of the vital reports weakens a manager's ability to accomplish tasks in keeping projects operating smoothly and

TABLE 28

MAJOR PROBLEMS IN APPLYING
PERT AND PERT/COST

Problem	Number
Management skepticism	6
Cost of implementation	5
Lack of adequate training	2
None listed	5
TOTAL*	18

*Total exceeds number of PERT users because of multiple answers.

orderly. Six companies did not indicate that they are using any form of out reports (Table 29). If this is actually the case, it is doubtful that these companies receive any of the benefits made possible by these techniques. Some companies list the use of as many as five different output reports. The value of any report depends upon how it is used. If the report is not used, then it not only represents

TABLE 29

PERT AND PERT/COST OUTPUT REPORTS*

Kind of Output Reports	Number
Program/Project Status Report	7
Management Summary Report	6
Schedule Outlook Report	6
Financial Plan & Status Report	3
Manpower Loading Report & Display	3
PERT Milestone Report	3
Problem Analysis Report	2
Cost of Work Report	1
Others	2
None Given	6
TOTAL**	39

*Examples of Output Reports are given in Appendix B.

**Total exceeds number of PERT users because of multiple answers.

unnecessary costs, but it also may cause confusion among personnel having access to the report.

Summary

Chapter IV sets forth the findings from a survey of over 150 companies selected at random from the 100 largest companies in each of the eight major industrial classifications in the State of Alabama. A study was made to determine the extent of PERT and PERT/Cost use in nondefense companies in Alabama by examining: (1) type of projects using PERT and PERT/Cost; (2) reasons for use; (3) cost of use; (4) training employed; (5) procedures for making cost estimates; (6) use and limitations of accounting records; and, (7) advantages and disadvantages of this relatively new management control technique.

The results of the questionnaire answer some of the questions concerning PERT and PERT/Cost. Moreover, the study may possibly motivate others to make in-depth investigations of some of the problem areas discussed.

Thirteen of the 159 respondents, or 8.2 per cent, report using PERT; ten additional companies anticipate its use within the next three years. The most frequent reason given for nonuse of PERT was the feeling that it is inapplicable to company operations. The reasons for nonuse of PERT do not reflect any significant difference as to industry classification.

The use of PERT is related to industry classification, with the construction industry leading with approximately one-half of the total users of PERT reporting. Manufacturing shows the next highest users. However, there is noticeable interest in PERT by companies outside the construction and manufacturing industries. Most of the projects using PERT are nonmanufacturing, with construction reporting the most predominant area of use.

Control of resources and time savings are major factors used in deciding whether or not to use PERT on a given project if its use is not already a con-

tract requirement. The complexity of projects is cited only once, which seemingly indicates that many of the jobs are not so complex as to be considered a factor.

Most of the respondents feel that the use of PERT saves time and money, as well as giving greater control on all, or most all, of the projects using PERT.

One of the attributes of a good manager is his ability to measure the success of an endeavor. Management techniques are no different; they must be measured in some manner if management is to continue to place sufficient confidence in the technique to make it work. Only one company indicates that it did not make any attempt to measure the success of PERT; all the other companies list two or more methods in use.

There is a wide range in the findings of certain departments being given the responsibility of applying PERT. However, each department is in the

higher levels of management and reports to top management--a fact which indicates the importance of the PERT and PERT/Cost technique.

Time estimates are one of the most important aspects of networking techniques. The majority of respondents assign the responsibility of making time estimates to the personnel or department most closely involved with the project under consideration. The single-time estimate is used most often since a number of companies feel that the three-time estimates do not offer any better results. Moreover, three-time estimates often prove confusing to the supervisors involved.

Some form of training is necessary for understanding and acceptance of new and complex techniques. One of the objectives of the study is to ascertain if any training is given, and the type of training and qualifications necessary for individuals to be accepted for training. On-the-job training is emphasized, and

at least a high school education is required for employment. Some companies set a minimum requirement at the bachelor's degree level. Most of the companies expect their employees to have some experience, even of a limited nature, before beginning formal training.

As expected, the use of PERT/Cost is found to lag behind the use of PERT. Two of the principal reasons for this lag are: (1) PERT/Cost was introduced approximately four years after PERT; and, (2) the cost estimates are more difficult to make than the time estimates. Additional companies plan to use PERT/Cost within the next three years; this trend should continue as the number of companies gaining experience in the use of this management tool increases.

Companies have not fully utilized their accounting records to supply management with cost information to use in PERT/Cost projects. In most cases, present accounting systems need to be revised to accommodate the gathering, summarizing, and reporting of cost data along the line of responsibility accounting.

There are certain major changes contemplated in the accounting records to meet the needs of the PERT/Cost technique.

Most PERT/Cost users responding to the survey questionnaire have experienced personnel problems in the application of this management tool. Cost of implementation is an important factor, but a large number of companies feel that management skepticism is more prevalent.

A management control technique, to be effective, must provide adequate reports on time for management use. An attempt was made to ascertain the kind of reports used most often by companies employing PERT and PERT/Cost. Many companies list several different types of reports being used, but one company did not use any type of special report to management. The ability to manage by exception, a strong point of PERT and PERT/Cost, is less effective if the exceptions are not made available for review.

This study does not provide definitive answers or solutions to many of the problem areas of the PERT systems currently in use, but the study does offer useful information and general insights into uses of PERT and PERT/Cost in Alabama. The study also poses additional questions that may be worthwhile to pursue in greater depth and at a later time. Some of these pertinent questions are outlined and discussed in Chapter VI, the concluding section of the study.

Chapter V deals with major factors affecting the use of PERT and PERT/Cost. A presentation and analysis of these problem areas are covered in detail in the chapter.

CHAPTER V

FACTORS AFFECTING IMPLEMENTATION AND OPERATION OF PERT AND PERT/COST

Problem Areas of Implementation

The general lack of utilization of PERT and PERT/Cost by a large segment of industrial companies is in many respects an understandable fact. This lack, however, is unfortunate because improved management techniques are essential to cope with increasing technical complexities.

The basic purpose of PERT and PERT/Cost--to provide information needed for effective decisions, ensuring that projects are completed successfully within the limitations of time, cost, and available resources--too often is misunderstood. Some of the problems are possibly inherent in the system, but many other problems are either avoidable or subject to solution by

an alert and competent management.

The problem areas discussed in this chapter are of primary importance. Identification of these specific areas results from: (1) research of the literature; (2) analysis of questionnaire responses; and, (3) interviews with individuals.[1] No attempt is made to enumerate or discuss all problem areas in the implementation of PERT and PERT/Cost. Such an attempt would not only be impossible, but would serve no worthwhile purpose in the research design of this study.

Any one or a combination of problem areas discussed may be present in any new management system. However, emphasis is on areas that specifically hinder the implementation and use of PERT and PERT/Cost. The following factors focus attention on representative

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[1]Problem areas are identified on the basis of a synthesis of all three sources of information; it is difficult to attribute a specific problem to any one of the three types of source material as an exclusive factor. The writer also assured persons interviewed and questionnaire respondents that all replies would be kept confidential. However, the writer has made selective use of reference citation where itwas possible to do so.

areas which seem to hinder present and potential use of the system. Order of arrangement of the factors does not imply a position of importance of one problem area over any other; such a comparison is indeterminate at this time.

Skepticism of Management

PERT and PERT/Cost use can realize ultimate success only if the system is endorsed by top-level management, and is viewed as an aid to decision making, planning, and controlling projects.[2] The system is not designed to solve any problems, nor to make any decisions. Its use, however, clearly points out possible problems at an early date and indicates the effects of certain decisions. Management alone can make decisions, but with complete and timely information supplied by PERT and PERT/Cost, more pertinent and timely decisions can be reached.

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[2] Information from confidential interview; see also, *supra*., pp. 91 - 92 for discussion of this problem area in terms of information gained from the survey questionnaire.

Management has seemed skeptical in applying this system to its operations. The presence of one or a combination of factors may be sufficient to defeat its implementation and utilization.

> The one major obstacle standing in the way both of initial adoption and of full utilization of the PERT system can be characterized as 'resistance to change.'[3]

Hostility toward change is a basic problem of human nature. Many managers tend to resist changes they do not understand; they tend to resist changes that appear to threaten basic securities; and they tend to resist the use of force in initiating change.[4]

For any innovation to be fully accepted, it must satisfy a basic need. This need must be present in the minds of the operating personnel in industrial organizations.[5] For example, employees of a certain company were required to use PERT on a project after

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[3]Peter P. Schoderbek, "Overcoming Resistance to PERT," Business Topics, Vol. XIV (Spring, 1966), 52.

[4]Ibid.

[5]Information from confidential interview.

it was completed to comply with government regulations. Additional reports were prepared to supplement the regular reports to management. There was no felt need for these additional reports, and some resentment was expressed by participating individuals.[6]

Managers and personnel using the PERT and PERT/Cost system must be thoroughly convinced of the benefits to be derived. Sufficient knowledge of the basic fundamentals of the technique tends to decrease skepticism.

Lack of Training in PERT and PERT/Cost

Managers and operating personnel should receive training in the elementary fundamentals of network development, resource leveling, and other pertinent aspects of the PERT and PERT/Cost system. Personnel must understand the capabilities and limitations of the technique as a managerial tool; they must be able to furnish proper and timely input data; and they must be

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[6] Schroderbek, op. cit., p. 52.

competent in interpreting and using the output reports for the efficient utilization of the technique.[7]

Selected personnel can be trained in special workshops and schools to relay this training to other employees involved in the overall project. Seminars may be conducted by outside experts or by company-trained personnel before actual introduction of the PERT and PERT/Cost technique.

A search of the literature and personal interviews conducted reveal that many companies do not have any type of formal training for current or new personnel in the operation of a PERT and PERT/Cost system. In implementing the technique, the essential "why" is difficult to relay in a manner other than a formal training program. If the new system accomplishes all that it purports to do, then it is worthwhile to conduct special sessions or seminars to convey basic facts and to minimize false or erroneous assumptions.

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[7]Wilbur R. Ross, "Management Acceptance: Potential-Barrier to PERT/Cost Implementation," Management Accounting, Vol. LXIX (January, 1968), 59.

Job experience is also necessary for full comprehension of any new technique; PERT and PERT/Cost use is no exception. However, job experience alone cannot effectively familiarize management and operating personnel with all the details of this system.

In rank of importance, the "why" of a program probably supersedes the "how" aspect.[8] In both approaches, however, the practical advantages and the present and future rewards of the system should be emphasized.

The initial training program should be devoted to emphasizing the "why" of PERT and PERT/Cost. Natural resistance to change must be overcome and managers must be convinced of the substantial benefits to be derived from the use of the technique. A suggested second phase of the training program can be devoted to basic mechanics of networking, scheduling, time and cost estimating, resource leveling, and problem solving. Managers will be firmly convinced only after the system has actually

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[8] Information from confidential interview.

proved successful.

Top levels of management must assume the responsibility for keeping abreast of new developments in scientific management techniques being successfully used in related industries. These top-echelon levels can take the lead in adopting techniques that are superior to any system currently in use.[9] Much of the success of PERT and PERT/Cost depends on this favorable attitude which should permeate the operating levels.

Misplaced Responsibility for Planning and Scheduling

A frequent mistake made by companies is to delegate responsibility for planning and development of schedules to junior staff members, or to a selected group of specialists. If operational managers are not identified with planning and scheduling during the preparation stage, they often feel little responsibility for seeing a program through to successful completion.

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[9] Information from confidential interview.

This type situation may result from: (1) error in assigning personnel to the PERT/Cost team; (2) faulty or inadequate understanding of the team duties and/or responsibilities; or, (3) insufficient knowledge of the PERT/Cost approach.[10]

Some managers think it not only advisable but necessary to utilize experienced junior-level staff members in certain phases of preparing network diagrams and developing schedules.[11] Details of updating and monitoring the system can best be performed by these employees, leaving basic planning to top-level management and staff in charge of specific areas of the overall project. This latter group of personnel is in a position to be most knowledgeable of how the program should be performed, and how it is likely to progress. By wise and delegated patterns of responsibility, management is more likely to realize success in

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[10] Ross, op. cit., p. 59.

[11] H. P. Connor, "The Construction Industry--Use and Misuse of CPM," The Canadian Chartered Accountant, Vol. LXXXIX (December, 1966), 427.

planning and scheduling operations.

The PERT and PERT/Cost team must be competent and cooperative in directing activities of the project. The primary duties of the team are: (1) to perform the routine details of the system; and, (2) to provide operating managers with concise and useful output reports.[12]

Inadequate Resource Allocation

A responsible planner, in developing a network diagram, can depict graphically how and when the activities are likely to occur to complete a project on time. The first phase of a schedule may indicate manpower requirements in excess of those available at a specific time period or for a specific skill. Some reallocation of the resources from activities with slack to activities on the critical path may be necessary. A further rescheduling of some of the activities with slack may be necessary to coincide these activities

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[12] Ross, op. cit., p. 59.

with other activities on the critical path that require more manpower. The success of the PERT schedule depends, in part, on how well the resources are allocated to achieve desired goals.

The planner should keep the three basic types of constraints under consideration: (1) physical constraint; (2) policy constraint; and, (3) resource constraint.

Physical constraint.--In the development of a project, certain activities or tasks must be performed before completion of other tasks is physically possible; i.e., the foundation of a house must be completed before the framing can be done.

Policy constraint.--Top management decides that the work will be done in a specified manner. This designated manner may or may not be the most efficient plan, but under this type constraint the PERT team must also plan accordingly.

Resource constraint.--This constraint is possibly the most frequently forgotten one in the

planning stage. Many managers do not give sufficient consideration to resource constraint in network planning. Consequently, the network reveals enormous peaks in the resources required during certain time periods, and shows idle resources at other times. Manpower fluctuations are expected on most projects, but both management and company should make serious attempts to schedule the activities so that available resources are fully utilized.

Establishing time estimates for activities is dependent on both quality and quantity of resources available. Each activity should be planned to use the optimum level of resources, taking into consideration anticipated constraints. A resource chart for each type resource should be prepared to show the total resources required each day, assuming that each activity is to start on its earliest beginning date. If the total resources required exceed the resources available for any day, then the starting date for some of the activities can be adjusted withhin the available slack

time to initiate resource leveling.[13] By using this procedure, resource requirements can be kept to a minimum, and fluctuations will be reduced with little or no effect on the scheduled completion date. One author noted:

> . . . that in terms of actual experience with PERT, the process of network development forces more problems of resource constraint or loading analysis into the open for resolution than do other planning methods.[14]

Frequency and Updating of Schedules

The frequency of updating of schedules is a major problem facing most PERT and PERT/Cost users. Updating or re-estimating performed too frequently becomes a mechanical chore and is neither practical nor economical. Management may desire revised

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[13] Wilbur R. Ross, "PERT/Cost Resource Allocation Procedure," The Accounting Review, Vol. XLI No. 3 (July, 1966), 469.

[14] Robert W. Miller, "How to Plan and Control with PERT," Harvard Business Review, Vol. XL, No. 2 (March-April, 1962), 98.

schedules as added information is secured after a project is begun; but unless there are significant discrepancies, the variance can best be analyzed and reported through special reports. "The adulteration of critical data with routine data tends to diminish the effectiveness of the 'management by exception' reporting capability inherent in the PERT/Cost system."[15]

At the other extreme are problems encountered when companies do not monitor their progress or update the schedule once the PERT network is completed. Thus, these companies are using PERT and PERT/Cost for planning only, and in doing so fail to take advantage of the benefits of control. This factor is possibly understandable in actual practice, but violates the principle of the PERT and PERT/Cost system. A finding from interviews conducted in the research of this study reveals that top-level management usually participates in the planning of projects and establishes broad

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[15] Peter P. Schoderbek, "Is PERT/Cost Dead?" Management Services (November-December, 1968), 48.

policies for performance of the task; then superintendents are generally given a wide scope of power and freedom to carry the project to completion. In some cases, however, a superintendent is given complete responsibility of the project, even to the exclusion of top-level management.[16] This latter practice seems to be an unsafe business procedure although it may work in any situation where there is a competent and dedicated superintendent.

With the systematic updating of schedules, management is able to determine the quality of work of personnel who have been assigned to a given project. Orderly updating of schedules will indicate whether or not a project is "on schedule;" this information gives management notice of possible delays in final completion of the task at hand. Once significant slippage is indicated, top-level management should take an active role until the project is back on schedule, or is being performed satisfactorily once again. Manage-

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[16] Information from confidential interview.

ment, by using this procedure, can be certain that its planning and policies of performance are being carried out, and that the task will be successfully concluded.

The frequency of updating schedules is a management responsibility, and as such, should be left to the discretion of this echelon of authority. Updating is probably of more importance during the early part of an assignment when a large part of the total project is still in progress. Interviews with officials who contributed their experiences to this research indicate the following generalization:

> . . . we [the company] do not update schedules after the project is more than half completed because it provides little of value and we usually cannot alter our plans sufficiently to justify the modification in schedule.[17]

Orderly and timely updated schedules which are in turn well monitored is a vital element in the planning and control function of the PERT and PERT/Cost system.

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[17] Information from confidential interview.

Use of Improper Reports
to Management

A common misconception of the operating managers is that a large portion of their time will be taken up in preparing and reviewing PERT and PERT/Cost output reports. A manager spends much time in the initial planning stage in work breakdown structure development, end-item work package determination, network development, and time and cost estimating.[18] However, the major portion of a manager's "paper work" is in the planning stage, and decreases after the plan becomes operative.

Some PERT and PERT/Cost users become overly enthusiastic with the quantity of data available in the system and prepare useless schedules and reports. "One of the most common weaknesses of PERT/Cost is the over reporting of data."[19] The use of computers in a PERT/Cost system generates production reports for any type information at any specified and desired level.

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[18] Ross, "Management Acceptance: Potential Barrier to PERT/Cost Implementation," op. cit., 59.

[19] Schoderbek, "Is PERT/Cost Dead?" op. cit., 46.

Unless required by contract, the type and number of output reports varies, depending upon the needs of management.[20] A related factor is that some managers tend to believe that the greater the amount of information received, the better the decisions become. Of particular importance is the fact that the amount of updated information will not in itself lead to wiser decisions. Not only is the extra and useless data costly, but may also actually hinder the decision-making process.

At the other extreme is the company which fails to prepare a sufficient number of reports. Some of the respondents to the survey questionnaire used in this study indicate the use of very few reports, and at least one company did not use any type of output report. Companies using too few reports for project review do not benefit from one of the most important elements of PERT and PERT/Cost--the control feature.

Management should decide in advance what type

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[20] For a discussion of this problem area see supra., pp. 137-138 for information gained from the survey questionnaire.

of information is desired and the frequency needed. Adequate information should be provided at each level in the organization for control of resources. Charts and graphs may be more meaningful to some managers than elaborate printed schedules of data. The management-by-exception principle is of maximum usage when output reports are sufficient to call attention to deviations from the original planning. The individual company must decide, however, what and how much information it can utilize, and at what intervals such updated information is desired.

Invalid Estimates

The effectiveness of the PERT and PERT/Cost system depends heavily on the reliability of obtained data. When the level of available resources is known, application of PERT and PERT/Cost presents fewer variables. Since the technique facilitates organization and use of large amounts of data, there is a danger that results will be accepted as absolute, losing sight of the fact that they are based on esti-

mates of time and cost. Estimates of activity duration and resource requirements are of primary importance, but managers must remember that they are simply estimates. However, the estimates correlates almost equally to precision of expected results and support from operating personnel. Inadequate estimates or estimates with a lower degree of accuracy, moreover, are better indicators of expected results than the use of no estimates. The importance of estimating time and cost needed to perform an activity is best illustrated by the fact that time and cost are impossible to indicate exactly until an activity is completed.[21]

Management is often faced with completely invalid estimates that tend to defeat the success of the entire system. Time and cost estimating is too often the delegated responsibility of individuals who lack sufficient familiarity with the overall project. This factor was found to be particularly emphasized

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[21] Information from confidential interview.

in respondent companies that maintain a PERT and PERT/Cost team for developing the networks for a given project. Misplaced responsibility of estimating time and cost often results in the failure of companies to make use of the advantage of a valuable asset--the experience of their own operating personnel.

There must be a concise item delineation in the work breakdown stage, even when an estimater has much experience, for clear identification of work packages to obtain desired results. Therefore, time estimates and estimated dates of completion of a project, unless delegated to experienced and knowledgeable personnel, can be less than realistic.[22]

Four basic steps are necessary for valid estimating:

1. Consideration of the resources available;
2. Development of a method of performance by determining the type of resources to use;
3. Calculation of duration of use for each

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[22] Schoderbek, "Is PERT/Cost Dead?" op. cit.

resource; and,

4. Conversion of all resources used to the common factor of dollars.

The method of performance determines the duration of an activity, and in turn, the duration of an activity influences the cost since there is a definite relationship between time and cost to perform an activity.

Estimating time and cost is not a simple procedure; it is a skill that requires a high degree of experience. Networking techniques isolate the required estimates into easily manageable units. PERT and PERT/Cost is a useful aid in making the initial estimate; and even of greater importance, the system provides complete flexibility in handling deviations as they occur, and refines procedures for future performances.[23]

In many types of work, job duration and cost estimates are based on knowledge obtained from past experiences. However, there are still other types of jobs that are performed less frequently, and

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[23] Information from confidential interview.

experience is not so readily obtainable. Uncertainties present in the type of jobs performed less frequently cause serious problems in properly ascertaining valid time and cost estimates. The use of the three-time estimate was developed to specifically cope with such situations.

> Using these data and certain mathematical techniques, the estimated probabilities of indicated slack in the network and probabilities that specific schedule objectives will be accomplished in accordance with plans supposedly can be derived.[24]

The validity of the mathematical procedure is questioned by many PERT users. Some managers disregard the usefulness of PERT and PERT/Cost because of a reluctance to accept the mathematical formulas involved even though the system can be of significant value when using the single-time estimates.

Costly Implementation

One of the objections frequently applied to PERT and PERT/Cost is its cost of implementation. A

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[24] Schoderbek, "Is PERT/Cost Dead?" op. cit., 46.

basic point of investigation is whether or not the system gives value commensurate with cost. The PERT approach requires a higher degree of planning skill and a greater amount of detail than conventional techniques. Implementation cost of PERT and PERT/Cost varies significantly and depends upon certain factors:

1. The degree of planning capability already available;
2. The present effectiveness and homogeneity of the organization;
3. The amount and quality of PERT indoctrination given.[25] [Numbers supplied for emphasis.]

Proponents of PERT and PERT/Cost emphasize that cost savings achieved through efficient utilization of resources exceed the cost of implementing the system, thereby justifying its usage. In actual practice, the amount of savings is difficult, if not impossible, to determine because advanced planning eliminates many unrecognized costs. Management unfamiliar with PERT and PERT/Cost have very little realization of these cost savings.

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[25] Miller, op. cit.

The cost of a PERT and PERT/Cost system may be divided into two elements:

> . . . (1) the initial cost of implementation, which would be a onetime cost, and (2) the operating cost, which would be the cost of maintaining the PERT/Cost system less the cost of the traditional accounting system of the firm.[26]

Management must solve an additional problem in justifying the initial cost element by deciding whether such costs are to be charged off as a periodic cost, or are to be prorated over later projects.

The utilization of PERT and PERT/Cost may be expensive in practice, amounting up to 5 per cent of total project costs.[27] However, most companies report the cost as falling in the 1 to 2 per cent range.[28] This percentage does not appear to be excessive if the system achieves its intended objectives.

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[26] Schoderbek, "Is PERT/Cost Dead?" op. cit., 50.

[27] Philip L. Blumenthal (ed.), "Financial Management and Control," Vol. CXXV, No. 1, Journal of Accounting (January, 1968), 80.

[28] See supra., p. 134 for a discussion of this problem area in terms of information gained from the survey questionnaire.

The Necessity for Pertinent Accounting Data

In addition to providing an excellent media for cost planning and control, the PERT/Cost system is designed to accumulate actual cost in a highly usable manner. The actual collection of cost data must follow the identical pattern as designated in planning and budgeting activities for the project; otherwise the control feature of the technique is defeated. PERT/Cost provides accounting information in varying degrees of detail required for evaluation of schedule and cost performance, and for the prediction and control of cost variances. Managers, by using PERT/Cost, can appraise more realistically the relationships of accumulated and projected costs of the program, and also permits more accurate measurement of progress.[29]

Effective use of accounting data in the PERT/Cost system depends upon the propriety of:

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[29] Laurence S. Hill, "Some Cost Accounting Problems in PERT," The Journal of Industrial Engineering, Vol. XVII, No. 2 (February, 1966), 87-91.

1. Work breakdown structure;
2. Work packages;
3. Cost estimates;
4. Cost output reports.

The complexity of the overall project and the desired level of detail in the planning state must be given careful attention.

Accounting Data at Work-Breakdown-Structure Level

A division of each end item into its component parts creates a work breakdown structure which serves as the framework for various cost categories. The breakdown of a work program into subsystems continues until work units are reached that are manageable for planning and control purposes. Management must exercise sound judgment in determining proper levels of breakdown for efficient and effective utilization. An insufficient breakdown limits the effectiveness of the system as a control device, whereas an excessive breakdown usually

adds unnecessary cost.[30] An improper work breakdown not only makes the project more difficult to manage, but also prevents any meaningful accumulation of cost data for management decisions.

After the work breakdown structure is determined, networks are prepared which are consistent with the logical design of the work breakdown. The network is a graphic flow chart of all the activities and events necessary to achieve project goals. Costs are usually collected for each work package, but costs may be accumulated for each activity on the PERT network.[31] The work package represents a definite achievement in the total project and provides a unit for assignment of cost responsibility. Summary numbers are assigned at the work breakdown structure level and charge numbers are designated for the individual work packages for accumulating and summarizing accounting data.

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[30] Information from confidential interview and survey questionnaire.

[31] Wilbur R. Ross, "Accounting Aspects of PERT/Cost," Management Accounting, Vol. XLVIII (April, 1967), 47.

Importance of Accounting for the Work Package

If the numbering system is properly extended to every work package, costs can be accumulated and summarized by: (1) function; (2) department; (3) end item; and, (4) project.[32]

Cost-to-date of a project is computed by adding the cost of all completed work packages and the cost incurred on all work packages in progress. The difference in the budgeted cost and the actual cost incurred represents a cost variance which must be analyzed for proper managerial control of the overall project.

Necessity for Valid Cost Estimates

Valid estimates of costs to accomplish activities of work packages are essential for the preparation of realistic and reliable budgets. However, many projects are severely hampered by reporting of totally

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[32] R. A. Beaudoin, "Controlling Costs through PERT," The Canadian Chartered Accountant, Vol. LXXXIX, No. 6 (July, 1966), 38.

inaccurate and inadequate estimates. The inaccuracies in cost estimates, often attributed to individuals in authoritative positions, can be minimized if work-definition concepts of PERT/Cost are fully understood and initiated. Individuals responsible for providing the estimates must also exercise sound and conscientious judgments.[33] Closer supervision by top-level management will encourage lower-level echelons to strive for more appropriate cost information.

Cost Output Reports

The cost estimates and the actual costs of a project must be summarized for management at frequent intervals. The accounting reports must be designed so that information can be conveyed in a logical and easy-to-understand summarization. These reports should highlight cost exceptions to the original plan at time intervals most effective for decision making. The

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[33] Ross, "Accounting Aspects of PERT/Cost," op. cit., 48.

accountant must cooperate with operating management in providing types of accounting data which can be understood and utilized in accomplishing desired objectives.

Deficiencies in Accounting Data and Accounting Systems

"Much has been written about how easy it is to adopt PERT/Cost to a firm's accounting structure. This simply is not generally true."[34] PERT/Cost use is not intended to replace any existing accounting system, but depends on a sound cost system to maximize all the benefits of the technique. A company's cost accounting system must be capable of accumulating and summarizing costs according to work package designation.

Many companies utilize accounting systems which provide for compilation of costs by various procedures (jobs, processes, functional cost classifications, but most systems do not provide data

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[34]Schoderbek, "Is PERT/Cost Dead?" op. cit., 47.

for PERT/Cost utilization.[35] Current accounting systems are generally inadequate for estimation of manpower costs, skill classification, time/cost tradeoffs, and optimum scheduling in compliance with PERT/Cost output reports. However, this is not to suggest that all companies using PERT and PERT/Cost adopt a uniform accounting system; PERT and PERT/Cost techniques should be sufficiently flexible to allow for differences in organizational structure.[36]

A review of the responses to the survey questionnaire and personal interviews indicates that most accounting systems can be modified to facilitate adequate PERT/Cost reporting along responsibility accounting lines.[37] The degree of modification depends on the sophistication of the existing cost accounting system in use. Logical cost centers must be established

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[35] Information from confidential interview.

[36] Schroderbek, "Is PERT/Cost Dead?" op. cit., 47.

[37] See supra., pp. 131-132 for a discussion of this problem area in terms of information gained from the survey questionnaire.

to facilitate collection and summarization of costs. PERT/Cost is not feasible unless it can be incorporated in the basic accounting system since there is little or no justification for maintaining two separate accounting systems.

Deficiencies in Value of Work in Process

The differences between the actual cost of work performed to date, and the value of work performed to date is referred to as cost overrun, or cost underrun. The value of work performed to date is computed by adding the planned cost for each completed work package and a ratio-determined portion of the planned cost for work packages still in process.[38] The computation of value of work performed to date is derived from the formula shown on the following page.

The validity of the following computation is questioned by many managers; therefore, they are re-

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[38] Ross, "Accounting Aspects of PERT/Cost," op. cit., 49.

luctant to use or recommend its use in controlling projects.

$$\frac{\text{Actual Cost to Date}}{\text{Latest Revised Total Estimated Cost}} \times \text{Total Original Planned Cost}$$

$$= \text{Value to Date.}$$

"Value of work performed to date" would be a useful measure if determined by a realistic formula.[39] The accumulated cost of work packages in progress must be adequately evaluated. If the above formula, or any other formula, is insufficient in aiding management in this area of control, additional research is suggested to explore an acceptable solution.

Participation of Accounting Personnel in Planning

Research in this study indicates that some companies do not fully utilize their experienced accountants in planning for PERT and PERT/Cost projects; therefore, accountants are not always aware of the

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[39] *Ibid.*, p. 49.

types of data expected. The accounting staff should be an integral part of the planning team. Their participation will allow for communication to other personnel types of cost data that can be derived from the present accounting system. Modifications of existing accounting methods can then be suggested for accommodating PERT/Cost use.

Raw Material Costing

The procedure for charging materials to a work package continues to be a source of conflict and confusion to many PERT/Cost users. Generally, materials are ordered in amounts to take advantage of the economic order quantity. Two methods of assigning materials are usually employed: (1) assign the cost of the material to the work package when the purchase order is placed; or, (2) charge the work package with the cost at the time the invoice is paid.[40]

The writer of this research study suggests

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[40] Information from confidential interview.

that a third alternative is preferable--assigning cost at the time the materials are actually committed to the work package. This practice is used in many job order accounting systems and should also be adaptable to PERT/Cost. Materials are ordered for particular work package assignments, but it is also an accepted fact that raw materials are purchased for specific end items in a manufacturing company.

Material usage variances are expected in most projects requiring large amounts of material. The usage variance may be prorated over all work packages using the particular type of material, but the writer again suggests a better procedure is to charge each work package with quantity of materials actually required. By this method, material usage variance can be identified with specific units of responsibility, thus enhancing the review, evaluation, and control of each part of the total project.

Charging Overhead Cost to Projects

Overhead activities are generally omitted from the PERT/Cost network, but the burden costs are reported as single line items even though overhead costs are substantial in most companies. Many PERT/Cost users hesitate to attempt a breakdown of overhead costs for work package assignment.[41] However, a breakdown of overhead is necessary if top-level management is to effectively delegate authority, and to review the performance of each individual in charge of a work package. Every individual in a position of responsibility must be informed of the necessity of completing his work assignment within the specified time; an unfavorable cost variance is usually a very impressive reminder to personnel who do not meet specific time schedules. Control of overhead cost may be better achieved by an expansion, within the PERT/Cost structure, of the overhead line item into its basic

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[41] Information from confidential interview.

classifications, i.e., indirect labor, maintenance, and depreciation of equipment.[42]

Estimating Incentive Bonuses

There are still some government contracts assigned on a cost-plus basis, with an incentive bonus if total costs are held within certain limits. The bonus is computed on a sliding scale with the incentive reward decreasing in amount as total costs increase. Theoretically, project managers should strive to hold costs to a minimum to receive larger bonuses. In actual practice, however, the incentive bonus has not achieved its intended purpose. Because of the undertainties of the dollar amounts of an incentive bonus, if any bonus results at all, most project managers have not attempted to include this cost in the PERT/Cost estimates.

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[42] Hill, op. cit., 91.

Additional research is needed to determine whether or not a satisfactory method can be derived to ensure reliable estimates of incentive bonuses.

Summary

Present and potential users of PERT and PERT/Cost are confronted with many problems in the implementation of these systems. However, acceptance of the techniques during the last few years has revealed a degree of increasing support from management.

Certain problem areas in the implementation of PERT and PERT/Cost are identified and discussed. A review of eight specific factors most frequently encountered should provide project managers with added insights into PERT and PERT/Cost application. No attempt is made to discuss all problem areas inherent in these systems, nor is any determinant order of importance implied.

The importance of timely and applicable accounting data can not be overemphasized if the PERT

and PERT/Cost system is to function properly. Management must continue to strive for better utilization of accounting data to perfect a system adaptable to the basic requirements of the PERT/Cost methodology.

Deficiencies are encountered in available accounting data, but progress is being made in overcoming major objections to PERT/Cost use. Suggestions are made for more effective utilization of accounting records in projects using this technique.

CHAPTER VI

SUMMARY AND CONCLUSIONS

PERT and PERT/Cost concepts are widely accepted and used in the defense industry. Accounting literature contains a large amount of material pertaining to research of this management technique. However, a search of the literature reveals that information on PERT and PERT/Cost use in nondefense projects is sporadic, containing for the most part only illustrative and descriptive overviews. An obvious question arises as to the extent and nature of PERT and PERT/Cost in the nondefense area.

This study is specifically concerned with the application of PERT and PERT/Cost to industrial classifications in the State of Alabama.

A discussion of PERT and PERT/Cost and related techniques is given to provide a general background

of the operating intricacies of PERT and PERT/Cost to make data obtained from industrial classifications in Alabama meaningful and comprehensible. Insignificant details of and minor deviations from the basic fundamentals of PERT and PERT/Cost and specified contemporary techniques are purposely omitted. Sources are readily available on the procedures and details of networking techniques.

An integral part of the study is an examination of the factors affecting application of PERT and PERT/Cost to businesses in Alabama. "Not applicable to our operations," is the most frequently given reason for nonusage of the technique, while "unfamiliar with the technique," and "cost of implementation," followed.

A review of the literature, personal interviews, and data from the survey questionnaire reveals a disparity between the factors generally felt to rule out use of PERT and PERT/Cost.

The technique has gained acceptance in some companies within certain industries. Other companies

within the same industrial classification feel that the technique is totally inapplicable to their operations. At least two conclusions are advanced for this disparity: (1) Managers are reluctant to reveal their lack of knowledge of PERT and PERT/Cost and rationalize by stating that it is inapplicable or too costly for use, or (2) the company is not large enough to make effective use of this formal technique.

This study reveals that, of the 159 responses to a questionnaire of a stratified random sample of Alabama industries, 13 respondents presently use PERT; of the 13 companies, 4 also use PERT/Cost. One company had utilized PERT and PERT/Cost because of contract requirements, but discontinued its use. The reasons given for discontinuance were: (1) the system did not provide benefits as purported; and, (2) cost of implementation was too great [the cost was approximately 2 per cent of total project costs].

The increasing competition among firms and the resulting difficulties of profit making are causing

the manager to consider the benefits of PERT and PERT/Cost or other related systems. Additional education may be needed by today's managers to realize the usefulness of these techniques. Special seminars, university courses, and other extension activities are suggested to develop a more informed management team.

Management must use improved methods and techniques, but a blanket requirement for the adoption of a particular method in all instances is neither feasible nor advisable. Factors other than the cost of implementation are inherent in opinions regarding nonuse of PERT and PERT/Cost. Among the more prominent factors hindering effective use of PERT and PERT/Cost are: (1) skepticism of management; (2) lack of training; (3) inadequate planning and scheduling; (4) scheduling re-evaluation; (5) inadequate or irrelevant reports to management; and, (6) invalid estimates.

The findings of the survey indicate that PERT and PERT/Cost has little application throughout Alabama.

There is a touch of irony in this finding in view of the fact that there is extensive use of PERT and PERT/Cost in defense and space activities in the Huntsville, Alabama, area.

The size of the company has a definite relationship to the use of PERT and PERT/Cost. This study found no users by companies with fewer than 50 employees; only 5.5 per cent of the companies with 51-100 employees; but 20 per cent of the companies with employees in excess of 1,000 are using PERT. Companies with few employees have little need for highly complex methods of scheduling and control because there are seldom large projects undertaken by these companies. The higher the number of employees of a company, the more likely PERT and PERT/Cost can be and are being utilized.

PERT was found to be used in several industries such as wholesale and retail trade; finance, insurance and real estate; and government. However, two industrial classifications stand out in the use of PERT

and PERT/Cost--construction and manufacturing. This result was expected since PERT and PERT/Cost is primarily designed for projects of a one-time nature rather than for repetitive-type projects.

The findings of this study indicate that accounting data and accounting records are not being fully utilized. Accounting systems were designed to facilitate the collection of data for financial reporting, but management realized the need for a change in methods to promote responsibility accounting. The company managers interviewed and questionnaire responses state that the accounting system is being or will be revised to meet the needs of management accounting and reporting. Most basic cost accounting systems can be modified to provide data in usable form for PERT and PERT/Cost implementation.

Lack of effective output reports also hinders the control features of PERT and PERT/Cost. The acceptance and success of this system of management control is enhanced by proper utilization of relevant and

timely output reports to evaluate performance.

There is little need for new procedures for charging resources to the work packages. The methods used to assign cost of resources to manufactured goods in a regular cost accounting system is sufficient.

PERT and PERT/Cost success is not dependent upon the use of computers. Small projects are better coordinated by the use of manual operations. However, as the complexity of the project increases, a computer is a highly useful management tool.

Many managers appear hesitant to consider PERT and PERT/Cost because of the implied mathematical and probability aspects of the technique. Additional research and refinements in the mathematical formulas have been proposed for approximately four years, resulting in no significant efforts. Perhaps, there is no real need for a mathematical refinement of PERT and PERT/Cost. Since excellent results can be obtained without the use of highly sophisticated refinements, the presumed importance of statistical aspects of PERT

and PERT/Cost should be given less emphasis.

PERT and PERT/Cost are not sufficiently versatile to cope with all industrial needs, but these systems of management planning and control are designed for small as well as large and complex projects of a one-time nature. Nevertheless, if PERT and PERT/Cost, simple but highly logical systems, are not workable there is little chance for the success of other systems. Management must become more conscientious in reviewing and adopting better techniques for planning and control. However, this conclusion should not be construed as a specific criticism of the integrity of current management in handling intricate business operations.

Although observations and conclusions presented in this chapter may not be all-inclusive or absolute, they do, however, reflect the findings of the study.

From the materials discussed in this research project, the following recommendations are made:

1. A simple method to determine the value of work to date for work packages in progress needs to be determined.
2. A method of determining and applying the (sliding scale) incentive bonus to the estimated cost of projects on a realistic and reliable basis should be investigated.
3. A case study of the psychology of forced usage of PERT and PERT/Cost should be conducted.
4. A method to allocate and to apply the overhead cost to the work packages of a project for better control and more forceful emphasis of the cost factor on operations should be devised.
5. A method of separating the direct cost from the indirect cost should be researched so that valid time-cost trade-off evaluations can be made.

APPENDICES

APPENDIX A: SAMPLE OF SURVEY QUESTIONNAIRE AND LETTERS

P. O. Box 5387
University, Alabama 35486
July 8, 1968

Dear Sir:

As a part of the research for my Ph.D. dissertation at the University of Alabama, I am making an investigation of the uses of PERT (Program Evaluation and Review Technique) and PERT/Cost by companies in the State of Alabama. A look at the enclosed questionnaire will disclose the type of information sought.

Your company is one of those selected at random from a list of the one hundred largest companies in your industry in the State of Alabama. All information provided by your company will be held in strict confidence. Returned questionnaires will be used for statistical summaries only.

Because of the diversity of locations of PERT teams within a company as well as the diversity of titles for individuals in charge of PERT application, I am directing this questionnaire to the controllers. If there is someone else in your company more involved in PERT than you, please pass it along to him. My research indicates that this person may be the manager of the Operations Research department, the manager of the PERT department, or an individual project director.

You can make a valuable contribution to our developing accounting profession by participating in this study. A few minutes of your time in completing the questionnaire is all that it takes. It is essential that I receive completed questionnaires from all companies selected to avoid erroneous conclusions concerning the use of PERT and PERT/Cost by companies in Alabama.

If you have any questions about the project, please feel free to contact me. A prompt reply would be greatly appreciated. Thank you for your time and cooperation.

Sincerely,

J F Burney, Jr.

J F Burney, Jr.

JFB/h
Enclosure

P. O. Box 5387
University, Alabama 35486

Dear Sir:

Recently I mailed to you a questionnaire asking about the uses of PERT (Program Evaluation and Review Technique) and PERT/Cost in your company. In the event the initial mailing did not reach you, I am enclosing a second copy of the questionnaire. The information requested is essential for the completion of my doctoral dissertation at the University of Alabama. A few minutes of your time in completing the questionnaire will be greatly appreciated.

Your company is one of those selected at random from the one hundred largest companies in your industry in the State of Alabama. All information furnished by you will be held in strict confidence and used for statistical summaries only.

If there is someone in your company working more closely with PERT and PERT/Cost, please pass the questionnaire on to him.

I am sure you can appreciate the necessity of my receiving completed questionnaires from all the companies in the sample so that erroneous conclusions about the use of PERT and PERT/Cost may be avoided.

Sincerely,

J F Burney, Jr.

J F Burney, Jr.

JFB/h
Enclosure

PERT, PERT/Cost QUESTIONNAIRE FOR SELECTED

COMPANIES IN ALABAMA

Directions: Please check ( ) the correct answer where answer categories are provided. If you need more space to answer a question, please attach additional sheets.

PART I. Extent and Use of PERT Time

1. Is your company using PERT Time on any projects? Yes_____ No_____.

2. Has your company ever used PERT Time on any projects? Yes___ No____.

   [IF ANSWERS TO NO. 1 AND 2 ARE NO, PLEASE COMPLETE NOS. 3, 4, and 44 only and return questionnaire.]

3. Does your company plan to use PERT within the next 3 years? Yes___No___.

4. Are there any specific reasons why you are not using PERT? Yes____ No___.

   If Yes, please indicate reasons: [Check all reasons that apply.]

   Inapplicable to our operations _____.
   Discontinued projects where PERT used _____.
   Other techniques give better results _____.

   List: _____.

   Found method unsatisfactory _____.
   Too costly _____.
   Not familiar with PERT technique _____.
   Others (specify) _____.
   _____.

5. In what kind of projects have you used PERT Time?

   Commercial projects (nonmanufacturing) _____.
   Defense projects _____.
   Industrial projects (manufacturing & fabrication) _____.
   Service projects _____.

6. Of all projects PERT Time in your company, what percentage have been:

   Commercial projects (nonmanufacturing) _____.
   Defense projects _____.
   Industrial projects (manufacturing & fabrication) _____.
   Service projects _____.

7. In which of the following areas has PERT been applied in your company? [Check all answers that apply.]

	Extent of Use			
	Often	Frequently	Seldom	Never
Repair & Maintenance	____	____	____	____
Research & Development	____	____	____	____
Product Distribution	____	____	____	____
Machinery Installation	____	____	____	____
Construction	____	____	____	____
Product Planning	____	____	____	____
Service Engagements	____	____	____	____
Others (specify)				
_____	____	____	____	____
_____	____	____	____	____

8. For projects PERT Timed in the last 3 years, what are the approximate ranges for the following:

	Minimum	Maximum	Typical
Duration of the entire projects (in weeks)	_____	_____	_____
Number of events in projects	_____	_____	_____
Cost of a project	_____	_____	_____
Number of major revisions in network	_____	_____	_____

Approximately how many projects are included in the above analysis? _____.

9. Do you use a computer for your PERT and PERT/Cost projects? Yes___No___.

10. What are the major factors used to determine whether or not to use PERT in a project?

Contract Requirement	_____
Control of Resources	_____
Cost Saving	_____
Time Saving	_____
Others (specify)	
_____	_____
_____	_____

11. Do you feel that the use of PERT

	In all projects to which applied	To Majority of Projects	To only a few Projects	To None of the Projects
Saved Time?	____	____	____	____
Saved Money?	____	____	____	____
Gave Greater Control?	____	____	____	____

12. How does your company measure the success of PERT used in a project?

Ability to meet schedules	_____
Better informed personnel	_____
Elimination of some costs	_____
Better overall planning	_____
Better coordination of projects	_____
No attempt to measure	_____
Others (specify)	
_____	_____
_____	_____

13. Is there a specific department in your company to which the responsibility of applying PERT to a project is assigned? Yes____ No____

14. What is the name of the department? _____.

15. What is the title of the individual to whom the manager of this department reports?_____.

16. Does the department in charge of PERT perform (or is classified as) a line function or a staff function? [i.e., does it have the authority to implement a major activity or is it primarily an advisory group?] Line_____ Staff_____

17. For projects where PERT is not required by contract, what is the title of the individual (s) who decides whether or not to use PERT on a project? _____.

18. What department in your company makes time estimates for PERT?
_____.

19. Does your company use a single time estimate or three time estimates?

Single time estimate_____
Three time estimates_____

20. Do you think that probability estimates are sufficiently accurate?
Yes_____ No_____

21. What advantages do you think using three time estimates has over the use of a single time estimate?

22. What disadvantages do you think using three time estimates has over the use of a single time estimate?

23. Does your company have a program for the training of personnel in PERT techniques? Yes_____ No_____

24. If answer to No. 23 is Yes, is the training

Formal (special program) _____
On the job _____
Both _____

[If both, give portion formal _____; on the job _____.]

25. What are the minimum requirements necessary for personnel to participate in this training program?

Education (level) _____
Experience _____
Others (specify)

_____ _____
_____ _____

PART II. Extent and Use of PERT/Cost

26. Is your company using PERT/Cost now? Yes_____ No _____.

27. Has your company ever used PERT/Cost but is not using it presently?
Yes_____ No _____

28. If your company has never used PERT/Cost, does it plan to use PERT/Cost within the next 3 years?
Yes_____ No _____

29. What department makes cost estimates for your company?

Engineering _____ PERT _____
Accounting _____ Others (specify)
_____
_____

30. Does your company estimate cost for each:

Activity? _____
Work Package? _____
Other (specify) _____

31. How are the cost estimates determined?

Accounting Records _____
Engineering Analysis_____
Other (specify) _____

32. If your company does utilize the accounting records in determining cost estimates, how are they utilized?

33. What have been the major contributions of your historical accounting records in PERT/Cost estimations?

34. Have you made any major changes in your accounting records to facilitate cost determination for PERT/Cost projects? Yes____No____

35. What was the nature of such changes?

36. Do you contemplate any changes in your accounting records to comply with PERT/Costing? Yes_____ No_____
If Yes, what is the nature of these changes?

37. What areas in your accounting system are considered inadequate for proper utilization in PERT/Cost implementation?

38. Do you feel that the use of PERT/Cost:

	In All Projects to which applied	To Majority of Projects	To Only a Few Projects	To None of the Projects
Saved Money?	_____	_____	_____	_____
Gave Greater Control?	_____	_____	_____	_____

39. What is the estimated cost of operating a PERT/Cost system, in your company, as a per cent of total project cost?

Less than 1% _____
1% but less than 2% _____
2% but less than 3% _____
3% but less than 4% _____
4% but less than 5% _____
5% or greater _____; approximate per cent _____.

40. Have you made any modifications in the basic PERT and PERT/Cost approach? Yes_____ No_____. If Yes, what are these modifications? [List most important modifications.]

41. What have you found to be the major problems in applying PERT/Cost techniques? [Check as many as apply.]

Employee resentment _____
Management skepticism _____
Lack of adequate training _____
Cost of implementation _____
Inadequate validity of PERT's mathematical & probability concepts _____
Others (specify) _____.

42. What PERT and PERT/Cost output report(s) does your company use?

Management Summary Report _____
Problem Analysis Report _____
Program/Project Status Report _____
Organizations Status Report _____
Financial Plan & Status Report _____
Cost of Work Report _____
Cost Outlook Report _____
Cost Category Status Report _____
Manpower Loading Report & Display _____
Schedule Outlook Report _____
PERT Milestone Report _____
Others (specify) _____.

43. Would you grant me a short personal interview at a mutually convenient time in the near future? Yes_____ No_____

44. Would you like to have a summary of this study? Yes_____ No_____

Name _____
Company _____
Title _____
Address _____
_____
Telephone No. _____

PLEASE RETURN THE QUESTIONNAIRE IN THE POSTAGE-PAID ENVELOPE PROVIDED. THANK YOU FOR YOUR COOPERATION.

APPENDIX B: EXAMPLES OF OUTPUT REPORTS

BALLISTIC SHELL LEVEL/SUMMARY ITEM: 2/FIRST STAGE 320	REPORTING ORGN. ABCO--AERO. DIV.	CONTRACT NO. 100549662	REPORT DATES TERM (SPAN): TOTAL PROGRAM CUT OFF DATE: 30 NOV 65 RELEASE DATE: 10 DEC 65

IDENTIFICATION				TIME STATUS			COST OF WORK $(000)					
							WORK PERFORMED TO DATE			TOTALS AT COMPLETION		
CHARGE OR SUMMARY NUMBER	LEVEL	FIRST EVENT NO.	LAST EVENT NO.	SCHEDULED OR ACT (A) COMPLETION DATE	EARLIEST & LATEST COMPLETION DATES	MOST CRIT SLACK (WKS)	VALUE	ACTUAL COST	(OVERRUN) UNDERRUN	PLANNED COST	LATEST REVISED ESTIMATE	PROJECTED (OVERRUN) UNDERRUN
FIRST STAGE 320	2	1000	1999	31 DEC 66	31 DEC 66 31 DEC 66	0.0 1999	6,500	7,100	(.09) (600)	9,000	9,450	(.05) (450)
MISSILE SEC. ASSY. 321	3	1000	1099	31 DEC 66	31 DEC 66 31 DEC 66	0.0 1099	2,000	2,500	(.25) (500)	2,900	3,300	(.14) (400)
INSTRUMENTATION 322	3	1100	1199	A 15 MAR 65			400	380	.05 20	400	380	.05 20
POWER CABLE ASSY. 323	3	1200	1299	30 APR 66	01 AUG 65 15 AUG 65	2.0 1264	750	825	(.10) (75)	1,100	1,120	(.02) (20)
DOCUMENTATION 324	3	1300	1399	20 MAY 66	20 NOV 65 20 NOV 65	0.0 1388	50	40	.20 10	60	55	.08 5
OTHER LEVEL 3 BREAKOUTS (LIST SEPARATELY)	3	1400	1999	VARIOUS	VARIOUS	0.0 1999	3,300	3,355	(.02) (55)	4,540	4,595	(.01) (55)
ELECTRICAL DESIGN 321.71	4	1000	1019	A 09 JUL 65			50	55	(.10) (5)	50	55	(.10) (5)
MANUFACTURING 321.72	4	1020	1034	06 MAY 66	22 OCT 65 18 FEB 66	17.0 1031	756	850	(.12) (94)	800	900	(.13) (100)
TESTING 321.73	4	1035	1059	23 APR 66	18 MAR 66 15 JUL 66	17.0 1059	225	180	.20 45	400	320	.20 80
OTHER WORK PACKAGES re 321 (LIST SEPARATELY)	4	1060	1099	31 DEC 66	31 DEC 66 31 DEC 66	0.0 1099	969	1,415	(.46) (446)	1,650	2,025	(.23) (375)

Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D.C., March, 1963, Figure 4.

1. —PERT/Cost Program/Project Status Report.

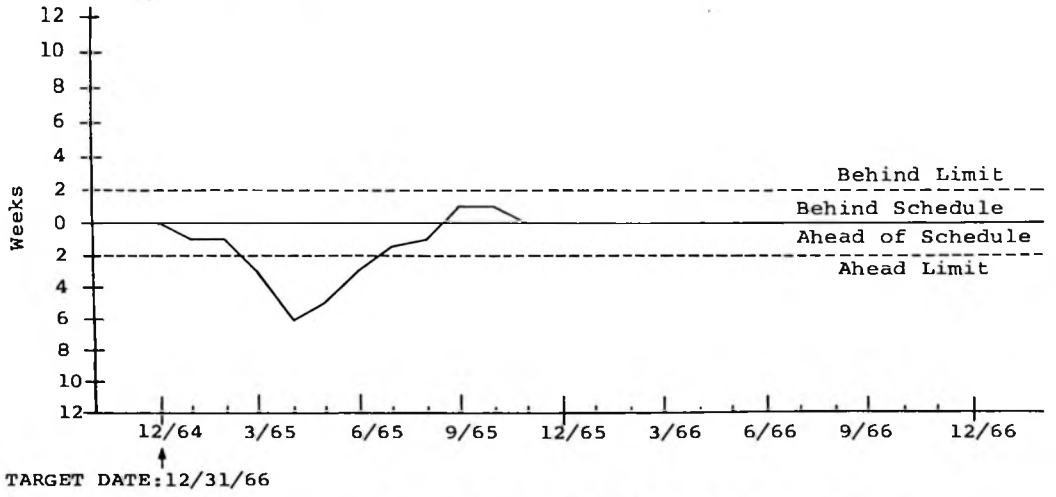
BALLISTIC SHELL	REPORTING ORGN.	CONTRACT NO.	REPORT DATES
	ABCO--AERO. DIV.	100549662	TERM (SPAN): TOTAL PROGRAM
LEVEL/SUMMARY ITEM: 1/BALLISTIC SHELL 300			CUT OFF DATE: 30 NOV 65 RELEASE DATE: 10 DEC 65

ITEM	COST OF WORK $(000)						MOST CRITICAL SLACK (WKS)	COMPLETION DATE	SCHEDULE	REMARKS
	WORK PERFORMED TO DATE			TOTALS AT COMPLETION					S:SCHEDULED COMPLETION DATE--TOTAL A:ACTUAL COMPLETION DATE--ITEM E:EARLIEST COMPLETION DATE--CRITICAL L:LATEST COMPLETION DATE--ITEM	
	VALUE	ACTUAL COST	(OVERRUN) UNDERRUN	PLANNED COST	LATEST REVISED ESTIMATE	PROJECTED (OVERRUN) UNDERRUN			PR YR 1965 JFMAMJJASOND 1966 JFMAMJJASOND 7 8 LTR YR	
BALLISTIC SHELL LEVEL 1 300	17,000	18,000	(.06) (1,000)	30,000	33,000	(.10) (3,000)	0.0	15JUL67 31DEC66 31DEC66	S E L	
NOSE FAIRING LEVEL 2 310	20	18	.10 2	150	150			01NOV65 09AUG65 13OCT65	A E L	
FIRST STAGE LEVEL 2 320	6,500	7,100	(.09) (600)	9,000	9,450	(.05) (450)	0.0	31DEC66 31DEC66 31DEC66	S E L	
SECOND STAGE LEVEL 2 330	1,280	1,267	.01 13	2,300	2,254	.02 46	9.6	30SEP66 15JUN66 22AUG66	S E L	
OTHER LEVEL 2 BREAKOUTS (LIST SEPARATELY)	9,200	9,615	(.05) (415)	18,550	21,146	(.14) (2,596)	0.0	VARIOUS	VARIOUS TIME NOW	

Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D.C., March, 1963, Figure 2.

2.—PERT/Cost Management Summary Report.

BALLISTIC SHELL	REPORTING ORGN.	CONTRACT NO.	REPORT DATES
	ABCO--AERO.DIV.	100549662	TERM (SPAN): TOTAL PROGRAM CUT OFF DATE: 30 NOV 65 RELEASE DATE: 10 DEC 65
LEVEL/SUMMARY ITEM: 2/FIRST STAGE 320			



Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D.C., March, 1963, Figure 17.

3. —**PERT/Cost Schedule Outlook Report.**

BALLISTIC SHELL	REPORTING ORGN. ABCO--AERO. DIV.	CONTRACT NO. 100549662	REPORT DATES TERM (SPAN): TOTAL PROGRAM CUT OFF DATE: 30 NOV 65 RELEASE DATE: 10 DEC 65
LEVEL/SUMMARY ITEM: 3/MISSILE SEC. ASSY. FIRST STAGE 321			

MONTH	CHARGE NUMBER	INCREMENTAL COST $(000) ACTUAL	PLANNED	LATEST REVISED ESTIMATE	(OVER) UNDER PLAN	CUMULATIVE COST $(000) ACTUAL	PLANNED	LATEST REVISED ESTIMATE	(OVER) UNDER PLAN	REMARKS
PRIOR	321.71					53	49	53	(4)	
	321.72					836	734	836	(102)	
	321.73					171	176	171	5	
	OTHERS					1,215	983	1,215	(232)	
	TOTAL					2,275	1,942	2,275	(333)	
NOV 65	321.71	2	1	2	(1)	55	50	55	(5)	
	321.72	14	17	14	3	850	751	850	(99)	
	321.73	9	9	9		180	185	180	5	
	OTHERS	200	191	200	(9)	1,415	1,174	1,415	(241)	
	TOTAL	225	218	225	(7)	2,500	2,160	2,500	(340)	
DEC 65	321.71						50	55	(5)	
	321.72		20	22	(2)		771	872	(101)	
	321.73		45	44	1		230	224	6	
	OTHERS		150	163	(13)		1,324	1,578	(254)	
	TOTAL		215	229	(14)		2,375	2,729	(354)	
OTHER MONTHS (LIST SEPARATELY) (ASSUMED TO GO TO JANUARY 28, 1967)	321.71						50	55	(5)	
	321.72		29	28	1		800	900	(100)	
	321.73		170	96	74		400	320	80	
	OTHERS		326	447	(121)		1,650	2,025	(375)	
	TOTAL		525	571	(46)		2,900	3,300	(400)	

Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D.C., March, 1963, Figure 9.

4.—PERT/Cost Financial Plan and Status Report by Month, Charge Number.

BALLISTIC SHELL	REPORTING ORGN. ABCO--AERO. DIV.	CONTRACT NO. 100549662	REPORT DATES TERM (SPAN): TOTAL PROGRAM CUT OFF DATE: 30 NOV 65 RELEASE DATE: 10 DEC 65
LEVEL/SUMMARY ITEM: 1/BALLISTIC SHELL 300			

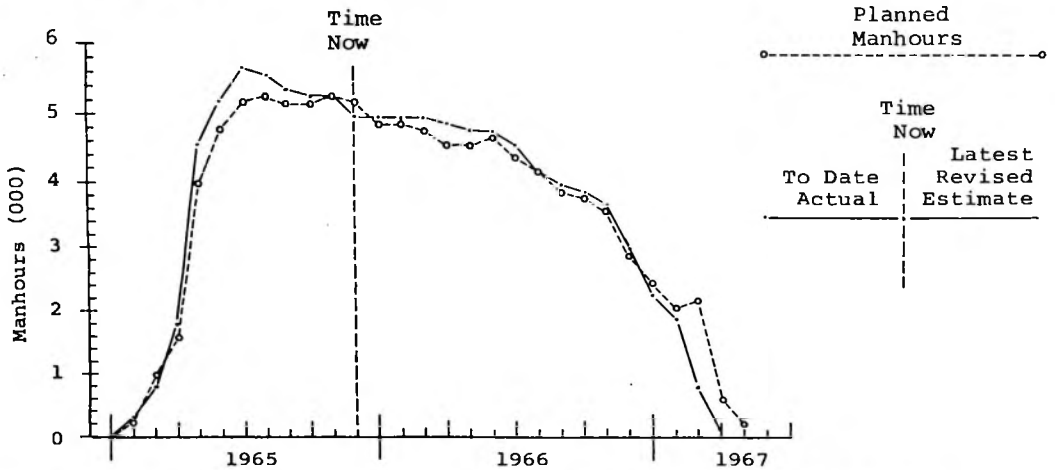
IDENTIFICATION				MANHOURS				TIME	
MONTH	RES (SKILLS) CODE	PERF ORGN	CHARGE NUMBER	ACTUAL	PLANNED	LATEST REVISED ESTIMATE	(OVER) UNDER PLAN	MOST CRIT SLACK (WKS)	REMARKS
PRIOR	L2	3547	321.71	6,400	6,000	6,400	(400)		
			323.71	1,600	1,800	1,600	200	3.5	
		3572	328.60	400	400	400		0.0	
		3581	332.14	1,800	1,700	1,800	(100)	2.4	
		OTHERS	(LIST SEPARATELY)	29,800	27,900	29,800	(1,900)	(VARIOUS)	
TOTAL				40,000	37,800	40,000	(2,200)		
NOV 65		3547	321.71						
			323.71	200	200	200		3.5	
		3572	328.60	450	500	450	50	0.0	
		3581	332.14	1,100	950	1,100	(150)	2.4	
		OTHERS	(LIST SEPARATELY)	3,250	3,550	3,250	300	(VARIOUS)	
TOTAL				5,000	5,200	5,000	200		
DEC 65		3547	321.71						
			323.71			400	(400)	3.5	
		3572	328.60		200	170	30	0.0	
		3581	332.14		1,800	1,700	100	2.4	
		OTHERS	(LIST SEPARATELY)		2,900	2,730	170	(VARIOUS)	
TOTAL					4,900	5,000	(100)		
OTHER MONTHS	(LIST SEPARATELY)				54,000	53,000	1,000		
	TOTAL			45,000	101,900	103,000	(1,100)		

Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D.C., March, 1963, Figure 12.

5.—PERT/Cost Manpower Loading Report by Resource, Month, Charge Number, Performing Organization.

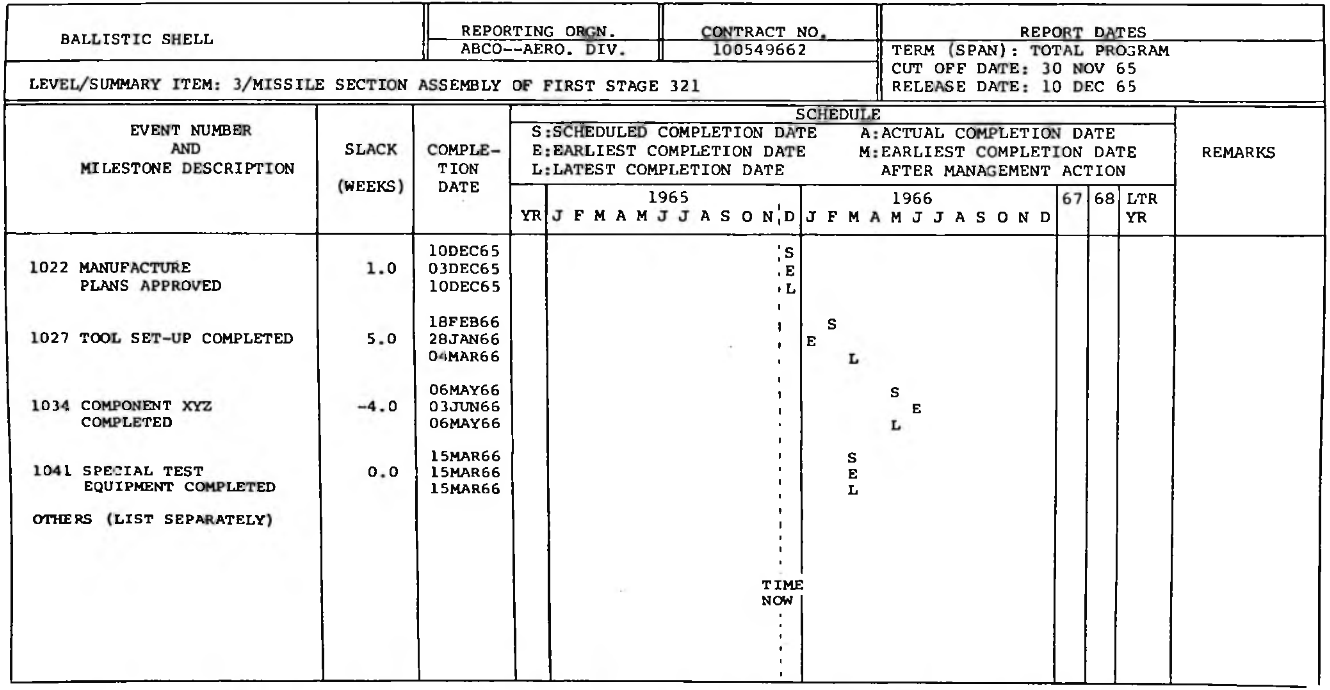
BALLISTIC SHELL	REPORTING ORGN.	CONTRACT NO.	REPORT DATES
	ABCO--AERO.DIV.	100549662	TERM (SPAN): TOTAL PROGRAM CUT OFF DATE: 30 NOV 65 RELEASE DATE: 10 DEC 65
LEVEL/SUMMARY ITEM: 1/BALLISTIC SHELL 300			

RESOURCE (SKILL) CODE: L2



Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D.C., March, 1963, Figure 14.

6 —**PERT/Cost Manpower Loading Display**



BALLISTIC SHELL	REPORTING ORGN.	CONTRACT NO.	REPORT DATES
	ABCO--AERO. DIV.	100549662	TERM (SPAN): TOTAL PROGRAM CUT OFF DATE: 30 NOV 65 RELEASE DATE: 10 DEC 65
LEVEL/SUMMARY ITEM: 3/MISSILE SECTION ASSEMBLY OF FIRST STAGE 321			

SCHEDULE
S:SCHEDULED COMPLETION DATE
E:EARLIEST COMPLETION DATE
L:LATEST COMPLETION DATE
A:ACTUAL COMPLETION DATE
M:EARLIEST COMPLETION DATE AFTER MANAGEMENT ACTION

EVENT NUMBER AND MILESTONE DESCRIPTION	SLACK (WEEKS)	COMPLE-TION DATE	YR	1965 J	F	M	A	M	J	J	A	S	O	N	D	1966 J	F	M	A	M	J	J	A	S	O	N	D	67	68	LTR YR	REMARKS
1022 MANUFACTURE PLANS APPROVED	1.0	10DEC65													S																
		03DEC65													E																
		10DEC65													L																
1027 TOOL SET-UP COMPLETED	5.0	18FEB66															S														
		28JAN66														E															
		04MAR66																L													
1034 COMPONENT XYZ COMPLETED	-4.0	06MAY66																		S											
		03JUN66																			E										
		06MAY66																		L											
1041 SPECIAL TEST EQUIPMENT COMPLETED	0.0	15MAR66																S													
		15MAR66																E													
		15MAR66																L													
OTHERS (LIST SEPARATELY)																															

Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D.C., March, 1963, Figure 20.

7.—PERT Milestone Report.

8. PROBLEM ANALYSIS REPORT

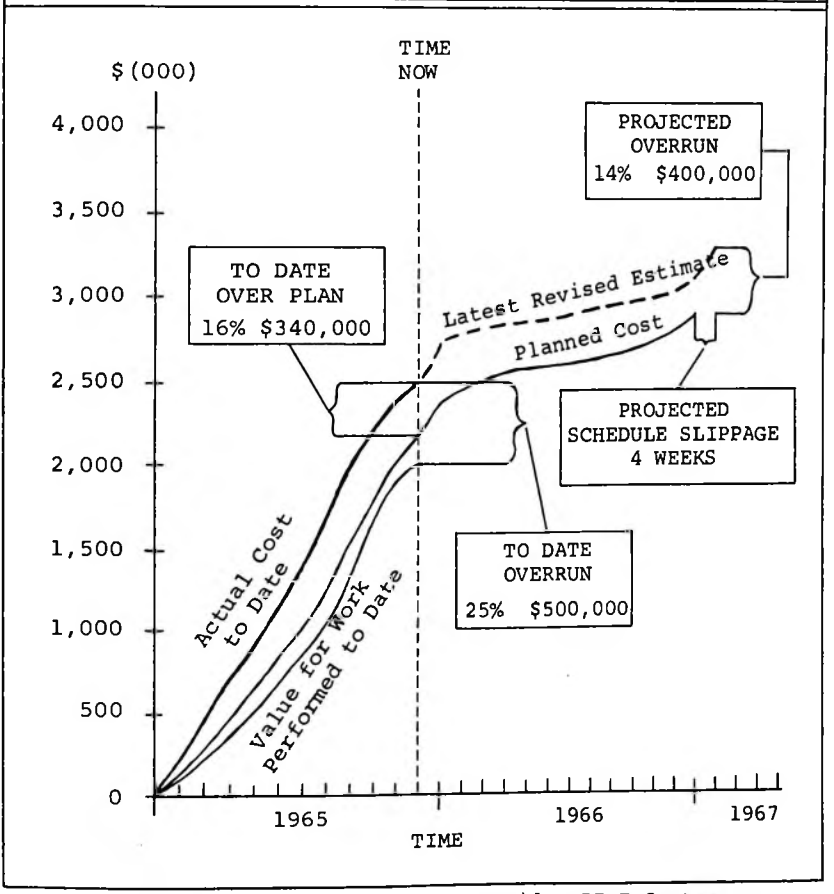
The Problem Analysis Report is a narrative report to supplement the Management Summary and other reports which identify significant schedule, cost, or technical performance problems--either current or potential. It may be desirable to prepare separate Problem Analysis Reports for each level of managers corresponding to the progressively more summary nature of the tabulated information furnished them. The individual analyses of problems whould be adequately cross-referenced to the report which they supplement so as to facilitate ease of identification.

The narrative description should include--

- the nature of the problem;
- the reasons for cost and/or schedule variance;
- the impact on the immediate task;
- the impact on the total program; and,
- the corrective action: what action, by whom, when, and
- expected effect.

Source: Adapted from DOD and NASA Guide: Pert Cost--"Output Reports," InterAgency PERT Coordinating Group, Department of Defense, Washington, D. C., March, 1963, p. 8.

BALLISTIC SHELL	REPORTING ORGN.	CONTRACT NO.	REPORT DATES
	ABCO--AERO.DIV.	100549662	TERM(SPAN):TOT.PROG.
LEVEL/SUMMARY ITEM: 3/MISSILE SECTION ASSEMBLY, FIRST STAGE 321			CUT OFF DATE:30NOV65 RELEASE DATE:10DEC65



Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D.C., 1963, Figure 15.

9. —PERT/Cost. Cost of Work Report.

BALLISTIC SHELL	REPORTING ORGN.	CONTRACT NO.	REPORT DATES
	ABCO--AERO. DIV.	100549662	TERM (SPAN): TOTAL PROGRAM
LEVEL/SUMMARY ITEM: 1/BALLISTIC SHELL 300			CUT OFF DATE: 30 NOV 65 RELEASE DATE: 10 DEC 65

IDENTIFICATION	MANHOURS					TOTAL COST $(000)				
	TO DATE		TOTALS AT COMPLETION			WORK TO DATE		TOTALS AT COMPLETION		
COST CATEGORY	PLANNED	ACTUAL	PLANNED	LATEST REVISED ESTIMATE	PROJECTED (OVERRUN) UNDERRUN	PLANNED	ACTUAL	PLANNED	LATEST REVISED ESTIMATE	PROJECTED (OVERRUN) UNDERRUN
3547 DEPT. A	15,000	18,000	21,500	24,000	(.12) (2,500)	1,600	1,700	2,600	2,800	(.08) (200)
3555 DEPT. B	38,000	40,000	65,000	65,000		4,800	5,600	9,000	9,900	(.10) (900)
3562 DEPT. C	22,000	19,500	37,000	34,900	.06 2,100	1,700	1,500	2,200	2,300	(.05) (100)
3571 DEPT. D	1,700	1,650	1,800	1,750	.03 50	400	390	500	480	.04 20
OTHERS (LIST SEPARATELY)	84,000	89,000	133,500	141,200	(.06) (7,700)	8,000	8,810	15,700	17,520	(.12) (1,820)
TOTAL						16,500	18,000	30,000	33,000	(.10) (3,000)

Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D.C., March, 1963, Figure 18.

10.—**PERT/Cost. Cost Category Status Report.**

BALLISTIC SHELL	REPORTING ORGN. ABCO--AERO. DIV.	CONTRACT NO. 100549662	REPORT DATES TERM (SPAN): TOTAL PROGRAM CUT OFF DATE: 30 NOV 65 RELEASE DATE: 10 DEC 65
LEVEL/SUMMARY ITEM: 2/FIRST STAGE 320			

IDENTIFICATION				MANHOURS				DIRECT COSTS $(000)				TIME	
				WORK TO DATE	TOTALS AT COMPLETION			WORK TO DATE	TOTALS AT COMPLETION				
CHARGE NUMBER	RESP ORGN	PERF ORGN	RES CODE	ACTUAL	PLANNED	LATEST REVISED ESTIMATE	PROJECTED (OVERRUN) UNDERRUN	ACTUAL	PLANNED	LATEST REVISED ESTIMATE	PROJECTED (OVERRUN) UNDERRUN	MOST CRIT SLACK (WKS)	SCHEDULED OR ACT (A) COMPLETION DATE
	3547												
ELECTRICAL DESIGN, MISSILE SEC. ASSY.													A
321.71		3547	L2	6,400	6,000	6,400	(400)	32	30	32	(2)		09 JUL 65
			L4	2,250	2,000	2,250	(250)	9	8	9	(1)		
		3581	L6	500	500	500		3	3	3			
			M50					11	9	11	(2)		
											(.10)		
TOTAL								55	50	55	(5)		
ELECTRICAL DESIGN, POWER CABLE ASSY.													
323.71		3547	L2	1,800	2,000	2,200	(200)	9	10	11	(1)	3.5	15 JAN 66
			M65					3	3	3			
		3590	L8	1,250	3,000	2,250	750	5	12	9	3		
			M30					1	5	4	1		
											.10		
TOTAL								18	30	27	3		
											.05		
OTHERS (LIST SEPARATELY)					VARIOUS			137	220	230	(10)	VARIOUS	
											(.04)		
	TOTAL							210	300	312	12		

Source: Adapted from DOD and NASA Guide: PERT Cost--"Output Reports," Inter-Agency PERT Coordinating Group, Department of Defense, Washington, D.C., March, 1963, Figure 6.

11.--PERT/Cost Organization Status Report by Responsible Organization, Charge Number, Performing Organization, Resource Code.

APPENDIX C: GLOSSARY OF SYMBOLS AND TERMS

Symbols

a = The optimistic time estimate for an activity when three-time estimates are used.

b = The pessimistic time estimate for an activity when three-time estimates are used.

m = The most likely time estimate for an activity when three-time estimates are used.

S_E = Earliest completion date for an activity.

S_L = Latest completion date for an activity.

T_D = Directed date for an event.

T_S = Scheduled completion date for an activity or event.

t_e = Expected elapsed time for an activity.

t_s = Scheduled elapsed time for an activity.

T_E = The expected date on which an event will occur.

T_L = Latest allowable date for an event.

E = A symbol appearing on the PERT/Cost Management Summary Report to represent the S_E of the most critical activity within a summary work package.

L = A symbol appearing on the PERT/Cost Management Summary Report to represent the S_L for the most critical activity within a summary work package.

σ = (Sigma). Mathematical symbol for standard deviation.

Terms

Account Code Structure: The numbering system used to assign summary numbers to elements of the work breakdown structure and charge numbers to individual work packages.

Activity: A work effort of a program which is represented by an arrow. An activity cannot be started until the event preceding it has occurred and it may represent a process, task, procurement cycle, waiting time, or simply represent a connection or interdependency between two events on the network.

Activity Slack: The difference in time, comparing the earliest completion date (S_E) with the latest completion dates (S_L) for a given activity. The activity slack indicates the range of time within which an activity can be scheduled for completion. When the S_E for an activity is later than the S_L, then the activity is said to have negative slack and either the current activities or subsequent activities must be replanned or the project schedule will slip. When the S_L for an activity is later than the S_E, then the activity is said to have positive slack and additional time is available for performing the activity without causing the project schedule to slip.

Activity Time: The time estimated for completion of an activity.

Actual Costs: The actual costs incurred to date on an activity or project.

Beginning Event: An event which signifies the beginning of one or more activities on a network.

Budget: The planned expenditures and commitments, broken down by time periods.

Charge Number: A number used for identifying the costs to a work package.

Constraint: The relationship of an event to a succeeding activity wherein an activity may not start until the event preceding it has occurred. The term "constraint" is also used to indicate the relationship of an activity to a succeeding event wherein an event cannot occur until all activities preceding it have been completed.

Critical Path: That particular sequence of events and activities on the network path that has the greatest negative, or least positive, algebraic slack; that is, the most time consuming path through the network.

Directed Date for an Event (T_D): A time commitment for a specific accomplishment.

Dummy Activity: An activity requiring zero time; i.e., if in a network two events are such that one must be completed before the other can be started but no time is required between them. Dotted lines are commonly used to indicate dummy activities.

Earliest Expected Date (T_E): The earliest calendar date on which an event can be expected to occur. The T_E value for a given event is equal to the sum of the expected elapsed times (t_e) for the activities on the longest path from the beginning of the program to the given event.

Elapsed Time: The total time estimated to complete an activity, including time required for the transmittal of information, delays, waiting periods, etc.

Event: A specific, definable accomplishment in a program plan, recognizable at a particular instant in time. Events do not consume time or resources.

Expected Elapsed Time (t_e): The elapsed time which an activity is estimated to require. The expected elapsed time is identical to a single time estimate for the work to be accomplished, or is derived from the calculation of a statistically weighted average time estimate, incorporating the optimistic (a), most likely (m), and pessimistic (b) estimates for the work to be accomplished: $\frac{a + 4m + b}{6} = t_e$.

Fragnet: An acronym fragment of a network (combined form). Fragnets usually: Portray the efforts of individual responsible organizations, reflect the activities pertaining to a significant component or subdivision of work, breakdown the network into presentable or manageable sizes.

Input: Information required in order to perform data processing operations.

Interface Event: An event which signals the transfer of responsibility, end items, or information from one part of the plan to another. Examples of interface events are the receipt of an item (hardware, drawing, specifications) or the release of an engineering drawing to manufacturing.

Item: A project end item or end item subdivision down to the lowest level work package. This term includes services and other nonhardware parts of a project.

Joint Cost Activity: Joint cost activity is one which shares resources in such a way that it is impractical to further allocate them to individual activities.

Latest Allowable Date (T_L): The latest calendar date on which an event can occur without delaying the completion of the program. The T_L value for a given event is calculated by subtracting the sum of the expected elapsed time (t_e) for the activities on the longest path between the given event and the end event of the program from the latest date allowable for completing the program. T_L for the end event in a program is equal to the directed date (T_D) of the program. If a directed date is not specified, $T_L = T_E$ for the end event.

Latest Completion Date (S_L): The S_L value for a given activity is calculated by subtracting the sum of the scheduled elapsed times (t_s) for the activities on the longest path from the given activity to the end event of the project from the latest allowable date (T_L) for completing the project. Therefore, S_L represents the latest date on which an activity can be scheduled for completion without delaying the completion of the project.

Level: The number of the tier or level on the work breakdown structure at which a charge or summary number appears.

Milestone: Milestones are synonymous for events in a network.

Most Likely Time Estimate (m): The estimated length of time required to complete the activity under normal circumstances. A result which would occur most often if the activity were repeated many times.

Network: A flow diagram consisting of activities and events which must be accomplished to reach the program objectives, showing their logical and planned sequences of accomplishment, interdependencies, and interrelationships.

Optimistic Time Estimate (a): The estimated length of time required if no complications or unforeseen difficulties are encountered in performing the activity. In most instances a result which would be obtained only if unusually good luck is experienced.

Overrun: The amount by which the actual costs plus the estimates-to-complete exceeds the current approved contract estimate.

Pessimistic Time Estimate (b): The estimated length of time required in unusually difficult circumstances. This estimate represents the maximum time required under adverse conditions.

Probability (P): A statistical measure of the chance of an event occurring by its earliest expected date (T_E). This probability is determined through the equation:

$$Z = \frac{T_L - T_E}{TE}.$$

Scheduled Completion Date (T_S): A date assigned for completion of an activity (accomplishment of an event) for purposes of planning and control.

Scheduled Elapsed Time (t_s): The period of time scheduled for performing an activity.

Simulation: The planning and processing of alternative actions to determine the effect of such actions on the program concerned.

Slack: The difference between the latest allowable date and the expected date ($T_L = T_E$). Slack is a characteristic, as such, of the network paths. Slack may be positive, zero, or negative.

Standard Deviation (σ): Mathematically, the square root of the arithmetic mean of the squares of the deviations of the various items from the arithmetic mean of the whole. Common PERT practice in reference to the three-time estimates (a, m, b) uses a standard deviation equal to one-sixth of the range of the distribution curve,

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

Summary Item: An item appearing in the work breakdown structure.

Summary Number: A number to identify the work packages to be grouped together in summarizing manhour and cost information for an item appearing on a higher level of the work breakdown structure.

Summary Work Package: A grouping of work packages equal to an item appearing on a summary level of the project work breakdown structure.

Underrun: The amount by which the current approved contract estimate exceeds the sum of the actual costs and the estimates to complete.

Value (Work Performed to Date): The planned cost for completed work, including that part of work in process which has been finished. This value is determined by summing the planned cost for each completed work package. If a work package is in process, the part of its total planned cost which applies to work completed is approximated by applying the ratio of actual cost to latest revised estimate for that work package.

Variance: A statistical term equal to σ^2.

Work Breakdown Structure: A family tree subdivision of a program, beginning with the end objectives and then subdividing these objectives into successively smaller end item subdivisions. The work breakdown structure establishes the framework for:

- defining the work to be accomplished;
- constructing a network plan;
- summarizing the cost and schedule status of program for progressively higher levels of management.

Work Package: The unit of work required to complete a specific job, such as a report, a design, a drawing, a piece of hardware, or a service, which is within the responsibility of one operating unit in an organization.

<u>Zero Cost Activity</u>: An activity that represents a precedence or dependence relationship but does not generate direct costs to the project.

<u>Zero Time Activity</u>: An activity which constrains the beginning of a following activity or occurrence of the event to which it leads by requiring that the event from which it proceeds occurs first.

APPENDIX D: COMPREHENSIVE LIST OF RELATED TOPICS

COMPREHENSIVE LIST OF RELATED TOPICS

Books

Antill, James M., and Woodhead, Ronald W. Critical Path Methods in Construction Practices. New York: John Wiley & Sons, Inc., 1965.

Archibald, Russell D., and Villoria, Richard L. Network-Based Management Systems (PERT/CPM). New York: John Wiley & Sons, Inc., 1967.

Baker, Bruce N., and Eris, Rene L. An Introduction to PERT-CPM. Homewood, Illinois: Richard D. Irwin, Inc., 1964.

Bock, Robert H., and Holstein, William K. (eds.). Production Planning and Control. Columbus, Ohio: Charles E. Merrill Books, Inc., 1963.

Boulanger, David G. "Program Evaluation and Review Technique," in Production Planning and Control. Edited by Robert H. Bock and William K. Holstein. Columbus, Ohio: Charles E. Merrill Books, Inc., 1963.

Broom, H. N. Production Management. Homewood, Illinois: Richard D. Irwin, Inc., 1962.

Evarts, Harry F. Introduction to PERT. Boston: Allyn and Bacon, Inc., 1964.

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