Elements of Project Management:

Plan, Schedule, and Control

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About the Author

M. (Pete) Spinner is Manager, Plant Engineering Department, Glass Division, Ford Motor Company, and a part time Lecturer in project management principles. In the latter capacity, he is presently conducting classes at the Lawrence Institute of Technology in the associate studies program. He has also taught at Oakland University, Henry Ford Community College, and the University of Tennessee.

He was employed by several engineering and construction firms before entering Ford Motor Company. At the present time he is in a responsible managerial position involving the planning and scheduling of major new buildings and facilities as well as expansion programs. In this capacity, he has also provided strategic and operational plans and schedules for proposed facilities in Europe and Mexico.

Mr. Spinner is a graduate in Civil Engineering from the University of Pittsburgh and completed his graduate work at Harvard University, earning a Master of Science degree in Civil Engineering. While on a tour of duty with the U.S. Army, he attended selected engineering classes in Army Specialized Training Programs at Purdue University.

Preface

A few years after I began applying network planning with other project management principles in my work as an engineering and planning manager, I entertained the thought of documenting my experiences at some appropriate time. This text is my initial effort in realizing my goal.

Supplementing my experiences in this text are the research and the lecture material that I use for teaching my project management classes.

The text is written so that readers of varying backgrounds in education and experience can understand its contents. In addition to the basic fundamentals, the text includes expansion of project management methods that will be useful to those with previous training and experience.

The reader, who may be our future planner, will be shown the principles (or "tools") to arrange an effective plan and schedule, and after the project has started, the methods to control the direction of the project to its successful completion. All of these phases are presented in the sequence of how an actual project evolves, and a sample project is used as an illustration for applying the project management techniques throughout the discussion in the text.

The text is arranged in such a manner as to illustrate first, the basic fundamentals of organized planning and scheduling; second,

monitoring and controlling projects (with emphasis on such communication styles as status reports); third, handling of project costs and labor allocation; and finally, computer application. There are also two chapters devoted to a companion network planning method, Project Evaluation and Review Technique (PERT). This approach to project management implementation may be beneficial in some areas of business and industry, and of special note are the time and cost status reports illustrated in these sections.

When calculations are required, elementary arithmetic supplemented with simple graphs is used. Purposely avoided are any detail analytical exercises that may be used for substantiating the derivation of several of these techniques. Using successful applications as examples can show more than any management science displays such as linear programming or mathematical modelling.

The text emphasizes that the planning and scheduling can be done and is accomplished without a computer; however, there are situations where the application can make good use of a computer. One chapter explains how the speed and accuracy of computers is especially useful for large and complex programs.

Included in the text are problems concerning the major subjects that can be used for those readers who want to determine how well they understand the elements of project management. Several sample projects are included that can be selected for a term project problem. These problems are so designed as to incorporate all of the aspects of project management that are covered in this text. Completed project problems are useful as reference material.

Most of the actual applications shown in the text are from my experiences at Ford Motor Company. This is "where it all started" for me in applying and developing the techniques explained in this text.

I wish to acknowledge Ford Motor Company for their permission to use portions of a Ford training manual entitled, "Training Course 3315—Critical Path Method." I also want to state that Ford Motor Company is not responsible for the accuracy or content of any of the material used for inclusion in the textbook. The contents are of my own design and I assume full responsibility.

I wish to express my appreciation to those who shared in the preparation of this book: Chairman Wayne H. Buell, President Richard E. Marburger, and Dean Richard E. Michel of the Lawrence Institute of Technology, for their support and cooperation; my son, David, and my cousin, Nina Mayers, for their proofreading efforts; Nan Scullin for her untiring efforts in preparing the initial diagrams and cover design; and a very special thanks to Louanne Snyder, my "Girl Friday" on this project for her valuable suggestions and particularly for having the patience and ability to transfer my handwriting into a typed manuscript.

M. (Pete) Spinner
Southfield, Michigan

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Introduction

A knowledgeable authority in project management has stated: "The requirements for project management are simple—you only need infinite patience, understanding, and wisdom."[1]

There is much truth in this statement, especially in the handling of modern-day projects that are complex and are of large proportions. However, there are tools available, simple to learn and apply, that can alleviate the problems encountered in project management. Among these tools are the following:

1. Planning, scheduling, and controlling time and costs.
2. Program reporting and forecasting time duration.
3. Cost reporting and forecasting total expenditures.
4. Use of computers, in conjunction with the above, especially for large and complex projects.

We shall list several definitions before proceeding with a discussion of the major topics.

Project management in the business and industry fields is defined as managing and directing time, material, personnel, and costs to

[1] Eric Jennett, "Guidelines for Successful Project Management," *Chemical Engineering*, July 9, 1973.

complete a particular project in an orderly, economical manner; and to meet established objectives in time, dollars, and technical results.

One can define a *project* by means of the following distinguishing characteristics:

1. There is a specific start and a specific end point.
2. There is a well-defined objective.
3. The endeavor is unique and not repetitious.
4. The project usually contains costs and time schedules to produce a specified product or result.
5. A project cuts across many organizational and functional lines.

Project management principles are disciplines employed in planning, scheduling, and controlling a project. The most popular, *network planning*, is a relatively new technique used to help accomplish the successful practice of project management. There are other techniques that complement the application *network planning* and are included in the discussion of this text

- Management by objectives
- Management by exception
- Cost analysis
- Labor allocation/leveling

The use of these principles is associated with careful, detailed planning; therefore, the user is forced to think through the project.

NETWORK PLANNING

The most widely used project management principle is network planning. This technique is used to plan, schedule, and control a project consisting of a group of interrelated jobs (which may also be called work items or activities) directed toward a common goal. The network planning method is especially useful for those projects that have a well-defined starting point and a well-defined objective; project performance is usually very good when using this method. Modified versions of the usual network planning methods are required to plan and schedule production control or process control

operations or any type of activity that involves continual scheduling on a continuous flow of activities.

History of Network Planning

The initial undertaking in planning a project is the development of a graphical diagram. The idea of using diagrams to plot the progress of a project is quite old. Things that look like network diagrams appear in the literature as early as 1850. In particular, George Boole, who worked in the field of logic and algebra, used diagrams to explain propositions in logic and the flow of logical problems. The Prussians in the late nineteenth century developed diagrams to show tactical movements on battlefields. They showed where their troops would be, where the enemy troops would be, and how a battle would progress. One of the favorite pastimes of military people is still the construction of diagrams to show how famous battles occurred.

Another use of diagrams arose from the work of economists. An article published in 1944 indicates that economists developed arrow diagrams designed to show the flow of systems and the interrelation between systems. The diagrams look surprisingly like those used in network planning or some of the other systems that we have today.

The need for improved planning and progress evaluation techniques to help control the utilization of manpower, material, and facilities became apparent at approximately the same time in the 1950s. The pioneering application of the network diagram and the *critical path concept* was a jointly sponsored venture of E. I du Pont de Nemours and Company and the Sperry-Rand Corporation. The objective of this venture was to improve the planning, scheduling, and coordination of du Pont's engineering projects. By September 1957 an actual application was conducted on a pilot system using the UNIVAC I computer, and from this initial effort, network planning and the critical path method evolved.

Simultaneously, the Navy was devising a system to plan and coordinate the work of nearly 3,000 contractors and agencies on the Polaris missile program. From the Polaris project came the *Program Evaluation and Review Technique* (PERT), which is credited with helping advance Polaris development by at least two years.

Today many industries use networks to plan projects of varying size and complexity. Procurement and installation of tooling, building facilities, and machinery are being scheduled under network control. Network planning has many other applications. It can be used to plan design operations, construction projects, administrative programs, maintenance operations, model changeovers, and practically any other series of actions that, when combined, form a complete program having a start and a finish.

The multitude of different names applied to network diagramming methods, such as CPM (Critical Path Method), PERT (Project Evaluation and Review Technique), PEP (Project Evaluation Procedure), and LESS (Least Cost Estimating and Scheduling), merely distinguish the application techniques. The most commonly used are CPM and PERT. The main distinguishing characteristic is that CPM traditionally has been considered activity-oriented, whereas PERT is event-oriented. However, these differences are gradually melting away, and the term "network planning" is now commonly used as a general term to describe all these types of operational programming.

The network diagramming procedure used in this text is the *Critical Path Method* (CPM), which requires that all jobs be completed with no allowance for failure. This can limit the use of CPM in such programs as planning research projects, feasibility studies, test programs, and preparation of proposals. Such projects will have situations where there are alternative approaches, and all of the "paths" may not only have an unpredictable outcome, but all but one may be aborted.[2]

Graphical Evaluation and Review Technique (GERT) is a network diagram system that allows for jobs to be started when there is uncertainty as to whether the preceding jobs may or may not be completed. (However, for GERT to be effective, one of the jobs needs to be completed.)[3]

The reader is advised to gain a more thorough knowledge of the CPM technique before attempting application of GERT.

In network planning, the terms *planning* and *scheduling* are not synonymous. By definition, a plan is a proposed method of action or procedure. Planning may or may not be dependent on timing. Planning indicates *what* activities are to be accomplished.

Scheduling is the development of a timetable that puts time estimates next to the plan and indicates *when* activities are to be accomplished.

Bar Charts

The traditional approach to planning and scheduling has been through the use of *bar charts*, which portray the timing and duration of each activity in a project. These charts are familiar to almost everyone in industry. Basically, they depict graphically the jobs to

[2] Jerome D. Weist and Ferdinand K. Levy, *A Management Guide to PERT/CPM: with GERT/PDM/DCPM and Other Networks*, 2nd ed., © 1977, p. 150. Adapted by permission of Prentice-Hall, Inc., Englewood Cliffs, N.J.

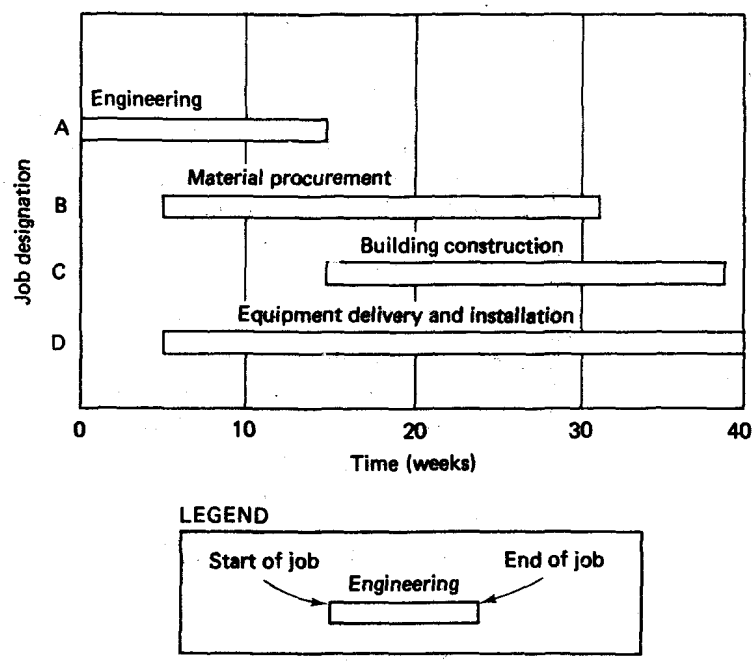
[3] *Ibid.*

be done and the timing for each job, as shown in Figure 1-1. This type of bar graph indicates the beginning and end dates for each of Jobs A, B, C, and D. These jobs represent the engineering, material procurement, construction, equipment delivery and installation phases, respectively, of an engineering project. In many cases, we might find that one or more of these jobs is subdivided and detailed on a second chart. To illustrate, Job A might be divided into several major components, each of which would become a bar or a bar graph.

A chart of this kind provides some valuable information, but essential data are missing. From the standpoint of effectively planning, scheduling, and controlling a project, additional and more accurate information is required. For example, the relationships among engineering, procurement, construction, and equipment delivery and installation (activities represented by Jobs A, B, C, and D) cannot be shown and the following questions cannot be answered:

1. What parts of these jobs can be performed concurrently?
2. What parts of each job are necessary to be completed before other parts begin?
3. Must certain jobs or parts of jobs be given priority in order not to hold up completion of the project on schedule?

Figure 1-1. Basic type of bar graph (chart)



4. Do some jobs or parts of jobs have optional starting and end dates, and what specifically are these optional dates?

Henry L. Gantt, one of the pioneers in scientific management, developed many kinds of charts and records for planning purposes. About 40 years ago, Gantt developed connected bar charts which bear some resemblance to arrow diagrams. Different kinds of shadings have been incorporated in bar graphs to show the activities that could be started early; however, there are limitations. Revisions to these charts are difficult to make and require a great deal of time to update, especially as projects have grown in size and complexity.

Using basically the same project elements as shown for the bar graph, a simplified *network diagram* can be illustrated graphically, as shown in Figure 1-2. Network diagrams overcome the deficiencies of bar chart construction by providing essential information necessary in planning projects:

1. Network diagrams explicitly show interrelations between jobs.
2. A network diagram shows which jobs can be done concurrently, which ones precede, and which ones follow other jobs.
3. Jobs with critical schedules are specified with their required beginning and completion dates.
4. Jobs of a noncritical nature are also shown with optional beginning and end dates.

Although bar charts have limitations for planning purposes, they have been refined over the years to provide an excellent communication expedient to management by summarizing the status of projects.

Network Planning Procedure

Planning, scheduling, and controlling projects, the three phases in the project management cycle, are handled separately for more effective results in the network planning procedure.

The planning phase can be the most time consuming of the total project process: however, the time spent planning can also be the most rewarding. Planning is determining *what* work is to be done.

Planning a project will follow these steps:

Step 1. *Establish Objectives*

a. State objectives that will be derived from the requirements which motivated the project.

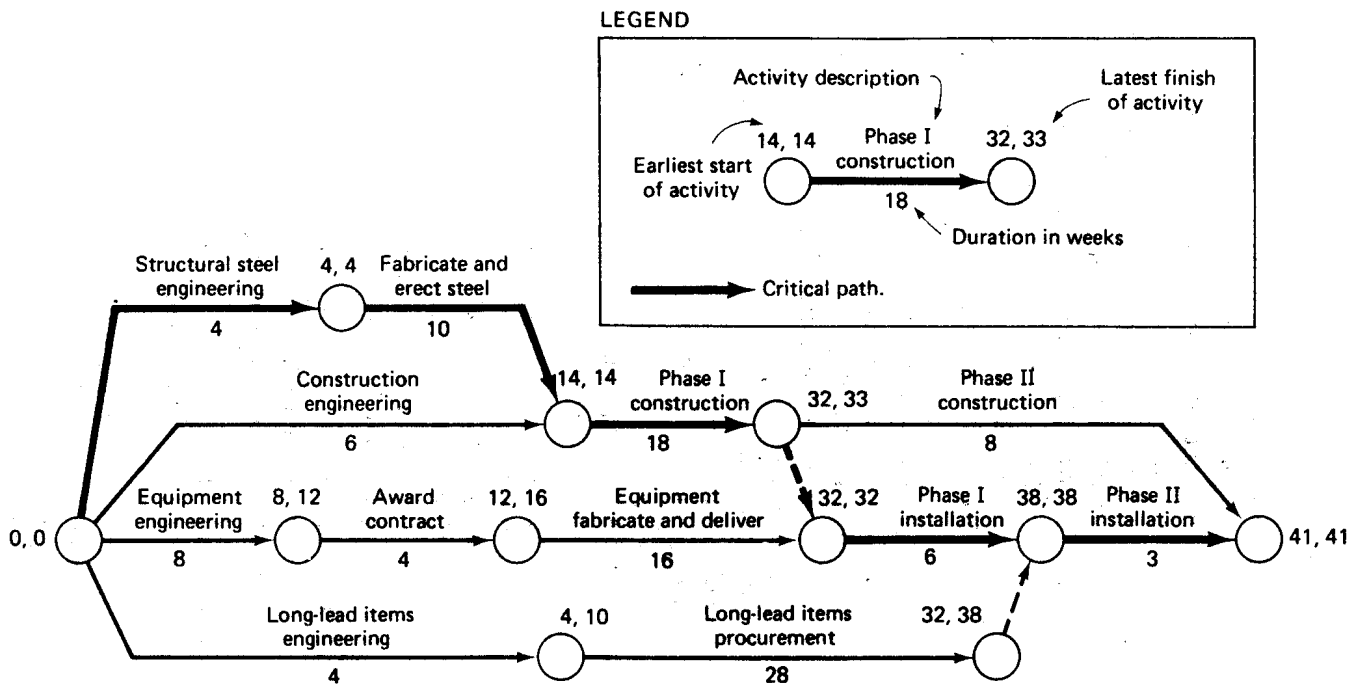


Figure 1-2. Network diagram

b. List interim objectives or milestones that are significant in meeting the main objectives.

Step 2. *Develop a Plan*

a. List the jobs (or activities) that have to be done to complete the project.
b. Delineate the jobs by the following procedure: After the jobs have been decided upon, the relations between them should be determined. This involves a careful analysis of each job, including such items as:
   (1) Which jobs precede and succeed other jobs on the list.
   (2) Which jobs can be accomplished concurrently.
c. Portray the sequence in a network (arrow) diagram.

Determining what is to be done must be the result of a careful analysis of the project by those knowledgeable in the particular field. The network plan then makes use of an arrow diagram to graphically display the sequence and interrelations of the jobs required.

After the network diagram has been completed, scheduling begins. The scheduling phase introduces the timing aspects of the job. Scheduling is determining *when* the work is to be done.

Scheduling a project will follow these steps:

Step 1. After the sequence of jobs has been planned and laid out in a network diagram, the timing can be established.

a. Estimate the time required to complete each of the jobs in the project.
b. Calculate the schedule.
c. Compute the available time to complete each job.
d. Identify the critical jobs.
e. Determine the float times of the noncritical jobs.

Step 2. If the project duration time that is calculated initially is not acceptable, make adjustments to the plan so as to meet a project deadline that is acceptable.

Step 3. Establish a calendar schedule. (Using a bar chart may portray the schedule effectively.)

Effective project control involves constant monitoring of each job in the project. Actual job progress is noted on charts or various other status reporting methods. Summary reports to management are submitted at periodic intervals, and these reports can be prepared

weekly, biweekly, or monthly, depending upon the dynamics and scope of the project. The reports will project completion status (generally including costs) and will highlight critical items that may jeopardize the schedule.

Supplementing the network planning technique as the major "tool" in managing a project to a successful completion are such techniques as management by objectives; management by exception; cost analysis, including time/cost trade-offs (or cost minimizing); and resource allocation. Next, we define these techniques as they apply to project management.

MANAGEMENT BY OBJECTIVES

Once the goals have been identified, an orderly procedure can be set up so that all of the combined efforts are directed in such a way that the goals are achieved. Through network planning, application of *management by objectives* can be readily achieved:

1. Because you have a goal, you know whether or not you are on the right road.
2. You can assess results all along the course of the project.
3. By regularly assessing performance of your goals, you know when you are "drifting."
4. You will perform with maximum effectiveness by knowing what goals the project requires and how well you are going in relation to these goals.

MANAGEMENT BY EXCEPTION (Recognizing Problem Areas)

Network planning facilitates application of the management by exception principle by readily identifying the critical operations. The critical operations usually make up about 20% of the project activities that can affect the overall progress. Through network planning there is a clear definition of just how far each of the other jobs can slip behind schedule without affecting overall progress. This permits true *management by exception*, since management can concentrate on the critical jobs. At the same time, limits are set up for the remaining jobs that must be met if the project is to be com-

pleted on schedule. Any slippage beyond these limits immediately signals the need for management attention.

COST ANALYSIS

Network planning also makes it possible to consider costs in the same way that project timing aspects are handled. Cost scheduling is helpful to those funding the project. It is a valuable tool for projecting cash flows and for preparing a planned expenditure distribution. On large projects cost schedules prepared in a disciplined manner are the basis of determining property taxes and depreciation schedules.

There are cost disciplines designed to ensure that project spending is contained within approved or authorized amounts. One effective project cost control technique used is the *indicated cost outcome.* It provides a periodic review and evaluation of the spending status of open projects to determine if spending is in line with approved authorizations. Specifically, an indicated cost outcome procedure will provide an "early warning system" for potential project overspending or underspending. Planning future spending levels and comparing them with authorized amounts will determine whether anticipated project spending may require additional authorization.

The results of the planning phase should produce the least costly schedule for a feasible project duration. The *minimum-cost expediting technique* available through the use of the network planning procedure does just that. It produces schedules for a number of different project durations, each of these being the minimum-cost schedule for that particular project duration.

How can the project be rescheduled to meet the required deadline at minimum additional cost? The first step in shortening the duration of a project is to select the critical jobs that can be reduced. We will assume that unreasonable time estimates have already been identified and eliminated. A reduction in time can usually be made through expediting overtime, assignment of additional people, use of air freight, and so on, but at some additional cost to the project.

Next, the additional cost involved in reducing project duration is matched with the benefits that can be realized when the time of the project is reduced. The objective is to reduce the duration of those jobs that can be shortened with least additional cost.

For this purpose, a cost-minimizing program has been developed as a management discipline. Through this discipline, rescheduling, including the selection of jobs to be accelerated, is accomplished in such a way that whether the final cost is smaller, larger, or unchanged, the added cost has been minimized.