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ABSTRACT

The purpose of this study was to determine if the Program Evaluation and Review Technique (PERT) which was developed by the U. S. Navy as a management tool could be applied to a library process. Several chapters are devoted to an explanation of the tool and its advantages and limitations. Its potential value in library management is also discussed, and six criteria are set up for determining whether or not PERT should be used. PERT was applied to the book cataloging process at Brigham Young University, Provo, Utah. A network of activities and events was developed, and three time estimates were used to obtain a critical part. It was concluded that PERT can be used successfully to show interrelationships between cataloging activities in the library. (JG)

PROGRAM EVALUATION AND REVIEW TECHNIQUE IN THE LIBRARY

A Research Project

Submitted to The

Graduate Department of Library and Information Sciences

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In Partial Fulfillment

of the Requirements of the

Master of Library Science Degree

by

Roger C. Flick

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ABSTRACT

In the late 1956's a management technique known as Program Evaluation and Review Technique, or simply PERT, was developed in connection with the construction of the large Polaris Ballistic Missile System of the U.S. Navy. The technique has generally been applied to large industrial projects and little use has been made of this system in library work.

The technique is presented in the first five chapters of the paper. PERT involves the development of a network of activities (tasks) and events (milestones or accomplishments). The activities and events, logistically speaking, are placed in a sequential order in diagram form to provide instant information to management personnel regarding the progress and interrelationships of tasks and accomplishments. Attention is focused on a three-time estimate concept for accomplishing tasks and the development of a critical path through the network to determine the shortest time to accomplish a particular project, program, or set of tasks. It's values and limitations are enumerated. Also a set of criteria have been developed to determine whether or not PERT may be applied to a given project, operation, or process.

Chapters six through nine make use of two of the criteria developed in the previous chapters by applying the technique to the cataloging process at the Brigham Young University Library. A network of activities and events is developed and three time estimates are given to obtain a critical path. The values and limitations of applying PERT to a library process are presented. It was determined that the PERT technique could be used successfully to show interrelationships between cataloging activities in the library.

Preface

The purpose of this paper is to investigate a management scheduling technique here-to-fore not used extensively in library work to determine its applicability in library management. The first five chapters will make available to the library community its basic concepts and principles, and indicate its values and limitations. Chapters six through nine will present a practical application of this technique to the cataloging process of the Brigham Young University Library and indicate its values and limitations.

Appreciation is expressed to Dr. Maurice P. Marchant and Mr. Keith Stirling of the Graduate School of Library and Information Science, Brigham Young University, for their interest, encouragement and time in helping to select and present this topic. Thanks is given to Donald Nelson, Brigham Young University Library Director and Gloria Jensen, Supervisor of the cataloging process, for giving permission for this study to be performed in the Cataloging Department. Special thanks is extended to Alora Hawker for explaining how the entire cataloging process is handled. Her help in correlating the cataloging manual with the actual tasks proved to be of great help. A total of thirty-two workers in the Cataloging Department assisted in providing data for this study. Appreciation is expressed to them for their help. Two floor librarians also participated in the study.

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CHAPTER I

INTRODUCTION

To understand the purpose of the management technique described herein it is necessary to place the management process in proper perspective. This chapter will include a short definition of management and the management process.

Management can be defined as "the art and science of planning, organizing, motivating, and controlling human and material resources and the interaction between them in order to attain a predetermined objective."[1] Management is generally concerned with the implementation of policy which has been decided upon by an administration. The librarian, under the administration of the library board or director, is essentially responsible for decisions relating to the use of people and resources. It is beyond the scope of this paper to attempt any lengthy definitions on the nature of planning, organizing, motivating, and controlling. The reader is left to his own intuitive definitions of these terms.

Three general management categories have been developed over the years with respect to managerial activities:

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[1] Desmond L. Cook, PERT: Applications in Education, Cooperative Research, Monograph 17, OE - 12024 (Washington: Government Printing Office, 1966), p. 5.

> One group relates to the quality characteristics of a product, a second category relates to the operations involved in producing the product, while a third group relates to the administration involved in carrying out the operations.[2]

The third group, that of administration or management of operations or activities, will be the general category that will be treated in this paper. Within this category the manager is generally responsible for the implementation, management and control of a particular project or program and works under the administrator. Effective management requires the fulfillment of certain types of information needs.

> There is a general consensus that managers operating within the project context require data or information relative to [1] time, or schedules; [2] costs, or resources; and [3] performance, reliability, or quality of objective accomplishment. Of these three types of basic data, the most common data obtained and used in a project situation is that relating to time or schedule.[3]

The management process or cycle can be said to consist of eight general steps, all of which are time dependent:

1. Obtain project or program requirements
2. Select project director
3. Develop program plan
4. Organize to accomplish plan
5. Motivate
   - .schedules
   - .budgets
   - .performance standards
6. Control
   - .schedule reporting
   - .budget reporting
   - .performance reporting

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[2] Desmond L. Cook, "Better Project Planning and Control Through the Use of System Analysis and Management Techniques" (paper presented at the Symposium on Operations Analysis of Education sponsored by the National Center for Educational Statistics, U.S. Office of Education, November 20-22, 1967, Washington, D.C.), p. 6.

[3] Ibid.

7. Assessment of program position
8. Corrective actions/replanning[4]
   [return to step no. 5 if necessary]

Most management techniques would include these steps. To further restrict the management technique described herein, only the management need of time and its function in the management cycle will be presented. The management technique is known as Program Evaluation and Review Technique, commonly and hereafter referred to by the acronym PERT.

Management techniques in industry have become very specialized due to the demands of technology and engineering. Many libraries have grown to such a large dimension, that management activities are consuming more and more of the head librarians time. Examination of the library literature for the past decade will reveal an acceleration of published material related to the management of resources and personnel. No longer can the head librarian be concerned with the management of simple tasks related solely to the care and keeping of materials. Management activities of libraries have become more complex and therefore involve additional or refined techniques in planning, organizing, motivating and controlling human and material resources for the benefit of the user.

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[4] Justin G. Longenecker, Principles of Management and Organizational Behavior (Columbus, Ohio: Charles E. Merrill, 1964), Chapter 2; also Robert M. Hayes and Joseph Becker, Handbook of Data Processing for Libraries (New York: Becker and Hayes, Inc., 1970), p. 108.

CHAPTER II

STATEMENT OF THE PROBLEM, DELIMITATIONS, LITERATURE SEARCH AND DEFINITION OF "PERT"

Specifically, what is PERT? It is a managerial tool which is used to understand and coordinate the interrelationships between tasks and accomplishments, particularly with respect to logical sequencing of events and time necessary for the completion of a given project. A diagram or series of diagrams, resembling flow charts are developed, known as networks, and allow the manager with the aid of time dimension estimates to establish a critical sequence of activities through the network that will provide the minimum amount of time for project or program completion. It becomes a dynamic tool when the manager uses it to evaluate progress as it allows him to shift, in a logical manner, time and resources to other tasks which require immediate and long range attention. "Its general value to the librarian is the aid that it will give him in making the most effective use of time and resources available."[5]

The purpose of this paper is to investigate and analyze the managerial scheduling technique, PERT, for subsequent use in library work. Chapters one through five will focus first on a brief introduction to PERT, which will include background, events and activities, network development and logic, three-time estimate concept and critical path. And secondly, the values and limitations for practical use of the management

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[5]Becker and Hayes, Handbook, p. 124.

technique will be presented and finally criteria for use in library management will be presented. Chapters six through nine will focus on an application of this technique to a library process. It will utilize the criteria developed in the previous chapters and the application will be confined to the Brigham Young University Library. Strengths and weaknesses of this application will be summarized with respect to the specific library process chosen. The PERT technique will be applied to the cataloging process of the Brigham Young University Library and will make an attempt to clarify interrelationships between functions and determine any bottlenecks which may be interrupting the flow of information.

An exhaustive treatment of PERT will not be presented. Such detailed concepts as replanning, simulation, computer operations, probability, and sophisticated tabular calculations will be omitted from this presentation. Hence no attempt will be made to discuss extensions of PERT such as PERT/Cost, PERT/LOB, PERT II, PERT III, PERT IV, NASA PERT or other such related network type systems.

Very few articles on PERT appear in Library Literature Index. Since PERT is associated with business, most of the relevant literature was located by using the Business Periodicals Index. The following types of periodicals proved to be most helpful: Advanced Management, Factory, The Controller, Harvard Business Review, Datamation, Operations Research, Management Science, and Data Processing. Books approached via the Brigham Young University Card Catalog were located under the heading of Critical Path, a name closely associated with the major characteristic of PERT. Excellent works included: Network-Based Management Systems

(PERT/CPM) by Russell D. Archibald and Richard L. Villoria, Schedule, Cost, and Profit Control with PERT by Robert W. Miller, A Management Guide to PERT/CPM by Jerome D. Wiest and Ferdinand K. Levy, Critical Path Scheduling by Joseph Horowitz, Planning and Control with PERT/CPM by Richard I. Levin and Charles A. Kirkpatrick, and PERT Fundamentals, Volumes I and II by PERT Orientation and Training Center, Washington, D.C. Since PERT was developed in conjunction with a United States defense program, United States government documents were also consulted with success.

After reading about the fundamentals of PERT it was observed that wide application has been made of this management technique and searches were therefore made with the Educational Research Information Center (ERIC) files which proved to be of assistance.

The bulk of the relevant periodical literature was published in the early 1960's shortly after the management system was developed. A special Dewey Decimal number was set up for materials relating to PERT, but it is the belief of this writer that most of the literature published today is being classified under Critical Path, Critical Path Scheduling and/or Network Systems. Sophisticated techniques using the PERT system are being presented in the current literature, especially applications involving the use of the computer.

CHAPTER III

EXPLANATION OF PROGRAM EVALUATION AND REVIEW TECHNIQUE

The PERT system was developed under United States Federal contract as a method of planning and controlling the construction of the large complex Polaris Fleet Ballistic Missile.[6] Thousands of activities extending years into the future had to be mapped-out and well planned. The Program Evaluation Branch of the Special Projects Office of the Navy was responsible for the development and implementation of the master plan and in mid 1957, they initially designated it as Program Evaluation Research Task or simply PERT.[7] The completed plan included some twenty-three networks containing more than 2,000 events and 3,000 activities related to those events.[8] The program was a success and has received considerable attention in the literature of management control. The United States government has since published instruction manuals on how to use PERT.[9]

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[6]Willard Fazar, "The Origin of PERT," The Controller, 30 (December, 1962), 599.

[7]Ibid., p. 600.

[8]Donald G. Malcolm, et. al., "Application of a Technique for Research and Development Program Evaluation," Operations Research, 7 (September-October, 1959), 668.

[9]PERT Orientation and Training Center, PERT Fundamentals (Washington: PERT Orientation and Training Center, 1963), Vols. I, II, III; and U.S., Department of the Navy, Bureau of Naval Weapons, Special Projects Office, PERT Instruction Manual and Systems and Procedures for the Program Evaluation System, (Washington: Government Printing Office, 1960).

A PERT system is a network of activities and events. Activities are tasks and are graphically represented by arrows (see Figure 1). Activities are of two types: 1) they may be sequential, that is one activity must be completed before another begins, or 2) they may be parallel where two or more activities may be carried on at the same time.[10] Time flow (indicated by arrows) on a PERT network is from left to right. The junction points at which these arrows meet are called events and are denoted graphically by circles, squares or rectangles. An event is "a specific definable accomplishment in a program plan, recognizable at a particular instant in time. Events do not consume time or resources."[11] There can be only one activity between two events.

If needed one other symbol may be used. It is a dashed arrow and represents a dummy activity.

> It [the dummy activity] connects events that require no expenditure of resource between them but have some constraint connection. That is, one event must occur before the second (connected by the dummy activity) can be considered to have occured. In a very real sense, a dashed arrow acts as a constraint on the event the arrowhead touches.[12]

The dummy activity is not used extensively, but is an important constraint that may be required on occasions.

Examples of library events include:

1. Start question-negotiation process
2. Start literature survey
3. Start check-out procedure

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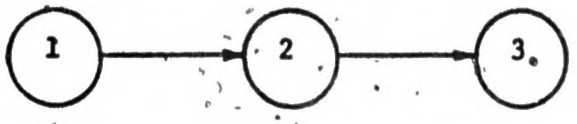
[10] Andrew J. Michaels, "Establishing a PERT System," Management Accounting, 53 (October, 1971), 26.

[11] PERT Orientation and Training Center, PERT Fundamentals, I, 39.

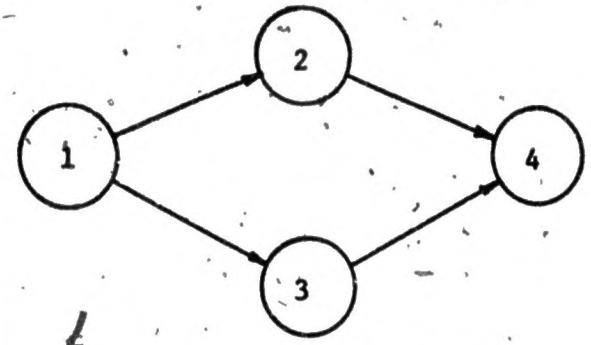
[12] William A. Bocchino, Management Information Systems, Tools and Techniques (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1972), p. 214.

FIGURE 1

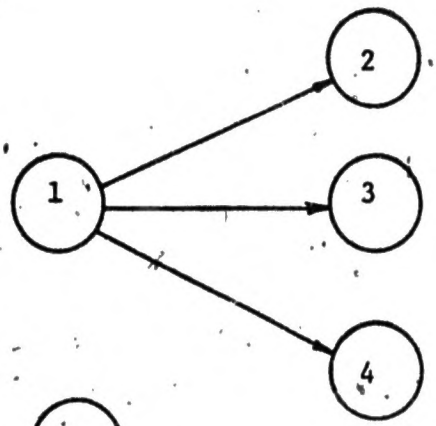
BASIC PERT CONSTRUCTIONS



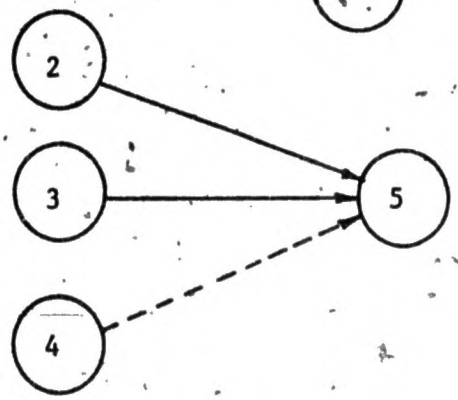
SERIES Construction-a linear progressive chain is developed. Event 1 must be completed before event 2 and event 2 must be completed before event 3.



PARALLEL Constructions-allows two or more activities to take place concurrently. They all eventually conflate into one succeeding event.



BURST Construction-several activities resulting from one preceeding event.



MERGE Construction-several activities conflating to one succeeding event.

EVENT

ACTIVITY

DUMMY ACTIVITY

4. Complete cataloging procedure
5. Complete periodical index search
6. Complete automatic-indexing project

It is important to keep in mind that events represent the start or completion of an activity and do not consume time, personnel or resources. Examples of library activities include:

1. Developing a training manual
2. Completing a check-out slip
3. Cuttering a book
4. Locating a periodical
5. Paying a fine
6. Developing a retrieval rule

Note the verbs in each of the above listed activities. The verb describes the type of activity required to proceed from one event to another.

The event-activity relationship is the fundamental component of a PERT network or system. According to A. J. Michaels, Corporate Controller, Fairfield Technology Corporation, the network:

> . . . is essentially an advanced concept of a flow chart or a diagram of the steps required to accomplish a given objective or task. It is also a logistic plan for work coordination to achieve a defined goal. When all the activities from the beginning to the end of a project have been put together according to their predetermined relationships, a network results. A network is a collection of activities connected to show their interdependencies.[13]

The process of developing a network system is very simple. It involves four basic steps: 1) identification of objectives, 2) organization of objectives 3) defining and listing events and activities, and 4) constructing the network.[14] The literature has indicated differences in opinion as to which of these steps (1, 2, and 3) should be completed

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[13] Michaels, "Establishing a PERT System," p. 26.

[14] PERT Orientation and Training Center, PERT Fundamentals, I, 75.

first. For the purpose of this paper they will be presented in the order given.

The major objectives of a program or project under consideration must be carefully determined:

> As in other management endeavors, the first step in the development of a PERT network is the establishment of objectives: the major objective to be accomplished and each of the supporting objectives in the entire project. When the major objective and each of its supporting objectives have been identified, they must be linked together so that the pl er can see the project in its true perspective, so that he can see the relationships between and among all the steps.[15]

If library program or project objectives cannot be defined then the PERT system cannot be applied. Objectives may range from simple to complex. Simple objectives would not require listing them before developing a network, whereas in average cases, lists or tables may be required. For more complex programs a task or Work Breakdown Structure has proven helpful. The task or Work Breakdown Structure is a graphic representation of the program which establishes a common framework for accomplishing all the work to be performed (see Figure 2). Robert M. Hayes, Director, Institute of Library Research, University of California, Los Angeles, and Joseph Becker, President of Becker and Hayes, Inc., have indicated the value of the Work Breakdown Structure:

> As a basis for effective program planning, it [the Work Breakdown Structure] ensures that no major program activity is overlooked. It provides graphic representation of the relationship of the various components of a complex program to each other and the achievement of stated program objectives.

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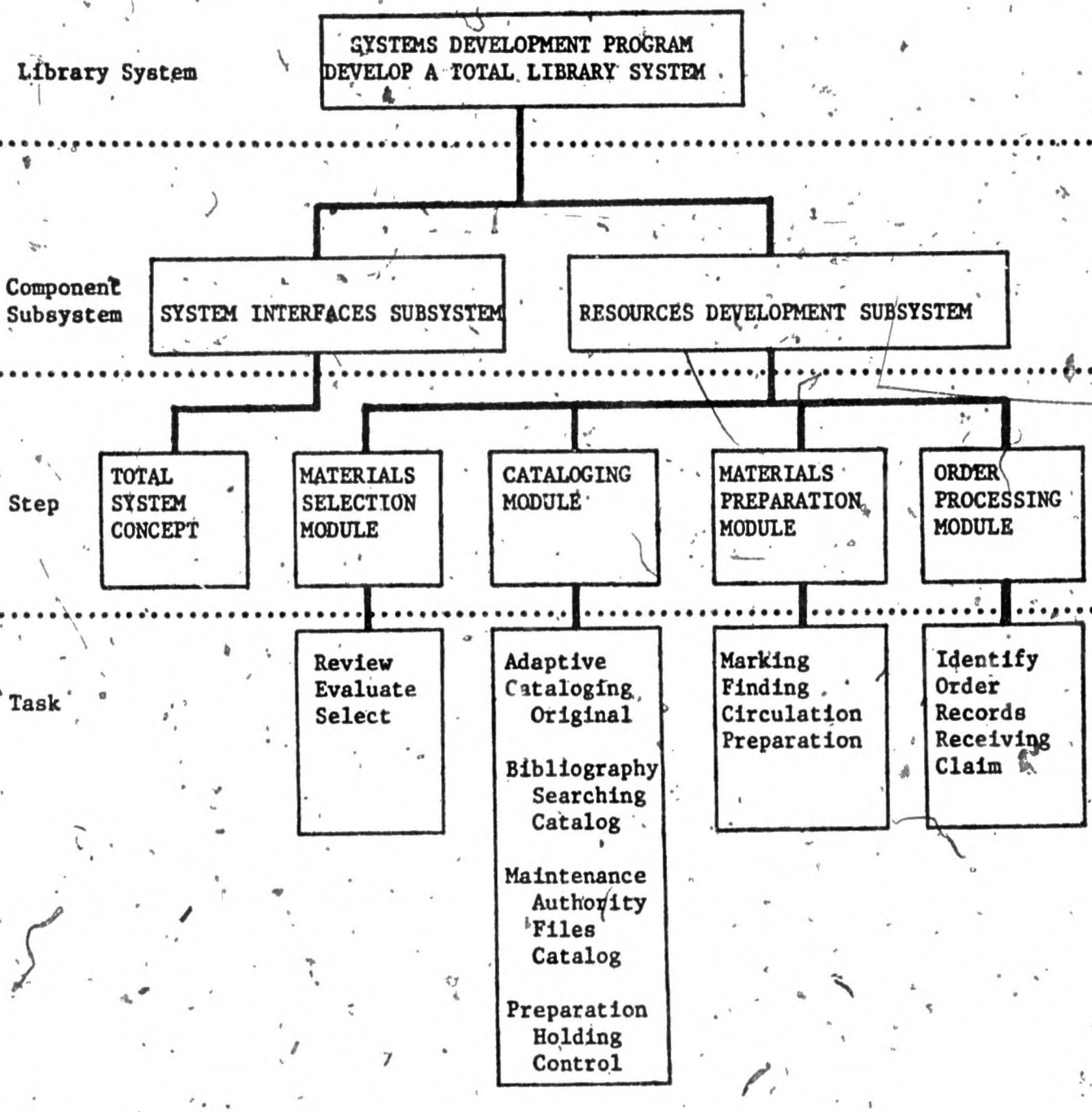
[15] Richard I. Levin and Charles A. Kirkpatrick, Planning and Control with PERT/CPM (New York: McGraw-Hill, 1966), p. 19.

FIGURE 2

Library Systems Development Program Work Breakdown Structure[19]



[19]Adapted from Becker and Hayes, Handbook, p. 121.

> Finally it provides a convenient means for monitoring progress toward achieving the objectives of a program.[16]

Becker and Hayes further indicate that the Work Breakdown Structure produces the following classification of work:

> Library System
> Component Subsystem
> Step
> Task[17]

The Work Breakdown Structure is a combination of product hardware/software as illustrated in Figure 2. The activity-event relationships are obscured under the general label of "library system" but become well defined as one moves toward a specific task in the Work Breakdown Structure. For example the Step and Task relationship correspond, respectively, to the event and activity relationship. The Work Breakdown Structure can be broken down vertically or horizontally (on paper) depending on personal preference. Analyzing the task structure is essentially a 'top-down' operation and may therefore "relate to equipment, service facilities, decisions, data or any combination of these."[18]

In summary, the Task or Work Breakdown Structure is generally required:

> .on complex or large sized projects for identifying and organizing objectives before planning networks can be developed;

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[16] Becker and Hayes, Handbook, p. 120.

[17] Ibid.

[18] PERT Orientation and Training Center, PERT Fundamentals, I, 50.

> .for systematically structuring, summarizing, and reporting to management, information generated on detailed PERT networks; and,
>
> .for integrating time, cost and/or technical performance information on a common framework for project management.[20]

When all program objectives have been defined and tasks clarified via the Work Breakdown Structure, then the next step is developing the network proper. Only one method of developing a network will be presented.

An adaptation of a program network development as presented by David G. Boulanger, Specialist-Engineering Budgets and Measurements, G.E. Missile Production, will be used to illustrate this procedure.[21]

The overall development involves the use of a Gantt Chart which serves to relate "components, personnel, and machinery in an organization with the tasks assigned to them over time. Requirements, assignments, costs, and schedules are pictured in a form that is easy to visualize."[22] Boulanger has also used program Milestone Charts. Russell D. Archibald and Richard L. Villoria in their excellent work Network-Based Management Systems (PERT/CPM) indicate that:

> Milestones are key events or points in time which can be identified when reached as the program progresses. The milestone system provides a sequential list of the various tasks to be accomplished in the program. This innovation was important because it recognized the functional elements of the program, reflecting more accurately what is now known as the program work breakdown or product indenture structure.[23]

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[20] Ibid., p. 55.

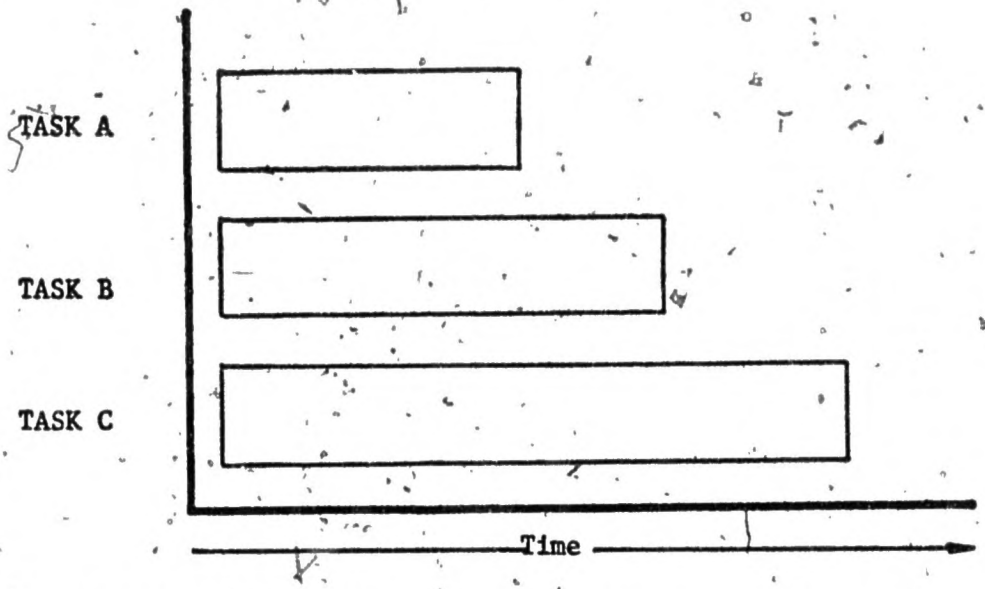
[21] David G. Boulanger, "Program Evaluation and Review Technique, A Case Study Application with Analysis," Advanced Management, 26 (July-August, 1961), 8-9.

[22] Becker and Hayes, Handbook, p. 60.

[23] Russell D. Archibald and Richard L. Villoria, Network-Based Management Systems PERT/CPM (New York: John Wiley and Sons, Inc., 1968), p. 11.

FIGURE 3

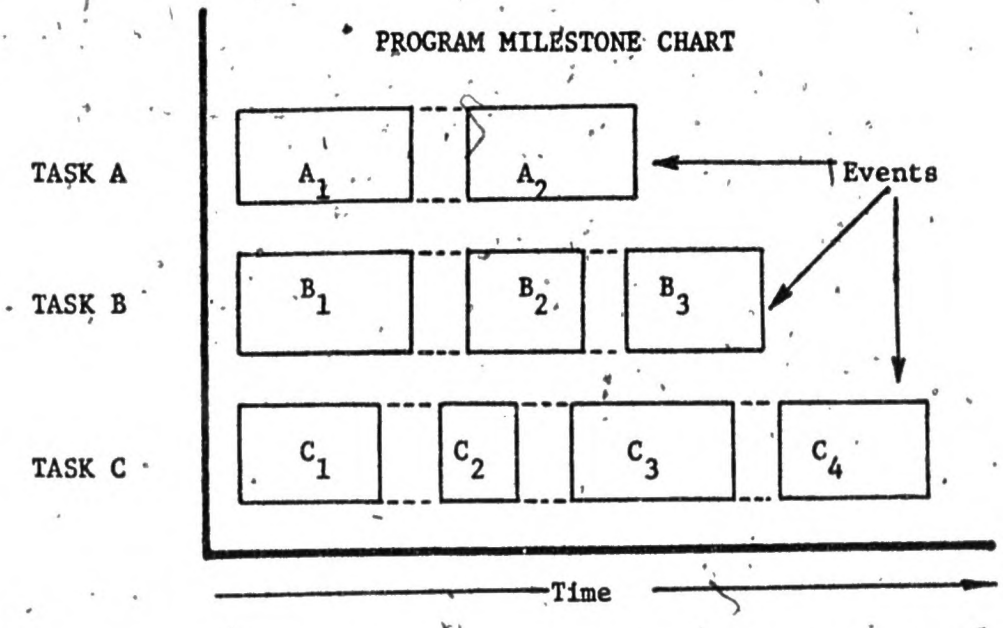
PROGRAM BAR CHART



The Program Bar Chart (Gantt Chart) is turned into a Program Milestone Chart by dividing the bars (tasks) into the significant accomplishments or milestones. These are events. The events may be parallel or in a series.

FIGURE 4

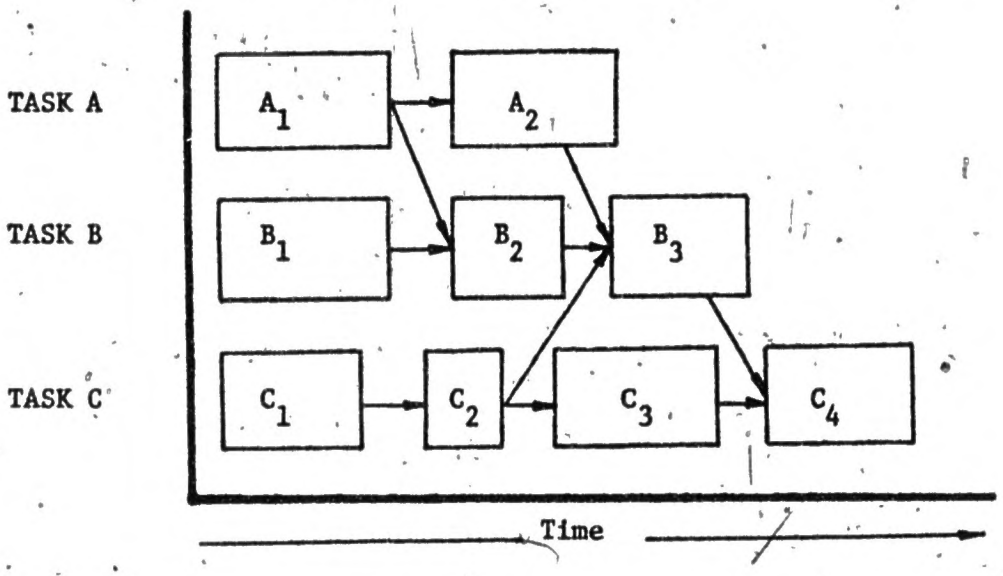
PROGRAM MILESTONE CHART



It will be noted that neither technique shows the interdependencies

between tasks A, B, C and significant events associated with those tasks. For example, in order to complete event B_2 it may be necessary to first complete event A_1 and B_1. A dependency on completion of previous activities may be necessary to proceed from one event to another. This is not illustrated on the Program Milestone Chart. In order to develop the PERT network a series of parallel, horizontal and diagonal lines may be drawn from one event to another to indicate predecessor and successor events. For purposes of illustration, let us assume that before event C_4 (the last event) can be completed, events B_3 and C_3 must be completed and in order to complete event B_3 it is necessary to complete events A_2, B_2, and C_2, and in order to complete event B_2 events A_1 and B_1 need to be completed, and event A_2 is dependent on the completion of event A_1, furthermore in order to complete event C_3 it is necessary to complete event C_2 and completion of event C_2 depends on the complecion of C_1. Events A_1, B_1 and C_1 may all begin at the same time. The program Milestone Chart becomes a PERT network when these lines of association are constructed. See Figure 5.

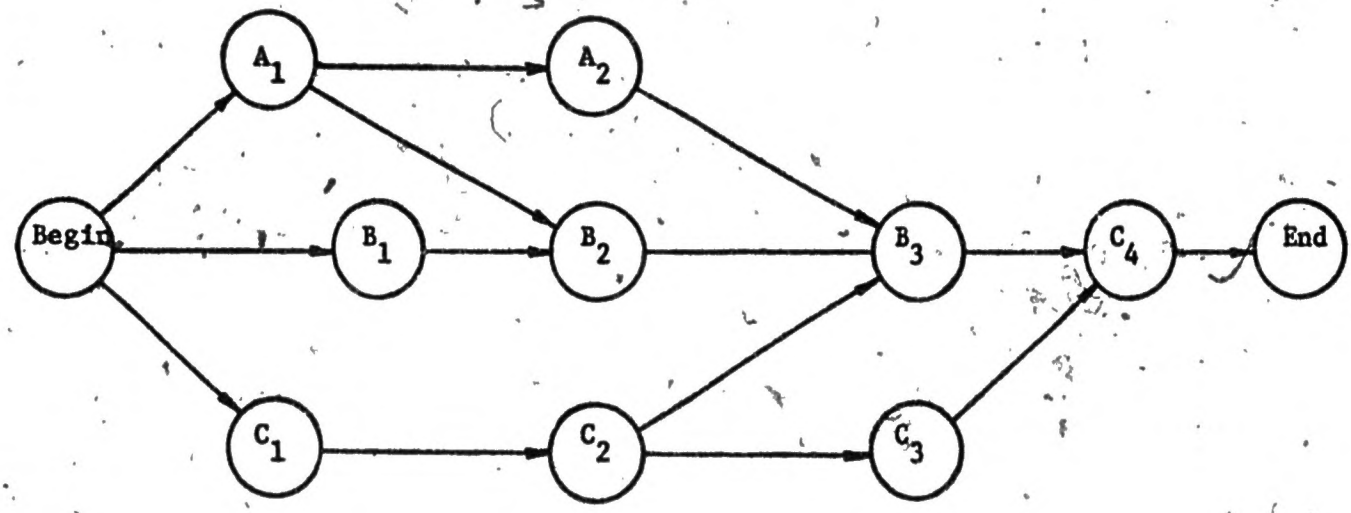
FIGURE 5 - PERT Network Chart



Using the graphical definitions given here-to-fore for events and activities the network can be "cleaned up" to look like Figure 6.

FIGURE 6

NETWORK



Once the network has been constructed and the logic of the plan approved by the users, estimated times for completion of each activity to accomplish the tasks are ascertained. One time estimate may be secured for each activity, but the general and recommended procedure is to obtain three time estimates for each activity in cases where the uncertainty of the scope of the work must be taken into consideration. The three estimates of time are known as: 1) the Most Likely Time, 2) the Most Optimistic Time and 3) the Most Pessimistic Time. Levin and Kirkpatrick, of the Graduate School of Business Administration, University of North Carolina, have defined these estimates as follows:

> Most Likely Time - the most likely time is the particular time that, in the mind of the estimator, represents the time the activity would most often require if the work were done again and again under identical conditions.

Optimistic Time - the most optimistic time is the particular time estimate that has a very small probability of being reached, a probability of 1 in 100. This particular time estimate represents the time in which we could finish a project if everything went along perfectly with no problems, no adverse weather, etc. We know this would be most unusual, but it could happen; thus, the probability of 1 in 100.

Pessimistic Time - the most pessimistic time is another particular time estimate that has a very small probability of being realized, once again a probability of 1 in 100. This particular time estimate represents the time it might take us to complete a particular activity if everything went wrong, if we were plagued by adverse weather, breakdowns, bad luck, etc. We know that this, too, will not be the usual case, but it too could happen, and thus we should at least give this time some weight in our deliberations and computations.[24]

The initial developers of the PERT system were interested in developing a probability distribution:

1. With a small probability of reaching the most optimistic time (shortest time)
2. With a small probability of reaching the most pessimistic time (longest time)
3. With one and only one most likely time which would be free to move between the two extremes mentioned in 1 and 2 above
4. In which the amount of uncertainty in the estimating can be measured.[25]

The distribution which satisfied these statistical assumptions was the Beta distribution.[26] Figure 7 gives an example of a Beta distribution with optimistic time (a) and pessimistic time (b) and most likely time (m). The optimistic and pessimistic times form the range of the curve and the most likely time appears at the mode of the curve.

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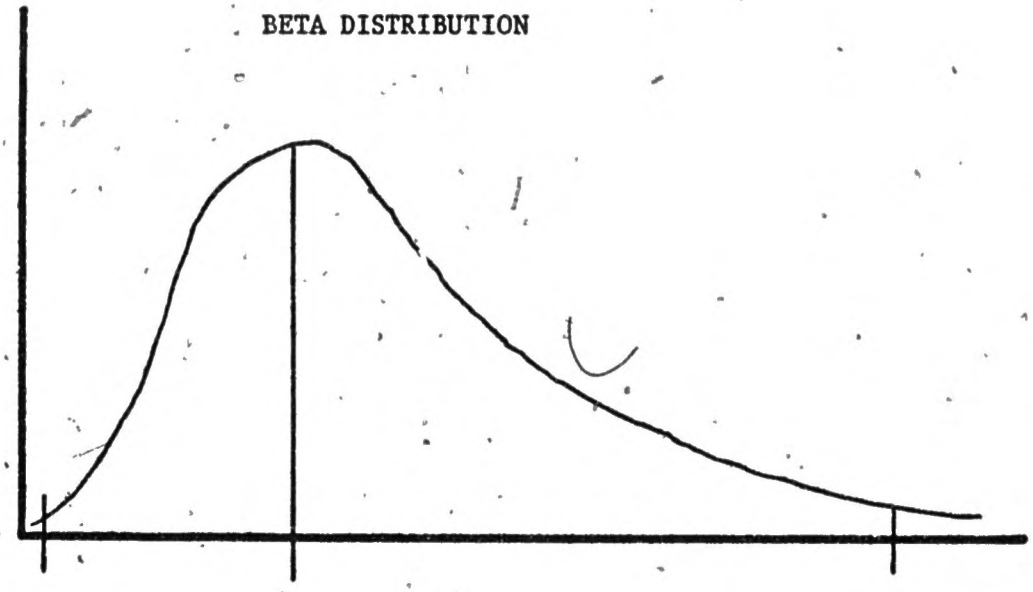
[24] Levin and Kirkpatrick, Planning and Control with PERT/CPM, pp. 40-41.

[25] Ibid., pp. 38-39.

[26] Ibid., p. 36.

FIGURE 7

BETA DISTRIBUTION



From these three time estimates, via statistical computations, a simple formula involving a weighted average was derived (the derivation of which is beyond the scope of this paper) to calculate the average or Expected Elapsed time for each activity in the network:

$$t_e = \frac{a + 4m + b}{6} \qquad (1)$$

Where

t_e = Expected time for the activity, or Expected Elapsed time

a = the optimistic time

m = the most likely time

b = the pessimistic time[27]

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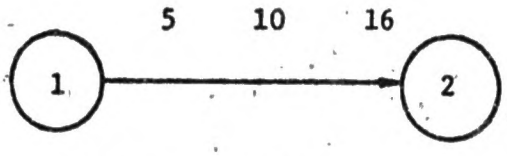
[27] Ibid., pp. 41-42.

An example using the three time estimates is as follows:



let a = 5 days
m = 10 days
b = 16 days

then

$$t_e = \frac{5 \text{ days} + 4(10 \text{ days}) + 16 \text{ days}}{6}$$

$$t_e = \frac{(5 + 40 + 16) \text{ days}}{6}$$

$$t_e = \frac{61}{6}$$

$$t_e = \text{approx. } 10.2 \text{ days}$$

Studies have been made to test the validity and accuracy of the formula for the computation of t_e (expected elapsed time). Based upon the assumed Beta distribution it has been shown that the error for the calculated t_e was small enough to allow the method to be satisfactory in most cases.[28]

Once the expected time has been computed for a given activity it is possible to obtain an estimate of the variability of the time estimate associated with the given activity. The range of the variation is determined by the standard deviation. The formula is:

$$\rho_{t_e} = \frac{(b - a)}{6} \qquad (2)$$

---

[28] K. R. MacCrimmon and C. A. Ryavec, "Analytical Study of the PERT Assumptions," Operations Research, 12 (January, 1964), 16-37.

where

ρ_{t_e} = the standard deviation

b = pessimistic time

a = optimistic time

Using the same values in the previous example, to calculate expected elapsed time, we have:

$$\rho_{t_e} = \frac{(16 - 5)}{6}$$

$$\rho_{t_e} = \frac{11}{6}$$

$$\rho_{t_e} = \text{approx. } 1.8$$

This value can be used to determine the probability that a given activity will be completed within the r nge of the estimated times by using the normal distribution concepts. Hence, in the example, there is a 68% chance that the activity will be completed within 1.8 days either side of the expected time (t_e). Also there is a 95% chance that the activity will be completed approximately 3.5 days on either side of the expected time and there exists a 99% chance that the activity will be completed approximately 5.5 days either side of the expected time.

The PERT literature indicates there has been some concern over this particular point of using the normal distribution figures with a beta-curve. It is not the purpose of this paper to explore the reasons behind this adaptation, but to refer the reader to the "More Advanced Discussions" part of the Bibliography for further inquiry.

One other extremely useful statistic which can be calculated from the time estimates associated with activities is the earliest expected

date for the network ending event. This figure is arrived at by summing up all the expected elapsed time estimates (t_e) for each activity (running left to right) for a given path through a network. There may be several paths through a network. The path that totals the maximum time yields the earliest expected time for completion of the program. This becomes the most significant or critical path in the network upon which effort is concentrated to see the program or project to completion. Relative to the critical path, Russell D. Archibald, of Project Management and Control Division, Booz, Allen and Hamilton, Inc., has indicated:

> Adding together the estimates of activity duration times along all the paths of the network reveals the path that will consume the most time in reaching the end event. This path is known as the critical path, and is one of the most important concepts in network-based systems. Isolation of this sequence of activities gives the manager some of the most vital program information he will need to plan and manage the program properly.[29]

Determining the critical path is the core of PERT. All subsequent managerial activities revolve around the determined critical path. The critical path may not be evident at the onset of a project and may therefore prove to be of surprise once it has been discovered. If average time figure (t_e) were assigned to the activities in Figure 6 we would have the network in Figure 8 from which to determine the critical path. There are five paths through the network in Figure 8. The paths are denoted by listing the events from left to right with a hyphen placed between events. All the events for this network would be:

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[29]Russell D. Archibald, Network-Based Management Systems PERT/CPM, p. 19.

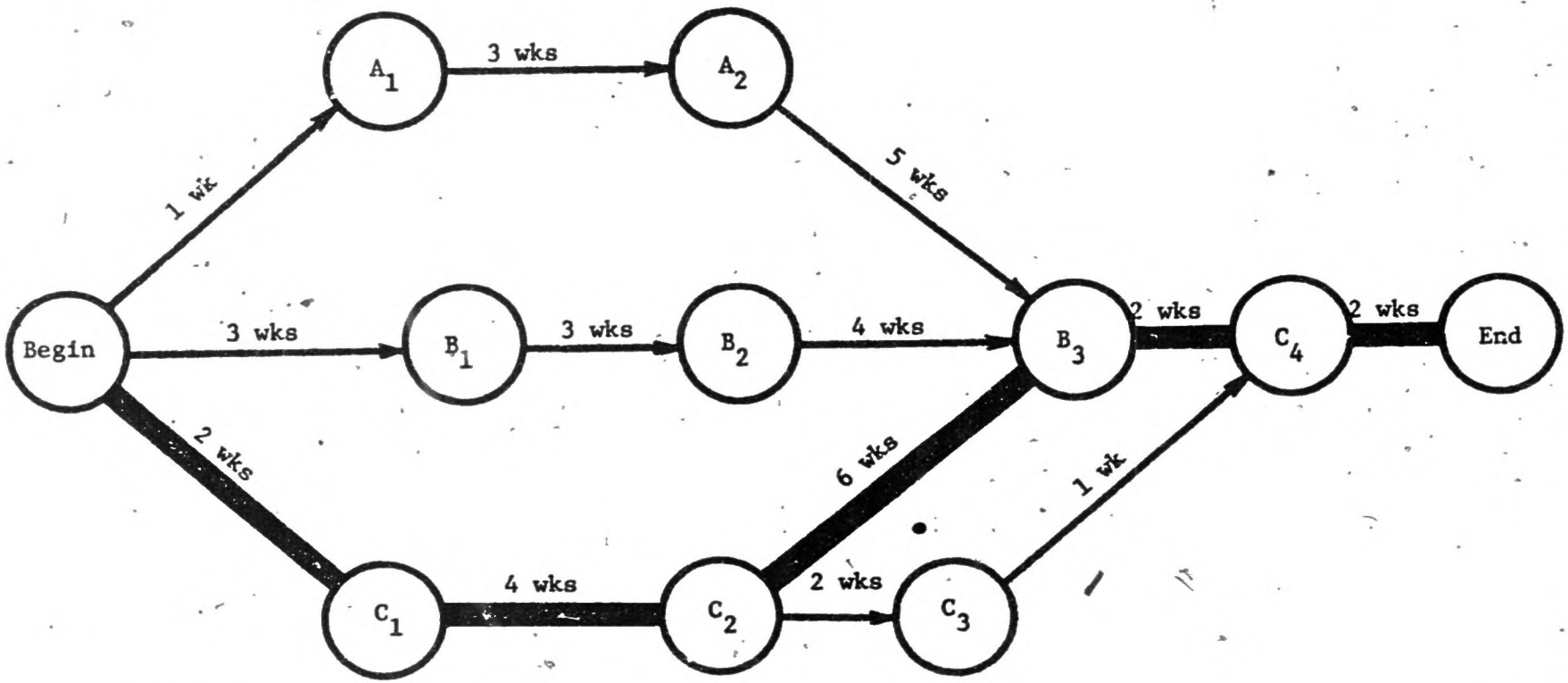

FIGURE 8

NETWORK PATH TIME ESTIMATES

Begin - A_1 - A_2 - B_3 - C_4 - End (1 + 3 + 5 + 2 + 2 = 13 wks)

Begin - A_1 - B_2 - B_3 - C_4 - End (1 + 2 + 4 + 2 + 2 = 11 wks)

Begin - B_1 - B_2 - B_3 - C_4 - End (3 + 3 + 4 + 2 + 2 = 14 wks)

Begin - C_1 - C_2 - B_3 - C_4 - End (2 + 4 + 6 + 2 + 2 = 16 wks)

Begin - C_1 - C_2 - C_3 - C_4 - End (2 + 4 + 2 + 1 + 2 = 11 wks)

The longest path through the network is Begin - C_1 - C_2 - B_3 - C_4 - End, and totals sixteen weeks. It will be noted that this is the longest time path. By the previous definition, this is the critical path and indicates to the program manager the shortest possible time the program could be completed.

Further considerations regarding PERT and critical path studies will not be discussed as they are too numerous and are beyond the scope of this paper.

CHAPTER IV

VALUES AND LIMITATIONS

Numerous individuals have written on the values, virtues, and vices of PERT. It does have its limitations as well as positive values. A summary of the positive values will be presented in terms of general characteristics as distilled from the business and applied science literature.[30]

One of the strongest values of PERT is that it shows relationships. Complex relationships and interdependencies can be quickly identified upon visual inspection of a network system. Also, time and function are related which helps to eliminate uncoordinated segmentation of activities and events. Besides yielding an integrated methodology, PERT attempts to show all significant program milestones. A unique dependency relationship is developed in graphic form, which provides the total

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[30]Robert W. Miller, "How to Plan and Control With PERT," Harvard Business Review, 40 (March-April, 1962), 93-104, and John G. Barmby "The Applicability of PERT as a Management Tool," IRE Transaction on Management, 9 (September, 1962), 130-31, and T. L. Healy, "Activity Subdivision and PERT Probability Statements," Operations Research, 9 (May-June, 1961), 341-48, and Willard Fazar, "The Origin of PERT," p. 598-621, and Willard Fazar, Advanced Management Systems For Advanced Weapons Systems (Presentation Abstract: Washington D.C.: U.S. Navy Special Projects Office, March, 1961), and Daniel D. Roman, "The PERT System: An Approach of Program Evaluation Review Technique," Journal of the Academy of Management, 5 (April, 1962), 57, and Ivan Avots, "The Management Side of PERT," California Management Review, 4 (Winter, 1962), 16-27.

program in perspective.

A second strong value of PERT is that it pinpoints the problem areas, and helps to focus management attention on those areas that may disrupt the system. Progress reports help to predict and highlight bottlenecks almost immediately. It becomes a good tool for simulation.

A third value is that of improved communication. Participation of high level personnel is required, also the low-level participants generally have a hand in planning the network. This can promote teamwork, develop orderly thinking processes relative to job or task performance and improve the general morale of the group. It, the network, serves as a framework or roadmap for discussion. Networking requires the adoption of positive and unambiguous definition of all events and activities, thus improving the overall communication process.

A fourth value of PERT is that it allows the manager to make intelligent decisions based upon the quantification of program planning and control in terms of time, resource applications and required performance specifications. Progress may be evaluated toward the attainment of outlined program objectives. It does have a predictive quality which may assist in the decision making process. It is primarily an analytical planning rather than a control method. More effective planning is carried out as a result of advanced program thinking. Overall goals as well as immediate objectives are accomplished if the management process is invoked to sustain the original time-schedule.

A fifth value of PERT is that of adaptation with respect to computers. One of the foremost innovations of PERT is that the overall

design permits it to be utilized effectively with the computer. Time and cost studies are currently being handled by the computer.

A sixth advantage of the technique is that the development of a network system is straight forward and is easily explained to the layman. The data calculations are relatively simple and nowdays can be handled by most of the personnel involved.

PERT has been considered a dynamic management technique. The technique itself, however, does not solve problems. It is often considered one-of-a-kind project or program planning for executives and managers. It cuts across organizational lines and looks at the total program, and it does not look to meeting a schedule but accepts uncertainty as part of the system. Above all it is not a panacea. PERT has generally been used in large complex programs, particularly with military defense programs, and it has served as a valuable extension of conventional planning and control devices.

PERT does have its limitations. It is difficult to list them in any special rank order, however a simple listing is easy to scan. Hence, only brief statements regarding limitations will be presented.

1. The PERT technique is obviously not applicable to all projects or programs. It can be very costly and time-consuming in the initial stages of planning.
2. A cursory glance at PERT can conceal the fact that the initial decisions regarding time estimates are based upon personal estimates. An uninhibited acceptance to the planning technique could lead to disillusionment if the management was not prepared for the demands of labor.

Biases do enter the system and must therefore be checked from time to time.

3. Small libraries with limited resources may find the technique too complex and expensive for adaptation.
4. Some have indicated that PERT is generally not used on activities which are under a recurring cycle, such as manufacturing processes.
5. The accuracy of the network is subject to question as no known method of examining the method for verification of the logic has been developed.
6. PERT obviously cannot be used if objectives cannot be defined. Also, the underlying theme is that of time. Reasonable time estimates must be incorporated into the network system.
7. Extremely large networks (over 700 events) are difficult to handle. They may add unwanted documentation.
8. The technique itself does not improve the time estimates.

In summary, the strong values of PERT will assist the manager to 1) 'see' the relationships between events and activities, 2) focus on potential problem areas before they occur, 3) improve communications among personnel through participation, 4) make intelligent decisions based upon facts, 5) utilize computer facilities if necessary and 6) explain the technique to the layman as it is relatively easy to understand. These appear to be the major values of the PERT technique. There are many other values not listed; however, upon inspection it will be found that they would probably come under the six major values listed.

Some of the more significant limitations are as follows: 1) it is not applicable to all projects, 2) it involves the human element of educated guesswork, thus creating some bias, 3) according to some it generally is not used on repeated activities, 4) the accuracy is in question with respect to the logic as it cannot be verified as being a one hundred per cent accurate tool, 5) extremely large networks are difficult to handle manually, 6) it has traditionally been used with large programs or projects and has been played down for use on smaller programs, and 7) it is not a universal panacea. In some respects it is rather unusual that this particular technique has not been used more among librarians. In the past, traditional "PERTologists" have placed this particular technique in the realm of accomplishing complex projects when in reality it appears as though it can be used very successfully in smaller and more down to earth programs which already exist and could possibly be improved.

CHAPTER V

CONCLUSION

A description of the basic PERT technique has been presented with no exhaustive treatment of its extensions. Now that the basic techniques are known, and some of its values and limitations, one can ask and answer the questions "Is the technique as useful as claimed? Does the PERT technique do what it is supposed to do? Will it really help the library management plan and schedule their time and resources more effectively?" These are important questions.

Program Evaluation and Review Technique offers many opportunities for creative management in the library. From a review of the library literature, it appears that very few libraries have employed PERT in their management planning. Libraries are generally faced with daily routine activities, hence the need for a project or program scheduling technique is generally not needed. As mentioned, traditionally the PERT system has been applied to projects that have never been performed. It assumes that accurate estimates of time are available, hence the average expected time formula is used. However, it would seem where various tasks have been performed and time estimates are available and are relatively accurate it would help establish a critical path with a much higher degree of accuracy. Once the critical path has been established it could be analyzed to determine if in fact this was the most "desirable path" for the work to be accomplished. It may be that alternate paths

are much more desirable than the critical path and may therefore require that library personnel shift time and resources to adjust accordingly.

Another advantage of applying the PERT technique to an existing routine sequence of activities is to allow the top administration in large libraries to be able to 'see' at a glance the flow of time and resources in the library. The head librarian is in a better position to talk more intelligently to all concerned personnel about the entire information flow in his library and thereby stay on top of existing problems. It becomes a good monitoring tool. The new librarian is often faced with a maze of activities and events which are occuring in his library in which there appears to be no apparent complete sequence of activities. Applying the PERT technique would aid him in understanding and clarifying the existing sequencing of activities and events. It becomes an aid for analyzing the system and can therefore be used as another tool by the systems analyst.

There are several kinds of library oriented projects which could benefit from such a scheduling technique. The PERT technique may be applied to:

1. Rearranging materials throughout a library
2. Developing a large collection from "scratch"
3. Eliminating bottlenecks (e.g. cataloging)
4. Analyzing present library procedures
5. Developing a critical path for an automated system
6. Remodeling of a library
7. Search strategies for library research
8. Microfilming of a large collection

9. Moving a collection to another facility

10. Reclassification of a large collection

Some of these activities or projects occur only once or twice in the history of a library. Other library activities, which include most of them, are somewhat routine in nature and some are improved from time to time.

In conclusion, the values and limitations presented suggest that a set of criteria can be developed to determine whether or not the PERT technique can be used in a library setting. The criteria presented will follow the same sequence of values as presented in Chapter IV. It will be observed that a set of criteria can be applied to two situations: 1) an already existing set of events and activities in sequence, in which case it would be used as an analytical tool by the manager or systems analyst and 2) a new project to be undertaken by the library personnel. The criteria developed for this paper will apply to both situations. It will be general in nature and has been created and distilled from the PERT literature. Six situations emerge as being criteria to determine whether or not the PERT technique could be applied. It can be used:

1. When interrelationships need to be clarified. It should be considered when any operation is complex enough that it cannot be remembered from several exposures to the sequencing of activities. This would benefit the managerial staff as well as new personnel. It would help each person to see where his particular task related to the entire library operation.

2. When problems or bottlenecks interrupt the flow of informatio.. This may require:
   a. the identification of the critical path in a routine sequence of events, and
   b. a change in sequencing to provide new alternatives from which to choose a more viable path.

3. When an improved communication system is desired. The sole objective of introducing the program may be to improve communication among library personnel and develop morale.

4. When intelligent decisions need to be made, based upon facts. The head librarian, whether new or experienced, needs to know the flow of information with respect to time and resources in his library. The PERT network will provide him with activity - event relationships.

5. When automatic techniques are considered for library use. A very valuable aspect of PERT is its:
   a. adaptability to computer use. The technique will provide a comparison to be made between manual and machine sequencing of activities and,
   b. allow the PERT data to be used directly with the computer operations.

6. When extensive training is not essential for use. The process of setting up a network involves common sense, logical thinking, and simple arithmetic calculations. Only one individual needs to be trained in the entire program to interpret technical aspects and extensions of the evaluation technique.

In view of the above criteria, it must be recognized that the one major characteristic of PERT is its predictive feature with respect to time, involving activities and events to accomplish a here-to-fore never performed project or program. The criteria presented indicate some corollary activities which are valuable and applicable to library management.

An application of the PERT technique to the cataloging process of the Brigham Young University Library will be presented in chapters six through nine of this paper. It will utilize the basic techniques of PERT and illustrate its applicability.

It has been demonstrated in the past that libraries as a whole have operated rather efficiently with respect to cost and that there is little 'fat' to be trimmed by introducing new programs or automated

techniques.[31] Therefore the "increased benefits" are those items that emerge as being of concern. The criteria have therefore been stated in terms of increased benefits. As an overall increased benefit, PERT can help to unify, streamline, and clarify library operations for "in-house" personnel and thereby develop the library as an integrated network of service facilities for the benefit of its users.

If allowed, PERT can be of valuable assistance to library management It is eclectic in nature and draws upon previous management techniques which have long been used in management circles. When wisely used by library management, who understands its limitations and values, PERT may be an effective amplifier of managerial skill.

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[31] Becker and Hayes, Handbook, p. 110

CHAPTER VI

INTRODUCTION TO APPLYING PERT TO A LIBRARY PROCESS

Only two of the criteria established in previous chapters will be examined in terms of applying PERT to a library process. The PERT technique will be applied to determine its applicability with respect to whether or not it can 1) clarify interrelationships between activities and events, and 2) identify possible bottlenecks which interrupt the flow of information. The library process investigated will be the cataloging of books at the J. Reuben Clark Library at Brigham Young University. All other incoming materials such as records, music scores, paintings, recordings, microforms, etc., will not be treated in this study.

The PERT technique has generally been used to help clarify interrelationships between various activities and events in large project systems and, as mentioned previously, it may be considered when any operation is complex enough that it cannot be remembered from several exposures to the sequencing of activities. Hopefully this technique would benefit the managerial staff as well as new personnel, and it would help each person to see where his particular task relates to the entire library operation. It is felt that the cataloging process offers enough different activities and events for the PERT technique to be applied. The author's personal contact with the cataloging process on three different occasions was not sufficient to allow him to remember all the activities involved in the cataloging process as well as the seqdencing of activities. In order to identify bottlenecks which may

interrupt the flow of information, a critical path will be established utilizing the three-time estimate concept. Although routine activities are undoubtedly well defined and understood by those involved in the cataloging process, the PERT technique may help to clarify existing and potential problem areas which may not be apparent from direct contact.

It is to be kept in mind that the purpose of this study is to determine if the PERT technique can be applied to the library process rather than try to improve the existing system. Hence, the performance measure will be built around the PERT techniques rather than someone's personal opinion of whether or not the technique has helped them to clearly understand the relationships between sequencing of activities and events and identifying the potential bottlenecks.

CHAPTER VII

METHODOLOGY

By way of review, four basic steps are involved in developing a PERT network system: 1) identification of objectives, 2) organization of objectives, 3) defining and listing events and activities, and 4) constructing the network. These steps become part of the performance measure to determine the applicability of PERT. Successfully completing these steps allows the first criterion, clarification of interrelationships, to be satisfied. The second criterion selected was that of identifying bottlenecks via establishing a critical path through the network. This is accomplished by obtaining three-time estimates for the completion of certain tasks in the work-breakdown structure. If these estimates are obtained then a critical path can be established and any possible bottlenecks identified.

Permission was secured from Donald Nelson, Library Director, to investigate various library processes with supervisors of three departments in the library. After a brief interview with two supervisors it was decided that the cataloging process would provide the greatest challenge and seemed adaptable to the PERT technique. Permission was granted from Gloria Jensen, Cataloging Supervisor, to work with the cataloging personnel.

In order to accomplish the four basic steps in developing a PERT network, an examination of the manuals written for catalogers and clerical workers was made. These included the reading of Clerical Procedures, Typists and Letterers' Manual for the Catalog Department, and Filing

Made Easy. These three manuals were written in detail and describe many of the tasks involved in the cataloging process. However, not all the cataloging tasks were presented in the manuals. Identifying and organizing the objectives for each task was summarized in topic form in a work notebook. Objectives were not stated as such in the manuals but were readily discernible from reading the work breakdown structure for each task. A sample of a work breakdown structure for helping in identifying and organizing objectives is as follows:

Task: Proofreading of Trucks (after lettering, and before going to circulation)

Summary:

1. Separate books by subject.
2. Thin books are to be kept separate from others.
3. Check number on book and book title printed on pink M.O.F.
   a. check for discrepancies
   b. check for lettering errors
4. Spray
5. Deliver truck to circulation

Rush Books

1. Proofread rush shelves at least twice daily.
2. Make corrections immediately-place back on shelf.

Discrepancy Shelf

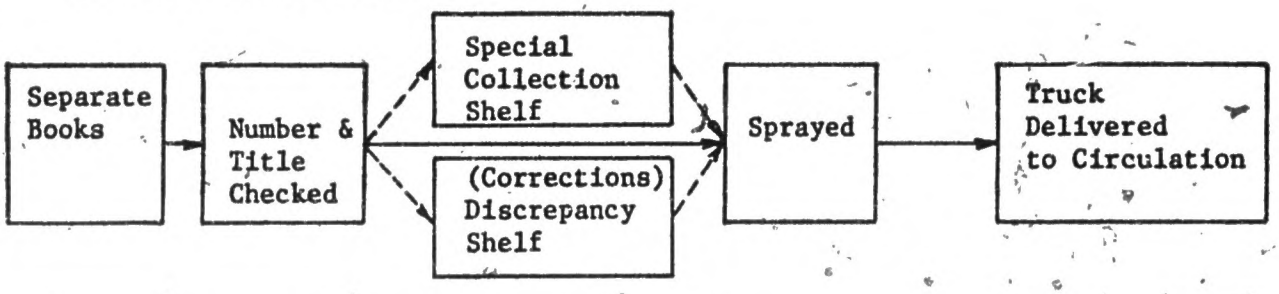
Clear shelf weekly or more often as needed.

Collection Shelf

Clear shelf weekly or as needed.

The objective is to proofread the truck. Sequential and related objectives include spraying and delivering trucks to the Circulation Department.

Defining and listing activities was accomplished in summarizing the work breakdown structure and graphically indicating the sequence of events and activities as follows:



It is not the purpose of this paper to list all the detailed work breakdown structures of the cataloging tasks; therefore, they will be omitted and only the description of events and activities in topic form will be included.

After reading the manuals, as many of these small sequencing activities as possible were expressed in graphic form. They were then presented to the clerical supervisor for integration. The interview with the supervisor was extremely helpful in synthesizing all the diagrams (activities and events), which, after several interviews, led to the development of a PERT network. Constructing the network was made possible through the use of personal knowledge of those who are well acquainted with the cataloging process. The printed manuals were helpful but failed to integrate the small events and activities into one big process.

Determining the three-time estimates (optimistic, most likely, and pessimistic) for each activity in the cataloging process was made possible by the use of a short questionnaire (see appendix). It was determined that fifty-eight tasks were necessary to complete the cataloging of a book. A questionnaire was given to each clerical worker and cataloger involved with the tasks. Some clerical workers were responsible for as many as five tasks. Since many books and cards were processed by "batches", which vary in number, figures were requested for processing 100 books. There was a one-hundred percent participation by the employees and all fifty-eight questionnaires were returned. The data were tabulated and a critical path was established to determine bottlenecks. See Tables I and II on pages 47-50.

CHAPTER VIII

PERT AND THE CATALOGING PROCESS

The main results of this study appear in the form of diagrams. Figures 9, 9a, 9b and 9c represent a topic description (one, two, or three word breakdown) of the completed activities in the cataloging process. It will be noted that the events and activities almost appear to be one and the same. For the purposes of this study the numbers immediately above the events will also represent the activities associated with that numbered event. This will allow a visual correlation to be made between Figures 9, 9a, 9b, 9c 10 and Tables I and II.

The entire cataloging process, which by definition for this study includes the placing of the book on the shelf as well as its corresponding card in the main card catalog, can be observed in Figure 10. The numbers, which represent events, can be correlated with Table I. An activity is denoted by two numbers, such as 24-25, which stands for typing of proof sheet numbers.

In Table I, the task of typing proof sheet numbers requires on the average six tenths of an hour to accomplish. However it will be noted that the task could be accomplished in the optimistic time of four tenths of an hour and, pessimistically speaking, the task will take as long as one hour. Using the Expected Elapsed Time formula, which incorporates the three-time estimates, the average expected time for completing the task is six tenths of an hour. The task or activity is denoted as 24-25, typing of proof sheet numbers, in Table II. Expected Elapsed times have

been calculated for all the activities associated with the cataloging process and appear in Table II. It is from this Table that the critical path was determined.

The Expected Elapsed times are totaled for all activities occuring simultaneously and the activities taking the longest time through the network determine the critical path. By adding up the Expected Elapsed times for all possible paths through the network, the longest time path through the system turned out to be:

1-10-11-12-13-14-16-17-18-19-20-21-22-23-52-53-54-56-57-58

In Figure 10 the critical path is denoted by the double line joining circles. A summary of the Expected Elapsed times of the various cataloging activities along the critical path indicate that it takes approximately 152 hours plus a variable slack period of 1.6 months to place 100 books on the shelf and their corresponding cards in the main card catalog. The variable slack period of 1.6 months is to be interpreted as a plus 1.6 months on the average for one specific type of activity (suspension file search) in the pre-cataloging phase. This is added to the 152 hours required for the card to be filed in the card catalog. See Table I, page 47, No. 13.

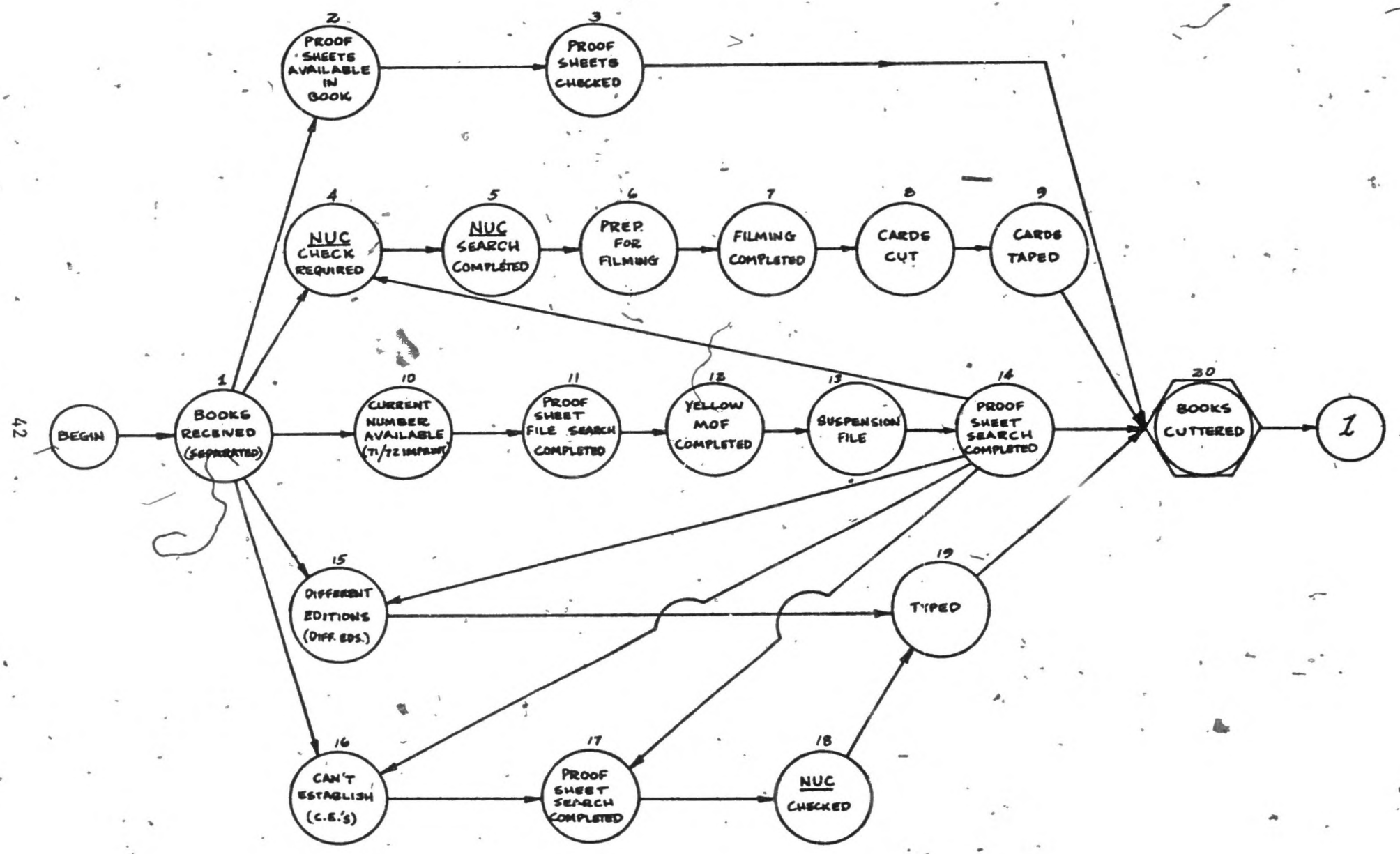


Figure 9 - Partial Network of Library Cataloging Process

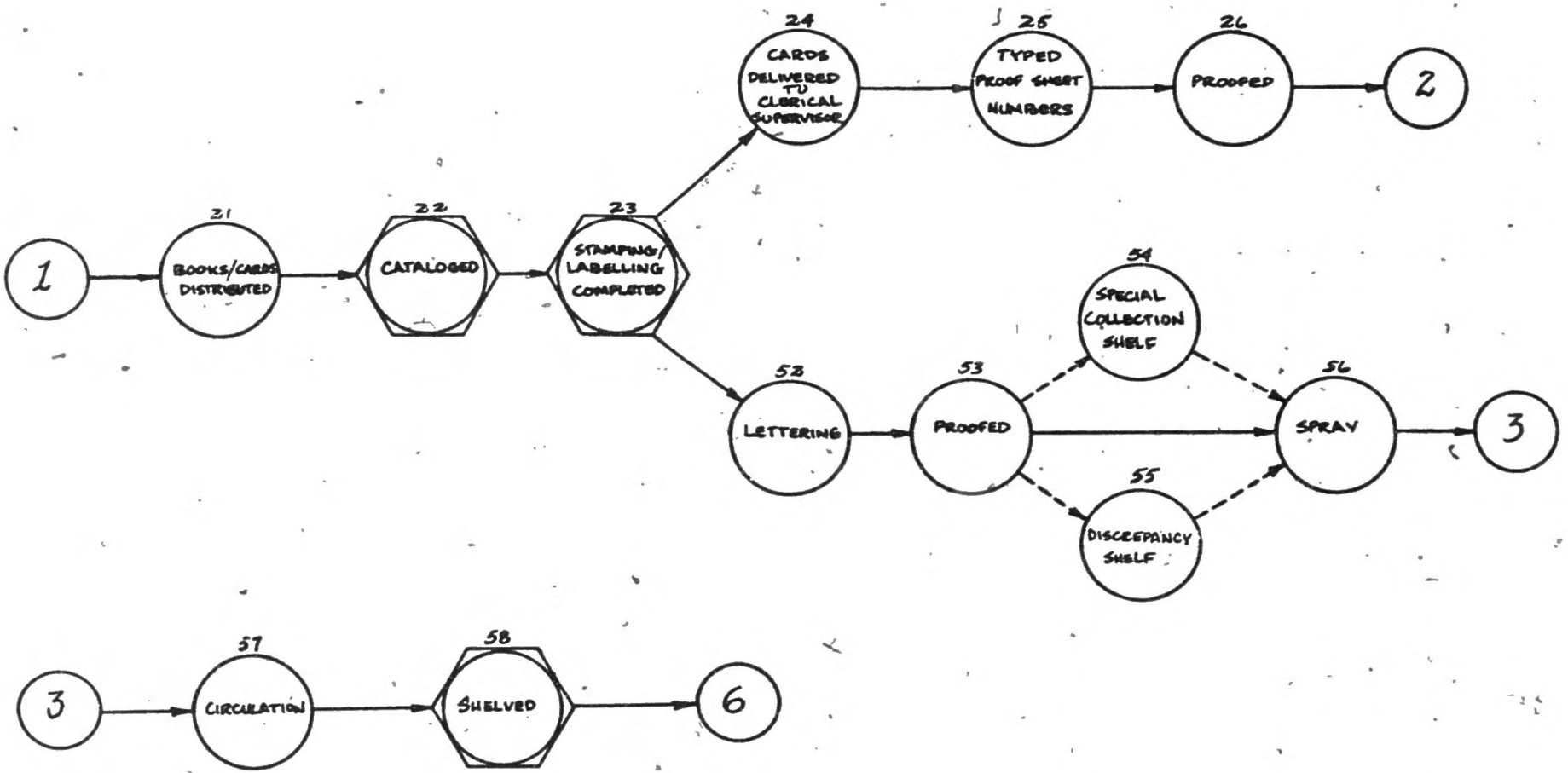


Figure 9 a - Partial Network of Library Cataloging Process

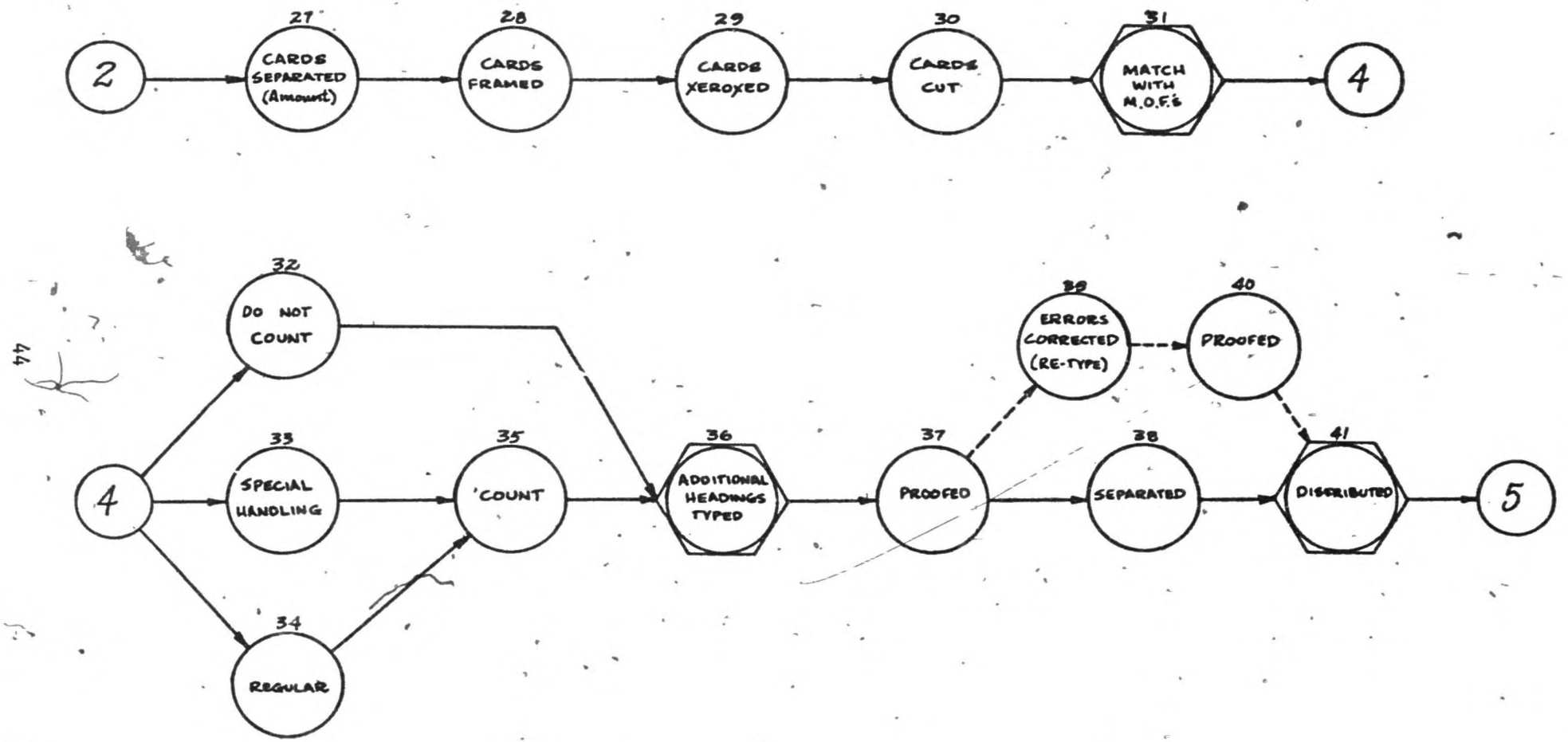


Figure 9 b - Partial Network of Library Cataloging Process

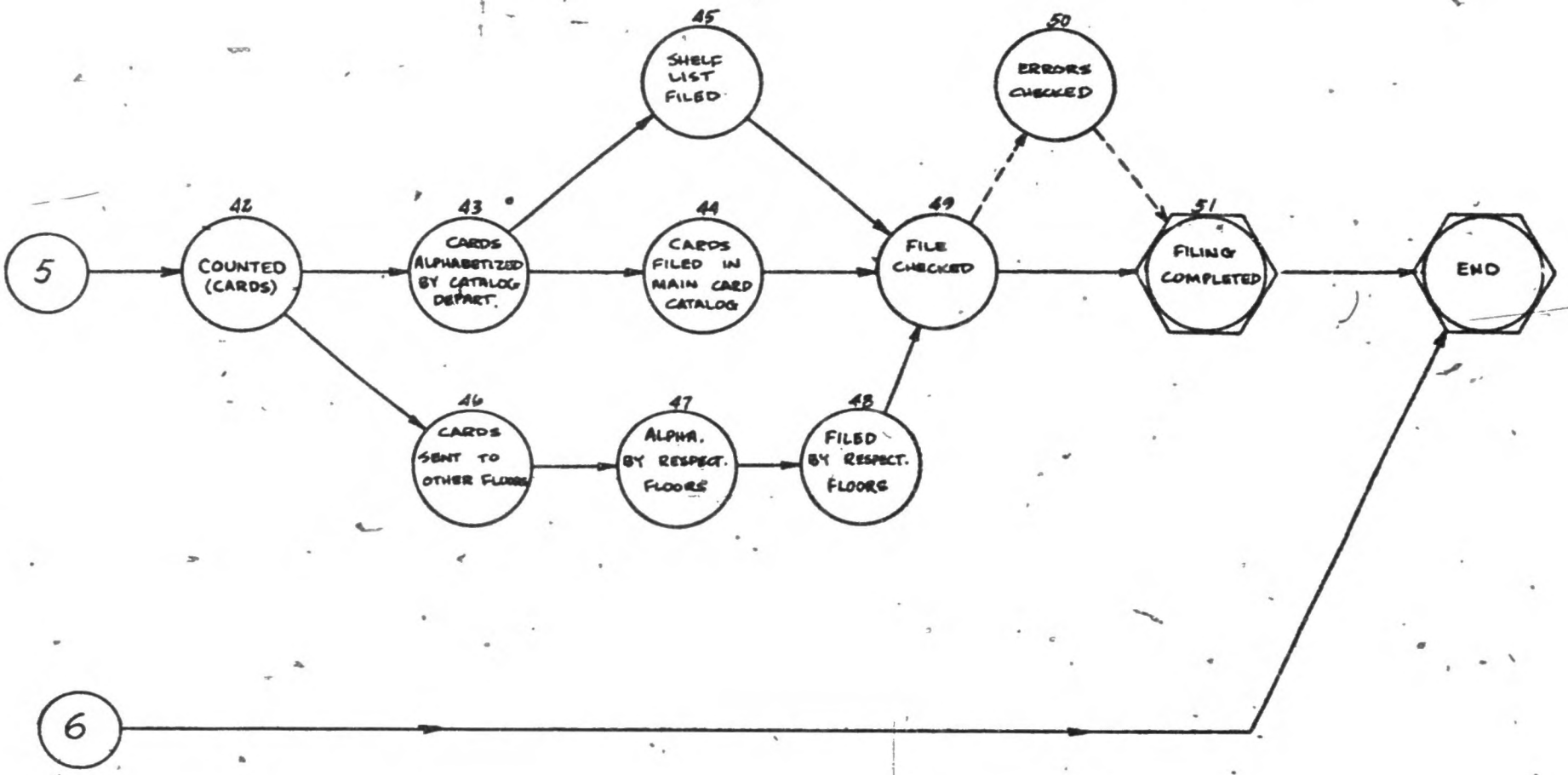


Figure 9c - Partial Network of Library Cataloging Process

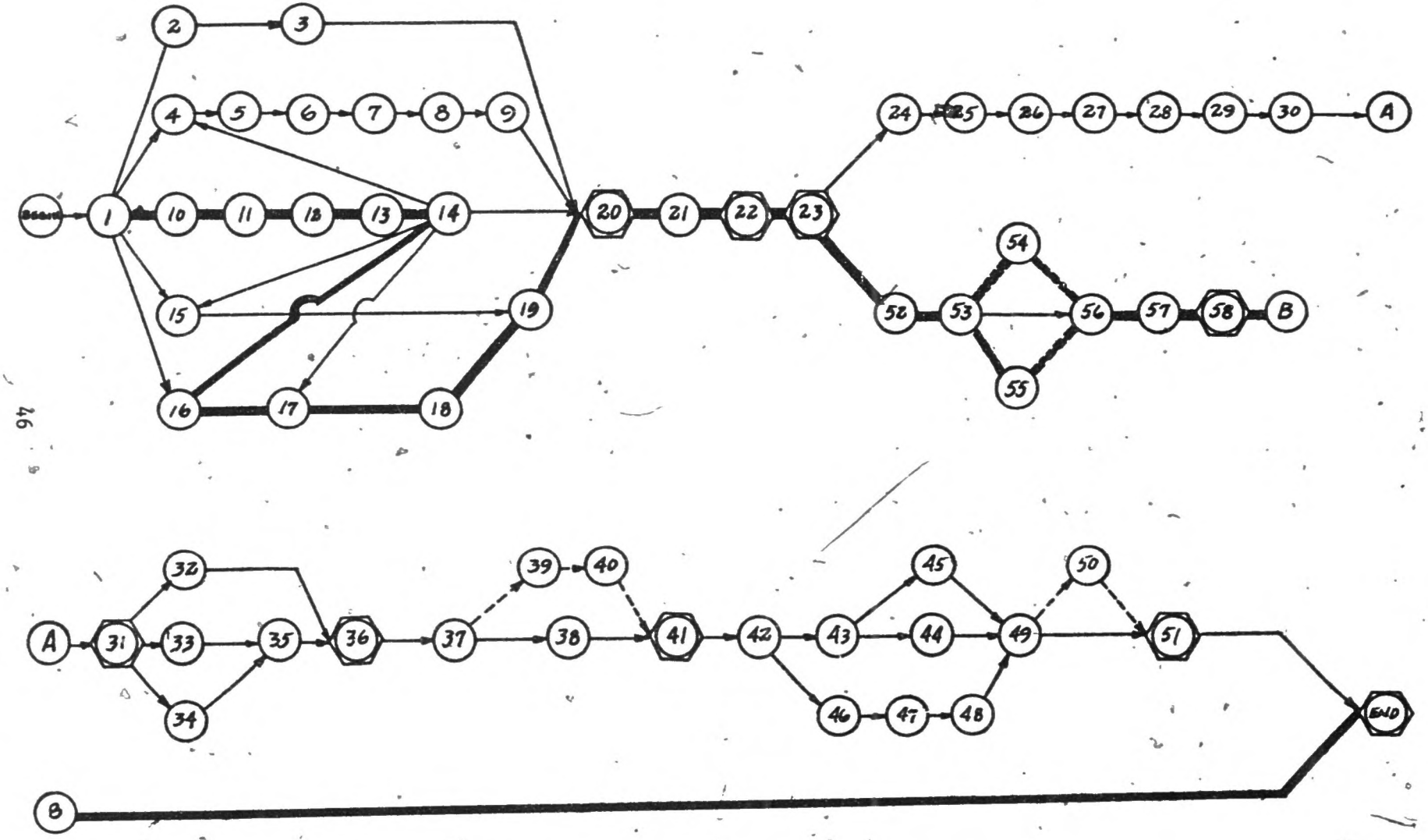


Figure 10 - Entire Network of Library Cataloging Process

TABLE I

TIME (Rounded to nearest tenth of an hour)

ACTIVITIES (TASKS)	OPTIMISTIC	MOST LIKELY	PESSIMISTIC	Critical Path
1- Books Received	-	-	-	
2- Proof Sheets in Book	.3	.5	2.0	
3- Proof Sheet Checked	2.5	3.5	5.0	
4- NUC Check Required	.3	.5	2.0	
5- NUC Search Completed	.5	.6	.7	
6- Preparation for Filming	.3	.3	.4	
7- Filming Completed	1.5	1.8	2.0	
8- Cards Cut	.5	.6	.7	
9- Cards Taped	1.1	1.4	1.6	
10- Current # Available	.3	.5	2.0	X
11- Proof Sht. File Search	8.0	10.0	13.0	X
12- Yellow MOF Completed	1.3	1.4	1.8	X
13- Suspension File*	8.0	1 Mo.*	6 Mo.*	X
14- Proof Sheet Search	8.0	10.0	13.0	X
15- Different Editions	.3	.5	2.0	
16- Can't Establish (C.E's)	.3	.5	2.0	X
17- Proof Sheet Search	1.0	2.0	4.0	X
18- NUC Checked for C.E's	10.0	25.0	50.0	X
19- Diff. Ed's. Typed	8.0	27.0	100.0	
19-1- C.E's Typed	9.0	20.0	48.0	X
20- Books Cuttered	1.3	1.8	2.9	X
21- Books/Cards Distributed	.3	.5	.5	X
22- Cataloging	14.7	25.3	70.3	X

*Difficult to Obtain

TABLE I (Continued)

ACTIVITIES (TASKS)	OPTIMISTIC	MOST LIKELY	PESSIMISTIC	C.P.
23- Stamping & Labeling Books	1.3	2.0	3.0	X
24- Cards delv'd to Cl. Sup.	.0	.0	.1	
25- Typed Proof Sheet No's	.4	.6	1.0	
26- Proofed	.3	.5	1.0	
27- Cards Separated	.3	.5	1.0	
28- Cards Framed	.1	.2	.3	
29- Cards Xeroxed	1.0	1.0	16.0	
30- Cards Cut	.1	.2	.3	
31- Match with M.O.F's	.0	.0	.0	
32- Do not Count	.0	.0	.0	
33- Special Handling-Separate	.0	.0	.0	
34- Counted-Regular	.5	.5	1.0	
35- Counted-Special Handling	1.0	1.1	1.8	
36- Type Add. Heading	.1	.2	.3	
37- Proofed	.0	.1	.1	
38- Separated	.0	.1	.1	
39- Errors corr. (Re-typed)	.2	.2	.3	
40- Proofed	.0	.0	.1	
41- Distributing Cards	.0	.0	.1	
42- Counted Cards	.0	.0	.1	
43- Cards Alpha. by Cat. Dept.	.1	.2	.3	
44- Filing in Main Card Cat.	.3	.5	1.0	
45- Filed in Shelf List (#44)	.3	.5	1.0	
46- Cards Sent to Other Floors	.2	.3	.3	

TABLE I (Continued)

ACTIVITIES (TASKS)	OPTIMISTIC	MOST LIKELY	PESSIMISTIC	C.P.
47- Alpha. by Respective Fl's	.1	.2	.3	
48- Filed by Respective Fl's	.3	.5	1.0	
49- File Check	.2	.3	.8	
50- Errors Checked	.3	.5	1.0	
51- Filing Completed	-	-	-	
52- Lettering of Book	1.5	2.0	3.0	X
53- Proofed	.5	.6	.7	X
54- Separated for Sp. Collect	.0	.1	.2	X
55- Separated for Discrepancy	.0	.1	.2	
56- Spraying Lettered Books	.1	.2	.2	X
57- Send to Circulation	.0	.0	.0	X
58- Books Shelved (2 estimates)	2.0	32.0	112.0	X

TABLE II

EXPECTED ELAPSED TIME*

FOR CATALOGING OF 100 BOOKS

ACTIVITY	EXPECTED ELAPSED TIME, T_e, HOURS	ACTIVITY	EXPECTED ELAPSED TIME, T_e, HOURS
1-2	.7	29-30	.2
1-4	.7	30-31	.01
1-10	.7	31-32	.01
1-15	.7	31-33	.01
1-16	.7	31-34	.6
2-3	3.6	32-36	.2
3-20	1.9	33-35	1.2
4-5	.6	34-35	1.2
5-6	.8	35-36	.2
6-7	1.8	36-37	.2
7-8	.6	37-39	.2
8-9	1.3	37-38	.1
9-20	1.9	38-41	.01
10-11	10.1	39-40	.01
11-12	1.4	41-42	.01
12-13	1.6 mo.	42-43	.2
13-14	10.1	42-46	.3
14-4	-	43-45	.6
14-15	-	43-44	.6
14-16	-	44-49	.4
14-17	2.1	45-49	.4
15-19	36.0	46-47	.2
16-17	1.5	47-48	.6
17-18	26.7	48-49	.4
18-19	22.8	49-50	.6
19-20	1.9	49-51	-
20-21	.5	50-51	.6
21-22	31.0	52-53	.6
22-23	2.1	53-54	.1
23-24	.01	53-55	.1
23-52	2.1	53-56	.1
24-25	.6	54-56	.2
25-26	.6	55-56	.2
26-27	.6	56-57	.0
27-28	.2	57-58	40.3
28-29	3.5		

*Calculation of Expected Elapsed Time is accomplished by using $T_e = \frac{a + 4m + b}{6}$, where a = optimistic time, m = most likely time and b = pessimistic time; see page 19 for explanation of formula.

CHAPTER IX

SUMMARY AND CONCLUSIONS

Applying the PERT technique was possible with the cataloging process to help clarify interrelationships between activities. This has been evidenced by the development of a network system for the process. Identifying and organizing the objectives was accomplished by reading the available manuals and conducting interviews with the cataloging personnel. Defining and listing events and activities was accomplished in a similar manner by observing and recording the sequencing processes. Most cataloging activities were performed only once, which made the network easy to develop. Only on a few occasions were the same activities performed more than once. Repeated activities cause problems in the development of a PERT network. If an activity has to be repeated, it is generally drawn twice on a diagram. Inspection of the network diagram in Figure 9 will show repeated activities, namely, activities 10-11, 13-14, and 16-17.

The three-time estimate concept was used to identify a critical path and possibly point to bottlenecks in the cataloging process. Extreme caution had to be used in order not to develop any time loops. The time estimates in general were considered to be as accurate as possible. There were not enough simultaneous activities to develop a good critical path. However, the network illustrated that the cataloging process is generally a linear process and that introducing any foreign element into the flow of material would essentially affect the entire output. Extra projects or faulty, unreliable equipment would have a

significant effect on the entire system. A block in the critical path would cause a serious stoppage. Once a book has been cuttered there are essentially two paths that develop; one for the handling of the books and the other for the handling of the corresponding cards. The network illustrates that there are no significant alternate routes to choose should there be equipment breakdown. This suggests that additional or auxillary equipment should be available on standby should the regular resources be unavailable. Those activities most likely to be affected, due to faulty equipment, would be filming cameras (6-7, page 42), lettering (23-52, page 43), and xeroxing (28-29, page 44). These activities require mechanical devices which are subject to breakdown and may cause bottlenecks. It is interesting to note that all other activities are performed manually.

According to this study the cards arrive in the main card catalog before the books are placed on the shelf. A summary of the expected elapsed times indicate that it takes approximately 150 hours for 100 books to be placed on the shelf, and it takes only 120 hours for the 100 corresponding cards to be filed in the main card catalog. As explained earlier, there is an estimated variable time period of 1.6 months attached to these time estimates. Some cards may arrive in the suspension file (proof sheet file) for a given day and be pulled out the next. Other searches may take up to six months before locating the card due to its periodic acquisition. If the estimates were discarded for placing the books on the shelves, once they have reached the floor librarians, then the figures would be amazingly close. According to this particular study, which is partly hypothetical, the PERT system indicates that if

100 books were introduced into the library and time calculations were kept for the various activities associated with each 100 books and cards, it would take longer for the books to arrive on the shelves than for the cards to appear in the main card catalog.

It has been shown that PERT can be used to illustrate the flow of information and materials in the cataloging process and can therefore be considered a tool for management to show interrelationships. The three-time estimate concept can also be used to establish a critical path, however with a large varying degree of time which may not prove to be that helpful. It is only one of the many management tools which can be applied to library processes to aid the librarian in making intelligent decisions.

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APPENDIX

Job Title:_____

Job Task:_____

ANONYMOUS QUESTIONNAIRE

Your frank, honest appraisal of three time estimates regarding your particular task in the cataloging process will be greatly appreciated. The data supplied by you and others will be used to determine whether or not a particular management technique can be applied to the cataloging process.

We would like to have three time estimates (optimistic, most likely, and pessimistic) regarding the accomplishment of the particular task in which you are involved. The times are defined below. Please confine your figures to books only (eliminate phonodiscs, paintings, etc.). We would appreciate your figures being based on 100 books.

THREE TIME ESTIMATES

OPTIMISTIC	MOST LIKELY	PESSIMISTIC
Considering no interruptions occurred and all materials were relatively easy to work with, the optimistic time would be the fastest time that you could accomplish the task.	The most likely time would be the average time spent in accomplishing a given task.	Considering everything went wrong (interruptions occurred materials were hard to work with, etc.) the pessimistic time would be the longest time to accomplish a task.
Time:_____ (100 books)	Time:_____ (100 books)	Time:_____ (100 books)